The economic breeding index: a generation on.

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INTRODUCTION

The Economic Breeding Index (EBI) was officially launched to the dairy industry in February 2001 by the Irish Cattle Breeding Federation. The EBI replaced the relative breeding index (RBI) which was a relative breeding goal made up of milk yield, fat yield, protein yield and protein percent. Since the introduction of the EBI, additional traits that affect dairy farm profitability have been identified, while updating of the Moorepark bio-economic model to account for revised parameters as well as the impact of changes in EU polices has also occurred. Decisions on parameter values to use in the bioeconomic model have been based on the work of others (FAPRI) as well as discussion with organizations within the dairy industry such as the Irish Dairy Board.

Research on the EBI is undertaken through strong collaboration amongst a large number of national and international scientists. Changes to the EBI and their impact are presented and discussed with members of the Irish dairy industry including, amongst others, breed societies, AI organisations, Department of Agriculture and Food, and farming organisations.

The objective of this report is to review the past 7 years (approximately 1 generation in dairy cattle) in the evolution of the economic breeding index and its impact on genetic gain as well as identifying areas of future research.

THE EBI FROM 2001 TO 2003

Traits included in the EBI when first launched in 2001 included milk yield, fat yield, protein yield, calving interval and survival. The rational for choosing calving interval as the fertility trait was due simply to a lack of recording of AI or natural services. By law, farmers had to record dates of birth for each animal and hence it was possible to derive calving intervals for cows. Survival was also included in the EBI to account for animals that did not re-calve and therefore were not included in the genetic evaluation for calving interval.

Genetic evaluations

Milk yield, fat yield, and protein yield breeding values were estimated using an animal repeatability model including the first 5 lactations for each cow. Fixed effects included in the model were herd-years-season-parity, year by month of calving (replaced calving period in 2003), age at calving within parity, days pregnant during the lactation and days dry (both replaced calving interval in 2003). A heritability of 0.35 and a repeatability of 0.55 were used in the evaluations. Heterogeneity of variances were accounted for in the estimation of breeding values for these traits. Unknown parents were represented by genetic groups which were dependent on breed, country of origin, birth year and six selection paths: 1) male with both parents known, 2) female with both parents known, 3) male with unknown sire, 4) male with unknown dam, 5) female with unknown sire and 6) female with unknown dam.

Calving interval is defined as the number of days between consecutive calvings; calving intervals greater than 600 days were set to missing. Survival was defined as a binary trait as whether an animal survived from lactation i to lactation $i+1$. If a cow's last record on the database was within 140 days of her herd's last record then she was assumed to be right censored and allocated a missing value for survival from her most recent lactation otherwise she was assumed culled. In 2002 research was undertaken on using the animal movement data (CMMS data) to better define when an animal was culled for use in the survival evaluation; this research was later implemented in 2004.

In 2002 the genetic evaluation for calving interval and survival moved from a single lactation multi-trait analysis to a multiple lactation multi-trait analysis. From 2002, breeding values for calving interval and survival were estimated using a 12-by-12 multi-trait sire linear model including milk yield in parities 1 to 3, calving interval in parities 1 to 3 and survival in parities 1 to 3 as well as the type traits body condition score, angularity, udder depth and foot angle. Following the estimation of breeding values for all traits, the breeding values for survival are adjusted for the breeding values of milk yield within lactation by regressing the survival breeding value on the breeding value for milk yield and calculating the residuals. Thus survival in the EBI is survival to the next lactation adjusted for genetic differences in milk production (i.e., functional survival). Only one EBV for calving interval and one value for survival is published which is the unweighted arithmetic mean of the EBVs of all three lactations within trait.

In 2003 the sire model was replaced by an animal model. Fixed effects included in the model for calving interval, survival and milk yield were herd-year-season within parity, breed (9 classes for percent Holstein-Friesian) and age at calving within parity (5 classes per parity). Fixed effects included in the model for conformation traits were herd-year-visit, breed (9 classes for percent Holstein-Friesian), age at inspection (linear and quadratic), lactation stage (15 classes) and month of calving (12 classes).

Economic weights

The economic values for milk, fat and protein yield as well as calving interval and survival were derived using the Moorepark bioeconomic model and their derivation is explained in great detail by Veerkamp et al. (2002). Three scenarios were simulated by Veerkamp et al. (2002): S1 - milk and fat% quota with a fixed number of cows per farm and quota leasing; S2 - non-quota scenario with a fixed number of cows per farm; and, S3 - milk and fat% quota with a fixed output per farm. S1 was chosen as the option for Ireland. Default parameters used in the bioeconomic model were obtained from results of experiments carried out at Moorepark over recent years (Dillon et al., 1995). An overview of the simulated herd parameters is given in Table 1.

The simulation of herd performance was based on groups of cows calving in the middle of February, March or April; within these groups no allowance was made for different age of lactation classes. In the default model the calving interval was 365 days, with 50, 40, 10% of the cows calving in February, March and April, respectively. Each cow was allowed a 305-day lactation. The model assumed that 45% of the female calves were reared as replacements but they were sold at 23 months of age and purchased back at 24 months of age in fixed proportions of 50%, 40% and 10% in February, March and April, respectively. A Markov chain model was used to simulate the effect of a one day increase in calving interval on the subsequent calving pattern. The transition matrix used was as follows:

		To month		
		February	March	April
From month	February	0.975	0.02	0.005
	March	0.025	0.97	0.005
	April	0.025	0.02	0.955

To approximate an increase in average calving interval of 1 day, 0.0439 of the cows clving in February and March were milked for an additional month (rather than being dried off), and moved to the next calving month the following year. As calving in May was not allowed, an additional 0.0439 of the April calving animals were culled. However, to keep the overall culling percentage at 15% the default culling percentage was reduced as survival is included separately in the EBI. The new transition matrix following these assumptions was

		To month		
		February	March	April
From month	February	0.9426	0.0547	0.0027
	March	0.0136	0.9398	0.0466
	April	0.0355	0.0284	0.9361

The steady state calving pattern was February = 0.286; March = 0.406, and April = 0.308. **T**he economic values included in the EBI in 2001 are summarised later in Table 24.

Table 1. *Default herd parameters (Veerkamp et al., 2002)*

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Animals present												
No milking + dry cows	47.6	50.7	53.2	53.3	52.5	51.8	51.5	51.3	50.9	50.6	50.2	49
No. calves	11.8	32.6	28.6	16.1	12	11.9	11.9	11.9	11.9	11.8	11.8	11.8
No. yearlings	6	7.2	10.9	12.1	12.1	12	12	12	12	12	12	12
Total Livestock Units	57	62.9	65.5	63.6	61.9	61.3	60.9	63	64.6	64.7	64.3	63.1
Animal sales and purchases												
No. cows died	0.03	0.06	0.14	0.16	0.1	0.1	0.09	0.05	0.04	0.02	0.02	0.03
No. cows culled	1.39	0.97	0.68	0.56	0.72	0.55	0.22	0.23	0.28	0.29	0.37	1.18
No. male calves sold	0	0	13.3	10.7	2.7	0	0	0	0	0	0	0
No. female calves sold	0	0	7.3	5.9	1.5	0	0	0	0	0	0	0
No. replacements sold	5.8	4.6	1.2	0	0	0	0	0	0	0	0	0
No. replacements purchased	4.1	3.3	0.8	0	0	0	0	0	0	0	0	0
Milk production												
Milk produced (kg)	6330	11667	29660	40358	40751	37074	33025	29946	25436	21602	15861	13118
Milk fed to calves (kg)	0	3206	4425	2081	384	36	0	0	0	0	0	0
Butterfat sales (kg)	266	331	939	1362	1396	1243	1166	1092	969	904	684	545
Protein sales (kg)	231	283	823	1226	1289	1177	1074	1009	888	805	584	479
Feed requirements												
Demand grass cows (kg DM)	0	0	8589	16733	19825	21917	22203	21935	19238	14651	5893	0
Demand concentrates cows (kg DM)	1107	2410	5453	4039	2807	212	0	0	1013	2093	1964	2516
Demand silage cows (kg DM)	15708	13217	4551	0	0	0	0	0	0	4186	11785	17315
Total demand grass (kg DM)	0	0	10330	20677	24458	26489	26867	27793	24970	19119	7185	0
Total deman silage (kg DM)	18539	15153	5675	0	0	0	0	0	0	5234	15420	21747
Land use												
Total area closed for silage (ha)	0	0	10.2	10.2	10.2	6.8	6.8	6.8	0	0	0	0
Area available for grazing (ha)	23.9	23.9	13.7	13.7	13.7	17.1	17.1	17.1	23.9	23.9	23.9	23.9
Area cut for silage (ha)	0	0	0	0	10.2	0	6.8	0	0	0	0	0
Grass growth utilised (kg DM/ha)	0	121	489	1504	2379	2087	1699	1299	963	514	128	0
Labour requirements												
Milking (hours/day)	1.9	2.1	2.6	2.9	2.9	2.8	2.7	2.6	2.6	2.5	2.4	2.3
No. cows related work (hours/day)	1.7	1.8	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.8
Fixed labour (hours/day)	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Labour per month	193.3	183.5	222.1	223.4	229.2	219.3	222.7	220.5	211	215	204.8	209.2

DEVEOPMENTS IN 2004

Genetic evaluations

In 2004, genetic parameters for calving interval, survival, milk production (first 3 lactations for milk yield) and type traits were re-estimated and included in the genetic evaluations. Genetic parameters for an additional trait, lifespan, were also estimated and this trait was subsequently included as a correlated trait in the multi-trait analysis of calving interval and survival. A cow was given a lifespan score of *i*-1 if the animal was known to have not survived to parity *i*. Where the fate of an animal was unknown (i.e., she was not coded as being culled and her last known calving date was within 600 days from the date of data extraction) then her lifespan score was calculated as:

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where *n* is the number of lactations the animal is known to have survived and *s* is the survival vector with each element denoting the probability of an animal surviving from age *i-1* to age *i*. The survival probability vector was derived from the data for the first five lactations and was assumed to decrease at a constant rate of four percentage units thereafter.

Economic weights

Parameters within the Moorepark bioeconomic model were updated in 2004. Following analyses of the implications of the Fischler proposals, the Food and Agricultural Policy Research Institute Ireland partnership (FAPRI-Ireland) predicted a fall in milk price from 28 cents/kg to 22.2 cents/kg under the Fischler proposals (FAPRI, 2003). Male calf value of €102 and a cull cow value of €270 were also predicted (FAPRI, 2003); the previous male calf and cull cow value were €190 and €381, respectively.

In line with a fall in milk price, quota purchasing cost was reduced in the bioeconomic model from 9.8 cents/litre to 4.8 cents/litre. Quota purchase price was assumed to be €1/gallon and the money was assumed to be borrowed over 5 years at 4% interest. The estimated cost included the interest and capital repayments. Also the cost of rearing a replacement heifer was revised in the EBI for 2004; the costs are summarised in Table 2. Processing costs were also updated in the bioeconomic model. The levies applied to milk changed since the derivation of the initial economic values. At the end of December 2003 the Bovine disease levy was 0.22 cents/liter; however this was expected to fall by 25% in 2004 (Lascurettes, Irish Farmers Organisation, p*ersonal communication).* Both the IFA/macra levy and the ICMSA levy are both voluntary levies costed at 0.15% of milk value. Only one of these levies was included at an average cost of 0.033 c/kg.

The main components of the transportation cost were the costs of fuel (diesel), labour and insurance. On average the cost of road transport increased by 17% from 2000 to 2003 (Brew, CSO, *personal communication)*. Therefore the cost of transport included in the bio-economic model increased from €0.0107 to €0.015/kg milk. Energy cost is the main factor associated with the cost of cooling; electricity charges increased by 21% from

2000 to 2003. However, this was countered by an increase of about 20% in the efficiency of cooling a unit of milk in the same period. There was thus no change in the cost of cooling in the bio-economic model. A number of different factors are associated with the cost of processing. Communication with Irish processors revealed that the cost of processing is generally expected to increase to about €0.04/kg in the future
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Table 2. *Costs associated with rearing replacement animals*

	Cost (€)
Variable Costs	
Concentrates	104.8
Fertilizer, Lime and Reseeding	128.6
Land Rental	118.4
Machinery Hire	9.5
Silage Making	90.4
Vet, AI and Medicine	128.5
Total Variable Costs	580.2
Fixed Costs	
Car use, water and electricity	20
Labour	221.7
Machinery operation and Repair	8.1
Phone	10
Insurance, A/Cs, T'Port, Sundries	39.6
Interest repayments- term loan	66.7
Total Fixed Costs	**366.1**
Buildings depreciation	58.8
Machinery depreciation	20
Total Costs	**1025.1**
Initial value of the calf	330
Sales of heifers failing to Conceive	-36.1
Net Cost of rearing a replacement heifer (€)	**1319**

The lactation curves included previously in the Moorepark bioeconomic model were based on work from Crosse (1986) on research herds. These were revised using the standard lactation curve method (Olori and Galesloot, 1999). The curves were derived from over 450,000 lactations and were estimated for different ages at calving (18 levels) and months of calving (12 levels).

Table 3. *Milk payment scheme (€/kg milk carrier) included in the EBI in 2001 and the EBI in 2004.*

	2001		2004	
	Fat	Protein	Fat	Protein
Reference milk	3.60%	3.30%	3.60%	3.30%
Gross price kg milk	27.8		21.7	
Price ratio	1	2	1	2
Gross price per kg solids	298	597	240	481
- VAT REFUND RATE (%MONTH)	305	611	251	501
Deduction per kg carrier				
EU Levy	0.448			
Irish Dairy Board Levy (formerly Bord Bainne Levy)	0.170		0.143	
Teagasc levy	0.025		0.062	
Bovine Disease Levy	0.380		0.170	
Dairy Inspection Levy (formerly Dept. Agric Inspection)	0.074		0.103	
IFA/ICMSA/Macra fund	0.025		0.033	
National Dairy Council Levy			0.071	
TOTAL LEVIES	**1.123**		**0.582**	
Cost of Transport	1.07		1.50	
Cost of Cooling	0.25		0.25	
Cost of Processing	1.63		4.00	
TOTAL DEDUCTIONS (cents/kg)	4.069		6.332	

Table 4. *Comparison of the effect of month of calving from the old lactation curves and the standard lactation curves (re-scaled to 6000 kg for a January calving cow).*

	Old lactation curves				New standard lactation curves			
	Jan	**Feb**	**March**	**April**	**Jan**	**Feb**	**March**	**April**
Milk	6000	5880	5760	5700	6000	5937	5792	5754
Fat	211.8	214.8	216.7	212.7	222.0	220.3	214.8	213.5
Protein	189.6	194.1	196.0	192.8	198.8	197.4	192.5	191.0
Fat %	3.53	3.65	3.76	3.73	3.70	3.71	3.71	3.71
Protein %	3.16	3.30	3.40	3.38	3.31	3.33	3.32	3.32

There was a substantial increase in the emphasis on calving interval when the revised lactation curves were included in the bioeconomic model. This is mainly attributed to the reduction in 305-day protein yield as cows calve later in the calving season; in the previous lactation curves an April calving cows yielded ~1 kg less protein than a February calving cow while with the new curves the difference was ~6 kg (Table 4); the effect of one day increase in calving interval shifts the calving pattern from 50:40:10 calving in Feb:Mar:Apr to 29:40:39.

The impact of all changes in the EBI are detailed in Table 24.

DEVELOPMENTS IN 2005

The number of traits included in the EBI was increased from 5 to 13 by including traits related to calving performance and beef performance. The EBI was divided into 4 sub-indexes: milk production, fertility/survival, calving performance, and beef performance.

Genetic evaluations

Research into estimating genetic parameters for calving performance traits such as direct and maternal calving difficulty, gestation length and calf mortality were undertaken and significant genetic variation was observed. Genetic parameters for these traits are summarised in Appendix 1. Breeding values were estimated for each calving performance trait separately in a series of bivariate analyses in ASREML (Gilmour et al., 2007) where one trait was the recent calving performance data collected through animal events and the other trait was the "old" calving performance data collected prior to animal events (i.e., as part of the progeny testing scheme). Breeding values for direct and maternal calving difficulty, gestation length and calf mortality were estimated using a sire-maternal grandsire model. All analyses were across breed and fixed effects adjusted for in the model were herd-year-season of calving, breed, and interaction between dam breed and parity and between dam breed and calf gender, a quadratic regression of age centered with parity, as well as a general heterosis and recombination effect of the cow and embryo. No genetic groups are fitted.

Following research in the estimation of genetic parameters for carcass related traits such as calf carcass weight, calf carcass conformation, calf carcass fat score and cull cow weight, a beef sub-index (with the economic weights described later) was included in the EBI in 2005. Fixed effects included in the 15*15 multi-trait animal model for estimating breeding values of carcass traits were a herd-year-season of birth, herd-year-season of slaughter, finishing system, animal sex and a cubic regression of age at slaughter within sex. Because the genetic evaluation was across breed, a general heterosis and recombination effects were also included as continuous linear effect in the model. The traits included in the multi-trait model were carcass weight, carcass conformation, carcass fat score, cull cow weight, weaning weight, live-weight, feed intake, development of hind-quarter, height at withers, length of back, length of pelvis, loin development, width at withers, width behind withers, and calf quality. Breed groups are fitted through the pedigree file.

Across breed genetic evaluations for milk production were undertaken although results from the non-Holstein-Friesian breeds were not made official in 2005.

Economic weights

With the introduction of additional traits not all expressed on a per lactation basis research into the generation of equations to derive cumulative discounted genetic expressions (CDEs) was undertaken (Berry et al., 2006) to facilitate the economic comparison of traits expressed at different frequencies and time relative to birth.

Calving difficulty

Calving difficulty may be partitioned into two components: direct calving difficulty and maternal calving difficulty. Direct calving difficulty refers to the characteristic of the calf itself (e.g., body size) while maternal calving difficulty describes the characteristics of the dam giving birth (e.g., pelvic dimensions). Estimates of genetic correlations between direct and maternal calving difficulty in dairy cattle, although variable are generally negative (Steinbock *et al*., 2003; Veerkamp *et al*., 2004; for review see Meijering, 1984). Thus, breeding objectives in dairy cattle must simultaneously consider the importance of both direct and maternal calving difficulty in an overall index of profitability.

Table 5. *Full economic value of a 1% change in the proportion of cows requiring severe calving assistance or worse in a dairy herd.*

Item	Caesarean	Veterinary assistance	Severe assistance	Slight assistance	Herd average cost
Stockman hours	6	4	4	1	
Stockman cost (€) per hour	13	13	13	13	
Veterinary costs (€)	160	40	0	0	
Probability of a dead cow	0.05	0.025	0.025	0	
Cost of a dead cow (€)	1319	1319	1319	1319	
Reduced reproductive success	0.25	0.1	0.05	0	
Barren cow costs (€)	1026	1026	1026	1026	
Lost milk (litres)	600	150	50	0	
Cost of lost milk (€)	0.17	0.17	0.17	0.17	
Calving cost relative to no assistance	662	253	145	13	
Percentage of calvings with 6% difficult	0.97	2.51	2.52	20.28	20.82
Percentage of calvings with 7% difficult	1.19	2.94	2.86	21.91	24.30
Economic effect (€) per cow of 1% change					-3.25

The economic costs of dystocia include increased stockman labour hours, veterinary fees, an increased probability of calf and cow mortality and reduced subsequent cow performance (both production and reproductive). The procedure to calculate the economic value for calving difficulty is outlined in more detail by Amer *et al*. (2001). For the purpose of inclusion in the EBI, the economic value for calving difficulty was defined based on an underlying liability scale within subclasses of sex of calf (M or F) by age of dam (parity 1, 2, ≥3) with the phenotypic values assumed to follow a normal distribution (Meijering, 1980). The phenotypic value of an animal (on the underlying scale) relative to the thresholds will determine the category of assistance required by the animal. The categories of assistance considered were: 1) no assistance; 2) slight assistance, 3) severe assistance, 4) veterinary assistance (excluding caesarean section), and 5) caesarean section.

Because the EBI is a multiple trait breeding index that includes milk yield, fat yield, protein yield, calving interval and survival (Veerkamp *et al*., 2002) it was necessary to derive two distinct economic values for calving difficulty. All costs associated with changes in calving difficulty were included in one estimate (full economic value) and all costs, excluding those associated with reduced milk production and fertility/survival, were included in the second estimate (reduced economic value) to avoid double-counting. It was also proposed to include calf mortality in the EBI. Therefore the cost of calf mortality associated with calving difficulty was not included in the economic value for calving difficulty.

Table 6. *Reduced economic value of a 1% change in the proportion of cows requiring severe calving assistance or worse in a dairy herd.*

Item	Caesarean	Veterinary assistance	Severe assistance	Slight assistance	Herd average cost
Stockman hours	6	4	4	1	
Stockman cost (€) per hour	13	13	13	13	
Veterinary costs (€)	160	40	0	0	
Calving cost relative to no assistance	238	92	52	13	
Percentage of calvings with 6% difficult	0.97	2.51	2.52	20.28	10.32
Percentage of calvings with 7% difficult	1.19	2.94	2.86	21.91	11.86
Economic effect (€) per cow of 1% change					-1.31

Calculation of total costs for each assistance category in excess of those of the "no assistance" category are summarised for the full and reduced economic values in Tables 5 and 6, respectively. Normally, the replacement rate of a herd does not increase by 1% as the weighted average mortality rate of the herd increases by 1% because older cows that die would need to be replaced anyway in due course. However, this phenomenon was ignored because the incidence of dystocia is most prevalent in primiparous cows (Meijering, 1984) and there is a one to one relationship between lost first calvers and the herd replacement rate (Amer *et al*., 2001).

The cost of a dead dairy cow is equivalent to the cost of a replacement heifer currently included in the bio-economic model for the calculation of the economic values in the EBI. The cost of a barren cow is the cost of a dead cow less the salvage value of a cull cow. The salvage value of a cull cow was assumed to be €293 based on FAPRI predictions (FAPRI, 2003) adjusted for price differentials depending on calendar month of sale; this is the current weighted average cull cow value used in the calculation of the economic values in the EBI.

The CDE of a dairy sire when mated to a dairy female were calculated for birth and annual cow traits using parameters extracted from national data (Berry *et al*., 2006a). The CDE for birth and annual cow traits (when multiplied by two for use with predicted differences in the EBI) were 2.10 and 1.78, respectively. When rescaled to annual traits the respective CDE were 1.33 and 1.13. The expression of direct calving difficulty is synonymous with birth trait expressions while the expression of maternal calving difficulty is synonymous with annual cow trait expressions.

The direct calving difficulty effect of a sire in the initial mating with a dairy dam will not be reflected in a differential in EBV for milk production and fertility/survival of the sire himself. This occurs since it is the dam (which is unrelated to the sire) that may experience the loss in production/reproductive performance thereby having no effect on the EBV of the sire himself. Thus, the initial expression of direct calving difficulty incurs the full economic cost. The CDE of this trait is one.

The remaining CDE for birth traits (i.e., 2.10 less 1.00) reflects the direct calving difficulty in the female replacement descendants of the sire of interest. This effect is the result of the characteristics of the calf attributable to the genes of the initial sire in his female descendants. The attributes of direct calving difficulty in the sire's female descendants will be reflected in the sires EBV for production/reproduction and thus the remaining CDE will incur the reduced economic value.

The impact on production and fertility/survival from differences in maternal calving difficulty will be reflected in the EBV of the sire through the traits already included in the EBI. Thus, the repercussions of impaired calving difficulty on these traits will be ignored and all expressions of maternal calving difficulty will be included in the EBI at the reduced economic value.

The economic weighting for direct calving difficulty (DEW_{CD}) and maternal calving difficulty (MEW_{CD}) within the EBI equate to

DEW_{CD}= $(FullEV_{CD} * 0.63) + (RedEV_{CD} * [1.33 – 0.63])$

MEW_{CD}= $(RedEV_{CD} * 1.13)$

Where $FullEV_{CD}$ = full economic value, $RedEV_{CD}$ = reduced economic value, CDE_{birth} = cumulative discounted expression for birth traits, CDE_{annual} = cumulative discounted expression for annual traits. Thus, DEW_{CD} = -€2.96 and MEW_{CD} = -€1.48.

Gestation length

Possible non-linear relationships between gestation length and calving difficulty (i.e., both short and long gestation length may predispose animals to higher incidences of dystocia) question the validity of selection for gestation length (Meijering, 1984). However, the genetic standard deviation for gestation length is low and thus genetic change will be small. If not included in the EBI, gestation length may lengthen based on correlations with other traits in the EBI.

The economic value for gestation length manifests itself through a longer subsequent breeding season and thus less barren cows (Amer *et al*., 1996). Additional benefits of shorter gestation length are the possibility for longer lactations and a longer period of growth for calves born earlier. Like calving difficulty, gestation length may be partitioned into direct and maternal components.

Assuming gestation length is independent of calving to conception interval then each one day increase in gestation length is synonymous with a corresponding one day increase in calving interval (i.e., we assume that the genetic regression coefficient of gestation length on calving interval should equal one because of the part-whole relationship between the traits, and the unlikely existence of a strong genetic correlation between gestation length and the calving to conception interval). The economic value for calving interval currently included in the EBI is -€7.09/day. Thus, the economic value for gestation length is -€7.09/day.

A sire's genes for gestation length are expressed once through his initial calf when he is mated to any cow (i.e., direct gestation length), but are also expressed annually in a selected portion of his self-replacing daughter descendants (i.e., direct and maternal gestation length). The CDE for birth and annual traits were reported by Berry *et al.* (2006a) for Ireland. Again, these CDE should be multiplied by two since genetic merit for gestation length will be reported in predicted differences within the EBI; thus the halving of the genes of the sire when passed onto his progeny is already included in the calculation of the predicted differences.

The CDE for direct gestation length from the initial mating is one. Any repercussions of subsequent expressions of direct gestation length will already be included through the EBV of calving interval for the sire; similar conclusions exist for maternal gestation length. The economic weight for direct gestation length (DEW_{GL}) and maternal gestation length (MEW_{GL}) is therefore:

$DEW_{GL}= (EV_{GL}*0.63)+(0*[CDE_{birth} – 0.63])$
$MEW_{GL}= (0* CDE_{annual})$

Thus, the economic weight for DEW_{GL} and MEW_{GL} are -€4.49, and €0.00, respectively.

Calf Mortality

Mortality affects profitability through the loss of a calf. Thus, the economic value for calf mortality is the opportunity cost of the calf (i.e., the price obtainable for a newborn calf). Similar, to calving difficulty and gestation length, calf mortality is influenced through direct and maternal genetic effects (Steinbock *et al*., 2003). Male calf value and female calf value were assumed to be €102 and €315, respectively in accordance with prices included in the bio-economic model based on FAPRI projections (FAPRI, 2003). In 2003, 57% of stillbirths were males. The weighted average value of a black and white calf was therefore assumed to be €193.59. Hence, the economic value per percentage increase in calf mortality is -€1.94.

The CDE for direct calf mortality is synonymous with the CDE for birth traits reported by Berry *et al*. (2006a) while the CDE for maternal calf mortality is synonymous with the CDE for annual traits reported by Berry *et al*. (2006a).

Calf mortality does not affect other traits included in the EBI and the traits included in the EBI that affect calf mortality (i.e., calving difficulty, gestation length) do not include possible effects on calf mortality in their economic value. Hence, no issue of double counting arises.

Thus, the economic weight for direct calf mortality (DEW_{MORT}) and maternal calf mortality (MEW_{MORT}) is:

$DEW_{MORT}= (EV_{MORT}*1.33)$

$MEW_{MORT}= (EV_{MORT}* 1.13)$

Therefore, the economic weights for direct calf mortality and maternal calf mortality are -€2.58 and -€2.19. Breeding values for maternal calf mortality are not currently available.

Cow carcass weight

The economic value for cow carcass weight is a function of three separate factors. The revenue from increased carcass size, the cost of increased maintenance of the cow and the cost of the increased energy demands of the cow as a growing nulliparous female.

The revenue attainable from a cull cow carcass is a function of the average carcass price per kg. However, animals slaughtered at a carcass weight of less than 272 kg are heavily penalised; it is assumed that they receive half the average cull cow price. Thus, as carcass weight increases the carcass value increases by the average carcass price per kg for each incremental kg increase in carcass weight. However, the proportion of cows with a carcass weight of greater than 272 kg also increases thereby increasing the average carcass price per kg across the population. Data on cull cow carcass weight for over 25,000 black and white cows throughout the years 2002 to 2004 were used to determine the percentage of carcasses slaughtered at a carcass weight of less than 272 kg as well as the phenotypic standard deviation for carcass weight. The phenotypic standard deviation for carcass weight was 50kg and 27% of carcass weights observed were less than 272 kg. Following an average increase in carcass weight by 1kg, 0.7 percentage units of animals crossed over the 272 kg carcass weight threshold thereby commanding higher carcass price and contributing to the economic value for carcass weight. The weighted average price of O3's was €1.61 /kg carcass weight. Thus, the economic benefits of a kg increase in carcass weight is €3.00.

The bio-economic model (Shalloo et al., 2004) includes a variable for cow live-weight as well as grass growth rate patterns; this facilitated the calculation of maintenance cost per incremental kg increase in live-weight. The maintenance cost per lactation for each incremental kg increase in liveweight was €0.167/year. Assuming a 45% kill out percentage this equates to €0.371/kg carcass weight (i.e., €0.167/0.45).

Table 7. *Diet composition and cost for a growing heifer for each additional kg increase in live-weight*

	UFL	KgDM	Costs /kgDM (€)	Total Cost (€)
65% Grass	2.93	2.87	0.058	0.166
25% Grass Silage	1.13	1.61	0.111	0.179
10% Concentrate	0.45	0.41	0.13	0.053
Total				€0.398/kg LW

In order for the cow to attain the heavier weight she also requires an additional amount of energy as a growing female. Every additional 1 kg increase in liveweight requires an additional 4.5 UFL of energy throughout the growing process (Jarrige, 1989). We can estimate the amount of this energy that comes from grazed grass, grass silage and concentrate. We can then convert this to kg of dry matter required and from there we can cost the additional energy required (Table 7). Assuming a kill out percentage of 45%, the growing cost to increase carcass weight by 1kg is €0.88 (i.e., €0.398/0.45).

Each of the three components of cow live-weight are expressed at different frequencies over different time horizons. Carcass weight is synonymous with "cull cow traits", cow maintenance requirements is synonymous with "annual cow traits" while heifer growth requirements is synonymous with "heifer replacement traits" as reported by Berry et al. (2006a).

The economic weight for cow carcass weight (EW_{COWCW}) was calculated as

$$EW_{COWCW}=(EV_{Carcass\ weight}*0.24)+(EV_{maintenance}*1)+(EV_{growth}*0.35)$$

Where each of the numerical coefficients represent the CDE for the respective trait. Thus, the economic value for cull cow carcass weight is €0.04/kg

Calf carcass weight

The economic value for carcass weight is the price attainable per kg carcass less the cost of increased dry matter intake associated with the increase. A projected future base carcass price of €2.40 was assumed. A projected price differential to O4L was assumed to be -€0.12 (Farmers Journal, 18th December 2004). Thus, the projected carcass price for a typical O4L steer is €2.28/kg carcass weight.

Calculation of the cost per unit effective energy is summarised in Table 8. Effective energy of the feedstuff are calculated as outlined by Emmans (1994)

Table 8. *Cost, metabolisable energy content (ME), digestible crude protein content (DCP), effective energy (EE) content and cost per MJ effective energy for silage and concentrates as well as a finishing diet (80% grass silage, 20% concentrates).*

	Cost (€/t DM)	ME (MJ/kg DM)	DCP (g/kg DM)	EE (MJ/kg DM)	EE cost (cent/MJ)
Silage	111	10.8	140	10.46	1.06
Concentrates	190	13	120	8.02	2.37
Silage / concentrate 0.8/0.2					1.32

Based on the procedures of Amer and Emmans (1998), assuming the costing structure in Table 12 and that the degree of maturity at slaughter in protein is 80%, the cost for each extra kg increase in carcass weight is €1.06. This is similar to the cost predicted (€1.13) assuming a correlation of 0.70 between lifetime dry matter intake and carcass weight assuming a standard deviation of 420 kg and 20 kg for lifetime dry matter intake and carcass weight, respectively, and an average cost of €0.07/kg DM.

Thus, the economic value for carcass weight is €2.28 - €1.06 = €1.22/kg. This accounts for increased revenue accruing from the sale of an extra kg of carcass weight, grading O4L and the increased maintenance and growth cost of the extra kg carcass weight.

The CDE for slaughter traits reported by Berry et al. (2006a), expressed for use with PTAs and scaled back to a per lactation basis by a factor of 1.58 is 0.75.

The economic weight for calf carcass weight (EW_{CCAR}) is:

$EW_{CCAR}=EV_{CCAR}*0.75$

Thus, the economic weight for calf carcass weight is €0.92/kg

Calf carcass conformation

It is assumed that the carcass price at a fixed carcass weight is comprised of the values derived from the weight of meat cuts from the loin, the hind quarter, plus the weight of the remaining meat cuts. In other words, no economic value is assigned to the value of bone, offals and trimmings etc derived from the carcass. From this, the economic value of an increase in the weight of "other" cuts (EV_OC) can be calculated as

$$EV\_OC = \frac{CP}{\rho LC \cdot RL + \rho HC \cdot RH + \rho OC}$$

where CP is the carcass price per kg (€2.40), ρLC is the proportion of all cuts which are loin cuts (0.115), RL is the ratio of the price of loin cuts relative to the price of "other" cuts (5.3), ρHC is the proportion of the carcass which is hind-quarter cuts (0.245), RH is the ratio of the price of hind-quarter cuts relative to the price of "other" cuts (2.2) and ρOC is the proportion of the carcass which is non loin cuts (0.640). The economic value of loin cuts is then taken as

$$EV\_LC = EV\_NLC \cdot RL$$

and the economic value of hind-quarter cuts is taken as

$$EV\_HC = EV\_NLC \cdot RH$$

Using the derived values for the parameters as shown above, economic values for weights of other cuts, loin cuts, and hind-quarter cuts, at a constant carcass weight are €1.34, €7.10 and €2.95 respectively. Currently, there is no data available of sufficient structure to estimate genetic relationships between recorded traits and the meat cuts profit traits. This is because the number of processors who currently capture cut weights is small. It is anticipated that in the future, mechanical grading systems will lead to accurate predictions of cut weights, and these will be able to be included as selection criteria as they are captured and stored on the national database. At present, the data that is being captured is limited to carcass weight, carcass fat score and carcass conformation score. Carcass conformation score was recoded to a 15 point scale prior to genetic analysis. Thus, in the interim, predictions of the goal traits of loin, hind-quarter and other cuts at a constant carcass weight will have to rely on

1. the ability of recorded traits to predict conformation scores

2. the expected change in cut weights with a unit change in carcass conformation score.

Therefore, the economic weights will be applied to carcass conformation score, based on the relationships between carcass conformation and cut weights. Data on carcasss of suckler herd owners where both carcass conformation and cut weights have been measured were used to estimate the relationships between carcass conformation (recoded to a 15 point scale) and cut weights. The resulting (phenotypic) coefficients and calculations to get the economic values for carcass conformation described in Table 9.

Table 9. *Regression coefficients for the three cut traits on carcass conformation and the respective economic values*

Cut trait	Carcass Conf. score (15pt scale)	Cut economic weight (€/kg)	Contribution to EW
Loin cuts	0.285	7.10	2.02
HQ cuts	0.829	2.95	2.45
Other cuts	0.576	1.34	0.77
Interim economic weight			5.24

The CDE for slaughter traits reported by Berry et al. (2006a), expressed for use with PTAs and scaled back by a factor of 1.58 is (i.e., to scale all expressions to a per lactation basis) 0.75.

The economic weight on calf carcass conformation score (EW_{CCONF}) is:

$EW_{CCONF}=EV_{CCONF}*0.75$

Thus the economic weight for calf carcass conformation score is €3.93

Calf carcass fat score

The economic value for carcass fat score was calculated from the relationship between carcass fat score and cut weights. Fatter carcasses will have lower weights of all types of cuts at the same carcass weight. Thus with a breeding objective based on cuts most of the economic influence of fatness will be implicit, rather than explicit in the breeding objective. However, because cut data is unavailable, in the interim, the economic weight applied to carcass fat score, will be based on the relationships between carcass fat score and cut weights at a constant carcass weight. The phenotypic coefficients and calculations to get the economic values for carcass fat score are described in Table 10.

Table 10. *Regression coefficients for the three cut traits on carcass fat score and the respective economic values*

Cut trait	Carcass Fat score (15pt scale)	Cut economic weight (€/kg)	Contribution to EW
Loin cuts	-0.315	7.10	-2.24
HQ cuts	-0.950	2.95	-2.80
Other cuts	-2.35	1.34	-3.15
Interim economic weight			**-8.19**

No account of the contribution of fatness to eating quality is taken, under the assumption that beef of exclusively dairy origin will not be exported in a form, and to markets, where fat cover is desirable.

The CDE for slaughter traits reported by Berry et al. (2006a), expressed for use with PTAs and scaled back by a factor of 1.58 is 0.75.

The economic weight on surplus calf fat score (EW_{CFAT}) is:
$EW_{CFAT}=EV_{CFAT}*0.75$
Thus the economic weight for surplus calf fat score is -€6.14

DEVELOPMENTS IN 2006

In 2006, a health subindex was added to the EBI including the traits somatic cell count and lameness. This increased the number of traits in the EBI from 13 to 15. furthermore. EBI's were made official for alternative breed sires on a common base.

Genetic evaluations

Heritability and repeatability estimates of lactation average SCS (i.e., $\log_e$ somatic cell count) in Irish cows were estimated at 0.11 and 0.49, respectively when estimated using a repeatability sire model across the first five lactations (Evans and Berry, 2005). Genetic correlations between lactation average SCS across the first five parities were all greater than 0.79 suggesting the appropriateness of using a repeatability model. Breeding values for SCS were estimated using a single trait repeatability model with the fixed effects identical to those used in the analysis of the milk production traits.

In 2006, genetic evaluations for calving interval and survival moved to an across breed evaluation incorporating data from all dairy breeds and crossbreeds. Breeding values for all other traits were already being estimated from an across-breed evaluation and therefore official EBI's were produced for alternative breed animals in 2006. Fixed effects included in the model were as before with the exception that heterosis and recombination were also included as fixed effects. Heterosis was included with 34 classes in increments of 3% (i.e,. 0%, 0.01% to 3%, 3.01% to 6% ... 100%). Recombination was included as a fixed effect also with 34 classes in increments of 1.5% Classes of heterosis and recombination but also adjusted for percentage unknown in the sire and dam are also fitted as fixed effects.

Economic weights

Lameness

Incidence of lameness

Due to a lack of lameness data, the incidence of lameness requiring veterinary treatment was assumed to be 3% (i.e., three treatments annually for each 100 cows calving). This represents the incidence of veterinary callouts for the treatment of lameness in Irish dairy herds. When considering the validity of this proportion it is important to remember that in the coming years it is possible that veterinary assistance will become a legal requirement for the administration of antibiotics to farmed livestock in Ireland. However, veterinary assistance is not always required for lame cows and most incidences of lameness are treated by the farmer or the farm relief service. An incidence of 12% was assumed for mild cases of lameness; this implies an overall annual incidence count of lameness of 15%. No data were available to (in)validate this incidence rate. Nevertheless, because the cost of farmer/farm relief services are low relative to veterinary required treatments, this assumption may not be critical. For example Stott et al. (2005)

argue that selection should only be targeted at veterinary required treatments because they assumed that "lameness dealt with only by farm staff constituted routine foot care carried out as part of normal husbandry practice and therefore was unaffected by marginal genetic improvement". In the present study an economic value was derived accounting for both severe (i.e., veterinary assistance required) and mild cases of mastitis, although a comparison with severe cases alone will be made.

Cost of lameness

The overall economic impact of lameness is comprised of reduced milk production, reduced carcass weights, compromised fertility, increased risk of being culled as well as the cost of treating the ailment. However, milk production, fertility, survival and beef merit are currently included in the EBI in their own right, and we would expect poorer performance in a bull's descendants due to lameness to be reflected directly in his PTA's existing within the EBI. Hence, to avoid double counting, the impact of lameness on milk production, fertility, survival and beef merit will not be included in the economic value for lameness proposed for incorporation into the EBI.

Veterinary treated lameness

Three main types of commonly occurring lameness are 1) digital, 2) inter-digital, and 3) sole ulcers. The costs of each type of lameness have been outlined in great detail by Esslemont and Kossaibati, (2002) and have been converted to Irish prices by Ryan and O'Grady (2004). Veterinary assistance costs used here are summarised in Tables 11, 12, and 13. They have been modified slightly from Ryan and O'Grady based on projected prices. The study of Esslemont and Kossaibati (2002) was also the basis of the derivation of the economic value for lameness in the UK (Stott et al., 2005) and Canada (Boettcher and Fatehi, 2001). The average cost of severe lameness where a veterinary is required was derived based on the expected proportion of each lameness type within the Irish population. However, data is currently unavailable on the relative prevalence of each lameness type in Ireland and thus prevalences used herein are based on UK data (Esslemont and Kossaibati, 2002). The weighted average cost of lameness is reported in Table 14.

Table 11. *Cost of lameness caused by digital lameness.*

	Cost (€)/unit	Total
Treatment costs	25	25.00
Vet cost (including time and callout)	104.30/hr + 50 callout	76.08
Herdsman labour (20 minutes)	12.44/hr	4.15
4 days milk withdrawal at 20 kg/day†	0.217 /kg	0.87
Total (€)		106.09

†Assumes only 5% of animals are treated with antibiotics requiring milk withdrawal

Table 12. *Cost of lameness caused by inter-digital lameness.*

	Cost (€)/unit	Total
Treatment costs	25	25.00
Vet cost (including time and callout)	104.30/hr + 50 callout	67.38
Herdsman labour (20 minutes)	12.44/hr	4.15
2 days milk withdrawal at 20 kg/day†	0.217 /kg	1.74
Total (€)		98.27

†Assumes only 20% of animals are treated with antibiotics requiring milk withdrawal

Table 13. *Cost of lameness caused by sole ulcers.*

	Cost (€)/unit	Total
Treatment costs	50	50.00
Vet cost (including time and callout)	104.30/hr + 50 callout	84.77
Herdsman labour (40 minutes)	12.44/hr	8.29
5 days milk withdrawal at 20 kg/day†	0.217 /kg	1.09
Total (€)		144.15

†Assumes only 5% of animals are treated with antibiotics requiring milk withdrawal

Table 14. *Prevalence of the alternative types of lameness and their associated costs as well as the weighted average cost of lameness*

Type of lameness	Digital	Inter-digital	Solar ulcer
Prevalence (%)	41	38	21
Cost (€)	106.09	98.27	144.15
Total (€)			111.11

The expected direct cost of €111.11 per severe case requiring veterinary assistance assuming an incidence of 3 annual treatments per 100 cows calving across the national dairy herd amounts to a direct cost of lameness of €4.2 m/year. Reducing the prevalence of lameness by 1 treatment per 100 cows calving (i.e., from 3 treatments to 2 treatments per 100 cows calving) is worth €1.4 m/year to the dairy industry through direct costs. Direct costs do not include the indirect effect of lameness on milk production and fertility/survival of the animal. Calculations by Esslemont and Kossaibati (2002) suggest that direct costs only account for around 41% of the total costs associated with lameness. Thus, our estimate of the economic consequences of severe lameness should be at least doubled when considering the overall cost.

Farmer treated lameness

One may assume farmer time of half an hour per cow treatment @ €12.44 hour. A call-out and treatment cost whereby the farm relief service is used may be estimated at €48 (Farm Relief Service, Fermoy, Co. Cork). However, generally the farm relief service will treat more than one cow at a time; in these calculations we assumed that on average two cows were treated per visit while the cost per visit remains the same. Usually no milk withdrawal follows and thus was not included in the cost. Hence, the average cost for farmer/farm relief treated lameness is €30.22/case.

Relationship between type traits and lameness

Several feet and legs-related type traits have been implicated as contributing factors to lameness incidence in dairy cattle. However, data on lameness is currently lacking in sufficient quantity to estimate accurate genetic relationships between the feet and legs type traits and lameness in Irish dairy cattle. It will be possible to better quantify these relationships in the future as the level and accuracy of recording is augmented through the animal events system.

Locomotion is a trait, scored by Holstein-Friesian classifiers since 1998, which describes the stride of an individual animal. Locomotion is scored on a scale of 1 (obvious signs of lameness) to 9 (walks with an even gait). Although based on a relatively small dataset, van der Waaij et al. (2005) reported moderate to strong genetic correlations between some claw health variables and locomotion (scale 1-9) as scored by the Royal Dutch Cattle Syndicate. Lower genetic correlations were reported between the claw health variables and the other feet and legs traits scored by the Royal Dutch Cattle Syndicate. Despite the fact that the genetic parameters estimated had relatively large standard errors, originated from a different population of cows on a different system of milk production as well as possible differences in the definition of locomotion between the two countries the correlations may be viewed as a guide to the correlations expected under Irish conditions, until such a time as sufficient data is available to estimate the correlations in Irish dairy cattle. One must be aware that these correlations may be different in Irish dairy cattle which may subsequently affect the economic value.

Data on all type traits were extracted from the cattle breeding database run by the Irish Cattle breeding Federation (ICBF). Data on 45,813 first parity animals were available to estimate phenotypic and genetic parameters for locomotion. However, since locomotion was only introduced into the type evaluation scheme recently older sires and sires originating from countries where locomotion is not scored may have no PTA for locomotion. Thus, phenotypic and genetic parameters for the feet and legs composite type trait were also estimated.

No estimates are available for the heritability of lameness in Ireland. Hence, the heritability for clinical lameness in the current study was based on that reported by Boettcher et al. (1998) in the US (0.10) using a linear model. The prevalence and heritability were used to calculate the genetic variance for lameness. All phenotypic and genetic parameters are reported in Table 15.

Table 15. *Phenotypic and genetic variance, and heritability estimates for lameness, locomotion and feet and legs composite.*

	Lameness (Vet)	Lameness (overall)	Locomotion	Feet & Legs
Phenotypic variance	0.029	0.127	1.07	21.88
Genetic variance	0.003	0.013	0.095	3.58
Heritability	0.100	0.100	0.089	0.16

Because of the unavailability of data, it was not possible to estimate the genetic correlation between locomotion and clinical lameness. A genetic correlation of -0.40 was assumed between locomotion score and lameness; this is lower than the genetic correlation of unity assumed by Stott et al. (2005). This is also lower than the absolute correlations reported by van der Waaij et al. (2005) between locomotion and interdigital dermatitis heel horn erosion (-0.71; SE=0.17), digital dermatitis (-0.67; SE=0.19), and chronic lameness (-0.91; SE=0.18) but stronger than the genetic correlation reported between locomotion and sole ulcers (-0.04; SE=0.40), white line disease (-0.04; SE=0.31) and sole hemorrhage (0.13; SE=0.24). A genetic correlation of 0.74 was estimated between locomotion and Feet & Legs from the dataset of 45,813 first parity Irish dairy cows. The genetic correlation between feet & legs and lameness was assumed to be 0.20; this was lower than the 0.95 assumed by Stott et al. (2005). The correlations are lower because of the lack of data on lameness in Ireland and hence our lack of confidence in assuming high correlations. Nevertheless, based on these correlations, it was possible to estimate the genetic regression of lameness on either locomotion or feet & legs as

$$b = r \cdot \frac{\sigma_{Lameness}}{\sigma_x}$$

where r is the genetic correlation, $\sigma_{Lameness}$ is the genetic standard deviation of lameness and σ_x is the genetic standard deviation of either locomotion or Feet & Legs.

Economic value for lameness

When deriving the economic value for all cases of lameness we want to investigate the marginal cost associated with shifting the mean of the underlying distribution. It is convenient that the height of the normal distribution at the truncation point giving the appropriate incidence gives us the expected change in incidence per unit change on the underlying scale. This is identical to taking the first derivative of a profit function which incorporates the incidence probability as a function of the mean of the underlying trait. The value of the distribution function at the truncation point then gets multiplied by the economic cost of an occurrence. This method is easily expanded to multiple categories of incidence (i.e. separate incidences of farmer treatment and veterinary treatment) with the products of probability changes and incidence costs summed over incidence categories to derive the economic value of a unit incremental change in the mean of the underlying distribution. Because there is a clear relationship between the underlying mean and the combined probability over all incidence categories, the units of the economic value can be translated to have units of the incidence rate of all cases of lameness (i.e. with a mean of 15%). This is done by dividing the underlying scale economic value by the expected change in the combined probability over all incidence categories per unit change in the underlying scale. The required value can be taken as the height of the underlying standard normally distributed trait at the truncation threshold which gives a 15% incidence. Hence, the economic value per incidence of any lameness accounting for both veterinary treated and farmer treatment costs was calculated as €53.83/case.

When the same calculations are repeated but ignoring the farmer treatment costs, the economic value of any lameness was reduced to a value of €32.43/case.

Hence, the index weight on locomotion is calculated as:

€53.83 * 0.147 * 0.144 = €1.13/standardised locomotion score

The figure €53.83 represents the economic value for lameness per new case, 0.147 is the genetic regression of lameness on locomotion and 0.144 is the standard deviation of the PTAs of the base bulls for locomotion which is used to standardise the published locomotion scores between ±3.

Similarly the index weight for Feet & Legs only in animals with no information on locomotion is:

€53.83 * 0.012 * 0.676 = €0.43/standardised locomotion score

The standard deviation of the PTAs of the base bulls for Feet & Legs is represented by 0.676 above.

The economic values when farmer treatment costs were ignored were €0.68 and €0.26 per standardised locomotion or feet & legs score, respectively. Hence, the economic value on locomotion score (or Feet & Legs) is larger when mild (farmer treated) cases of lameness were accounted for in the economic value calculation.

Susceptibility to lameness per cow calving as we have defined it here will be expressed annually by a cow and thus has the same cumulative discounted genetic expression (CDE) as the milk production traits (among others) in the EBI. All CDE in the EBI are re-scaled to the equivalent of annual traits which is set at one. Thus, the economic value is equal to the economic weight.

Mastitis

Incidence of mastitis

There is currently a paucity of data on incidence of clinical mastitis in Irish dairy herds. Data were extracted from the ICBF database on 25,510 daily treatment records for mastitis. Records on the same cow within five days of each other were treated as the same case. Only data from the year 2002 on were retained; 20,297 records remained. Parity number was allocated to each observation based on adjacent calving dates. Animal-parity records with a calving date in 2005 had their record for clinical mastitis set to missing as not all animals had the opportunity to express this trait for the whole of lactation. The data were merged with individual cow lactation mean SCC; the natural log of SCC was obtained so as to normalise the data. Only herd-years with more than fifteen cow records where at least one case of clinical mastitis was recorded were retained for inclusion in the analysis.

This dataset was used to determine the number of cases of mastitis per 100 cows calving in Irish dairy herds. On average 10 cases of mastitis were recorded per 100 cows calving across the entire dataset. This is considerably lower than other international estimates and may be due to less accurate recording as well as possibly a lower level of treatment/recording for sub-clinical mastitis due to the low level of milk recording in Ireland compared to other countries (ICAR, 2002). Other international studies have reported incidences per 100 cows of 26% in The Netherlands (Arnold Harbers, per comm.) to 56% in Denmark (Forshell et al., 1995). Hence, an overall incidence of 25% was assumed for Ireland of which one/tenth (i.e., 2.5% overall) were assumed to require veterinary intervention. This may be an underestimate given the likely policy changes in the future governing the use of prescription only medicines (POM) on Irish farms. The incidence of (sub)clinical mastitis should be verified by evaluating the number of test-day SCC records greater than 250,000 SCC/ml and linking to the data on treatment cases of mastitis. Farmers should also be encouraged by all organisations, including Teagasc, the ICBF, the IHFA, NCBC and all other AI organisations and breed societies to record treatment for mastitis.

Cost of mastitis

The cost for mild and severe mastitis are summarised in Table 16 and 17, respectively.

Table 16. *Cost per case of mild mastitis.*

	Cost/unit	Total
Treatment cost	€3/tube	9.00
Herdsman labour	12.44/hr	12.44
7 days milk withdrawl at 20 kg/day	0.217 /kg	23.87
Total (€)		45.31

Table 17. *Cost per case of severe mastitis.*

	Cost/unit	Total
Treatment cost	€3/tube + antibiotics/fluids	75.00
Vet cost (including time and callout)	104.30/hr + 50 callout	76.08
Herdsman labour	12.44/hr	12.44
6 days milk withdrawl at 20 kg/day	0.217 /kg	26.04
Total (€)		189.56

Economics of mastitis

The effect of an incremental change in the mean of the underlying normal distribution on the area under the curve between the thresholds mild and severe mastitis and between the threshold for severe mastitis and infinity were derived using the same methodology as described above for lameness. The change was multiplied by the respective costs and summed to give the economic value. This was re-scaled to an incidence rate based on the overall incidence of mastitis (i.e., 25%). The economic value for per case of mastitis was calculated as €71.84.

Genetic parameters

In order to estimate genetic parameters the data used to estimate the incidence of mastitis were further edited to retain cow records from known Holstein-Friesian sires. Lactation records from parity four or greater were deleted. Herd-year-season contemporary groups were created by concatenating herd, year and season (i.e., spring, summer, autumn, winter). If three or less records were present in any one herd-year-season then the records were merged with the adjacent contemporary group within herd-year. Following this edit, contemporary groups that still had three or less records were removed. The natural logarithm of SCC was calculated, herein referred to as somatic cell score (SCS), to normalise the distribution.

The heritability of mastitis was 0.011 irrespective of whether an animal or sire model was used. The repeatability was 0.016 when using a sire model; a permanent environmental variance was inestimable when using an animal model. The heritability of 0.01 is slightly less than previous heritability estimates of 0.02 to 0.03 (Philipsson et al., 1995; Heringstad et al., 2000). Hence, in the present study a heritability 0.02 was assumed although sensitivity analyses were performed assuming a heritability of 0.01. Due to the inability of the mixed model equations to converge it was not possible to estimate genetic correlations between mastitis and somatic cell score using either a sire or an animal model.

Index weight

A genetic correlation of 0.70 was assumed between SCS and mastitis which is the average across most studies that have investigated such (for review see Mrode and Swanson, 1996; Heringstad et al., 2000). Based on this correlation and the assumed incidence of 25% mastitis, it was possible to estimate the genetic regression of mastitis on SCS as:

$$b = r \cdot \frac{\sigma_{Mastitis}}{\sigma_{SCS}}$$

where r is the genetic correlation, $\sigma_{Mastitis}$ is the genetic standard deviation of mastitis and σ_{SCS} is the genetic standard deviation of SCS. The estimated genetic regression coefficient of mastitis on SCS was 0.167.

Hence, the index weight on SCS is calculated as:

€71.84 * 0.167 = €11.99 / unit SCS

The figure €71.84 represents the economic value for mastitis and 0.167 is the genetic regression of clinical mastitis incidence on SCS. Clinical mastitis incidence is an annual trait and thus has a cumulative discounted expression of one; hence the economic value equals the economic weight.

Somatic cell count

Somatic cell count has an economic value in its own right because of its effect on milk price paid to the farmer. In Ireland, tiered pricing operates based on the monthly arithmetic mean of the bulk tank SCC. The two main milk processors in Ireland, Dairygold and Glanbia apply a penalty to the volume of monthly milk collected when the arithmetic mean SCC of that month is greater than 400,000 with a greater penalty if the mean SCC is greater than 600,000; Dairygold applies a further penalty if the mean SCC is greater than 800,000. Neither processor currently provide a monetary incentive to low mean SCC although it is envisaged by both processors that in the future an incentive of

0.5 cents/litre will be given to monthly milk volumes with an arithmetic monthly SCC of <200,000 cells/ml. The penalty system operated by Dairygold and Glanbia and the proposed incentive for <200,000 SCC/ml are summarised in Table 18.

Table 18. *Somatic cell count penalty system currently adopted by Dairygold and Glanbia as well as the proposed incentive scheme*

SCC range	**Incentive/penalty per kg milk**	
	Glanbia	Dairygold
<200,000 SCC/ml	+0.5c/l	+0.5c/l
200,000 - 400,000 SCC/ml	Nil	Nil
400,000 - 600,000 SCC/ml	-0.66 c/l	-0.28 c/l
600,000 - 800,000 SCC/ml	-1.1 c/l	-1.12 c/l
>800,000 SCC/ml		-3.35 c/l

Bulk tank data

Data on bulk tank SCC and milk volume collected were obtained from 9,113 herds in 2004 from three processors representing approximately 40% of milk suppliers (Berry et al., 2006b). These data were used to determine the distribution of monthly arithmetic SCC within herd; the distribution followed a log-normal distribution. Only data from the year 2000 to 2004 was used in the subsequent analyses. The derived monthly arithmetic distribution was used to determine the proportion of herds in each of the SCC bands by month of year. The log of monthly SCC was used to normalise the SCC data for further analysis.

Economic weight

The proportion of milk supplied by month was derived from the herd represented in the MDSM model (Shalloo et al., 2004) under the base scenario of a calving pattern of 50:40:10 for February:March:April calvers. A shift in the distribution of the national herd SCS was modelled across each month of the year by obtaining the first derivate of the integral for each month separately. Although investigation of the data revealed that the variance of a log-normal distribution of SCC changes with the mean, the variance of the normally distribution SCS did not, thereby justifying using the first derivative of the integral as an estimate of a incremental change. The economic effect on milk price based on the change in proportion of herds within each of the SCC bands was estimated on a monthly basis. The monthly effects on milk price were weighted by the milk supply pattern of a spring calving herd and were summed to give the weighted annual effect on milk price. The sum was multiplied by 6000 which is the average cow yield assumed in the MDSM; this is the economic value. The economic value per unit logSCC (i.e. SCS) was €44.75 when assuming the Dairygold band pricing system and €42.23 when assuming the Glanbia band payment system. Hence, the average economic value of €43.49 per unit change in SCS is proposed.

Because lactation average SCC is a lactation trait it is expressed annually and thus has a cumulative discounted expression of one when scaled to the expression used in the EBI. Hence, the economic value equals the economic weight.

DEVELOPMENTS IN 2007

Genetic evaluations

There were no large changes in the genetic evaluations for 2007.

Economic values

Up until now in Ireland the biggest limiting factor at farm level on most farms was milk quota. However recent changes in economic policy in Europe (Luxembourg agreement) and around the world (WTO reform) will lead to reform of milk quota in Europe. The commissioner for agriculture in 2007 (Marian Fischler Bowel) stated recently in Denmark that milk quotas will be abolished in Europe by 2013-14. Within the EU Common Agricultural Policy (CAP) "health check" in 2008 milk quotas will be debated. The commissioner has stated her policy would be to allow EU milk quotas to increase by 1-2% per year between 2008 and 2013 therefore reducing their value over time. Within Ireland in 2007 the process of giving control of milk quota movement back to farmers will start with the running of a milk quota exchange. This is also projected to increase the volume of milk quota traded between farmers.

If the assumption is that milk quota will no longer be the limiting factor at farm level from 2013 and possibly before then the next limiting factor will be land for most farms. Therefore the economic values were calculated assuming that land was the limiting factor at farm level. In 2007, the Irish Dairy Board (IDB) paid a fat to protein ratio of 1.9 to 1 which was very similar to ratio in EU markets (Simms and Thompson, 2006). However with support for fat reducing within the EU budget the ratio of protein to fat was expected to increase to closer to 2.6:1 when quota was not the limiting factor.

The availability of additional carcass cut yield data facilitated more accurate quantification of the EUROP classification scoring system within carcass cut yield. Furthermore, a survey of veterinary charges undertaken by the Irish farmers Journal provided a better estimate of veterinary charges associated with calving difficulty in Ireland.

Calving performance

Median price of a caesarean increased from €160 to €204 while the median price to attend a calving increased from €40 to €70. A knackery charge to remove a dead calf of €20 was also imposed and the economic weight on gestation length was altered in line with changes in the economic value for calving interval as outlined below.

Carcass cut yield

The economic value previously generated for carcass conformation and carcass fat score were derived based on a regression of meat cut yield on carcass conformation or fat score scored by persons in the meat factories. The meat cut yields were obtained from Petitis and consisted previously of approximately 1,500 records. However, mechanical grading was introduced in December 2004 and more data has also been collected in the interim. Therefore the regression coefficients were re-estimated (Table 19).

Table 19. *Economic values for carcass conformation and fat score using Petits results since mechanical grading Dec 04– Dec 05 (1946 carcasss)*

Cut trait	Carcass Conf. score (15pt scale)	Carcass Fat score (15pt scale)	Cut economic value (€/kg)
Loin cuts	.385 (.023)	-.311 (.022)	12.52
HQ cuts	1.085 (.046)	-.991 (.043)	5.20
Other cuts	1.40 (.099)	-2.78 (.094)	2.36
Interim economic value	13.76	-15.61	

The cumulative discounted genetic expressions for carcass traits in the dairy EBI relative to lactation traits is 0.75 thereby suggesting an economic weight of €10.32 and -€15.61 for carcass conformation and fat score, respectively.

Milk production and fertility economic weights

The Moorepark bioeconomic model was adapted to calculate the economic values with land being the limiting factor rather than milk quota. Two scenarios evaluated;

(1) The cow numbers were adjusted using the solver program within Microsoft Excel to ensure land area was fixed in the model. Therefore for example when milk protein was increased cow numbers had to be reduced to ensure that the land area was fixed. This procedure was carried out for all 5 economic values.

(2) The second scenario involved bringing in supplementary feed when there was a change in the economic values. This feed was assumed to be purchased in at a cost of €140/tonne of dry matter with a UFL value of 1.07UFL per kg of DM

When the land based EBI is compared to the current EBI (Table 20);

- The economic value for milk volume doesn't change.

- The value for fat increases. This comes from two sources; Firstly the fat adjusted milk quota is no longer binding therefore there is no additional quota cost when milk fat is increased. However when fat is increased there is an increased energy requirement to produce this fat. When land is fixed cow numbers must reduce or there is feed purchased onto the farm. Overall the weighting for fat increases when cow numbers reduce and decreases where there is purchased feed brought onto the farm.

- The value for protein reduces. This is as a direct result of having to reduce cow numbers or bring in expensive feed onto the farm, to increase milk protein. Therefore the economic benefit to increasing milk protein is not as strong as if milk quota was the limitation and land was freely available.

- The value for survivability reduces marginally

- The value for calving interval decreases to -€13.95 where cow numbers are reduced and decreases to -€11.52 where feed is purchased onto the farm from -€7.17 per day. The effect of land being the limiting factor is most radical on calving interval. The economic value reduce from -€7.09 to -€13.95 or -€11.52 depending on the scenario.

Table 20. *Economic values in the EBI2006 and proposed EBI2007 with land constraints where cow numbers reduce and where purchased feed is brought onto the farm.*

Trait	EBI 2006	EBI2007 (fixed land)	EBI2007 (Purchased feed)
Protein	5.27	4.84	4.82
Fat	1.55	1.66	1.31
Milk	-0.08	-0.08	-0.09
Survival	10.80	10.27	10.22
Calving interval	-7.17	-13.95	-11.52
Maternal calving difficulty	-1.73	-0.62	-0.62
Direct calving difficulty	-3.26	-2.94	-2.94
Direct gestation length	-4.47	-2.38	-2.38
Calf Mortality	-2.58	-0.77	-0.77
Cull cow carcass weight	0.04	0.18	0.18
Carcass weight	1.40	3.96	3.96
Carcass conformation score	5.99	10.32	10.32
Carcass fat score	-4.49	-11.71	-11.71
Locomotion	1.13	1.13	1.13
Udder	-55.48	-55.48	-55.48

Ratio of Fat to Protein

Within the current EBI one kilogram of protein is worth twice what one kilogram of fat is worth. This ratio is expected to increase as the support for fat is reduced within the EU. The economic values were calculated where this ratio of protein to fat were increased from the current figures of 2.0 : 1 to 2.6:1 based on analysis carried out by (Simms and Thompson, 2006). When the ratio of protein to fat is changed from 2:1 to

2.6:1 milk fat and protein are fat, protein, survivability and calving interval are effected which are shown in Table 21. Fat reduces in value from €1.31 to €0.96 while milk protein increases from €4.82 up to €5.36, survivability increases from €10.22 to €10.51 and calving interval increases from -€11.52 to -€10.87. This change is directly as a result of changes to economic policy that can be expected in the future. With reduction in support for butter down to €954/tonne in July 2007 and widely talked about abolition of export refunds it is most likely that the value of fat relative to protein will decline rapidly over the next number of years.

Table 21. *Economic values in the EBI2006 and proposed EBI2007 with land constraints and where the ratio of fat to protein changes to 2.6:1.*

Trait	EBI 2006	EBI2007 (fixed land)	EBI2007 (Purchased feed)	EBI2007 (Purchased feed Ratio 2.6:1)
Protein	5.27	4.84	4.82	5.36
Fat	1.55	1.66	1.31	0.96
Milk	-0.08	-0.08	-0.09	-0.085
Survival	10.80	10.27	10.22	10.51
Calving interval	-7.17	-13.95	-11.52	-10.87
Maternal calving difficulty	-1.73	-0.62	-0.62	-0.62
Direct calving difficulty	-3.26	-2.94	-2.94	-2.94
Direct gestation length	-4.47	-2.38	-2.38	-2.38
Calf Mortality	-2.58	-0.77	-0.77	-0.77
Cull cow carcass weight	0.04	0.18	0.18	0.18
Carcass weight	1.40	3.96	3.96	3.96
Carcass conformation score	5.99	10.32	10.32	10.32
Carcass fat score	-4.49	-11.71	-11.71	-11.71
Locomotion	1.13	1.13	1.13	1.13
Udder	-55.48	-55.48	-55.48	-55.48

DEVELOPMENTS IN 2008

Genetic evaluations

In 2008 evaluations for calving difficulty, gestation length, and mortality estimated using a sire-maternal grandsire model in ASREML were replaced by an animal model with MIX99; each trait was still analysed in a bivariate analysis where one trait was the older data prior to the introduction of animal events recording and the second trait is data recorded as part of animal events recording system. Also, the expression of the calving difficulty PTA's were expressed relative to a base of -6 so as to avoid any negative PTA's which were thought to be sometimes difficult to interpret for some people.

Economic values

A considerable increase in milk price paid was observed in international market in 2007 and it was envisaged that this greater than expected milk price was anticipated to remain for several years. Therefore, in 2007 it was decided to undertake research in the impact of increasing milk price in the bioeconomic model as well as updating the costs of production. FAPRI projected a short-term and long-term milk price of 30 c/l and 26c/l, respectively while the OECD predicting a milk price of 28 c/l. It was the view of the dairy industry to implement the milk price of 30 c/l. This impacted on the economic values of milk yield, fat yield, protein yield, calving interval and survival. The impact of land being the limiting constraint as well as increased feed costs on cull cow live-weight was also investigated. The cost of growing an animal to an extra kg live-weight increased from €0.398 to €0.743 while the annual cost per extra kg live-weight increased from €0.167 to €0.295. Changing milk price also affects the economic weight on direct calving difficulty, lameness and somatic cell count as well as the economic weight on gestation length through its effect on the economic weight on calving interval.

The impact of the different milk price options on the economic value is illustrated in Table 22. As milk price increased the economic value for fat and protein yield as well as calving interval, survival, direct calving difficulty, gestation and somatic cell score increased.

Table 22. *Impact of altering milk price on the economic values (also included is the proposed changes in cull cow carcass weight economic value.*

		Milk price		
Trait	EBI 2007	26c/l	28c/l	30c/l
Milk yield	-0.085	-0.09	-0.09	-0.09
Fat yield	0.96	0.92	1.09	1.26
Protein yield	5.36	6.05	6.48	6.91
Calving interval	-10.87	-11.83	-11.9	-11.97
Survival	10.51	10.31	10.74	11.17
Direct calving difficulty	-3.26	-3.56	-3.6	-3.65
Maternal calving difficulty	-1.73	-1.73	-1.73	-1.73
Gestation	-6.85	-7.45	-7.50	-7.54
Calf mortality	-2.85	-2.85	-2.85	-2.85
Cull cow carcass weight	0.04	-0.51	-0.51	-0.51
Carcass weight	1.38	1.38	1.38	1.38
Carcass conformation	10.32	10.32	10.32	10.32
Carcass fat	-11.71	-11.71	-11.71	-11.71
Somatic cell count	-55.48	-56.42	-56.89	-57.21
Locomotion	1.13	1.13	1.13	1.13

IMPACT OF CHANGES IN EBI

A summary of the index weighting factors in the RBI and the different EBI's is given in Table 24. The economic weights on most traits within the EBI have increased with time in line with inflation although large increases in the absolute economic value for calving interval have been observed due mainly to changes in the bioeconomic model most notably the inclusion of milk production lactation profiles derived from national data for each month of calving. The heritability of each index was calculated as follows:

$$h^2 = \frac{\sum_{i=1}^{15}(ew_i^2 \cdot \sigma_{a_i}^2)}{\sum_{i=1}^{15}(ew_i^2 \cdot \sigma_{p_i}^2)}$$

where ew_i is the economic weight on trait i in the breeding goal, $\sigma_{a_i}^2$ is the additive genetic variance of trait i and $\sigma_{p_i}^2$ is the phenotypic variance of trait i.

The heritability of RBI, EBI2001, EBI2004, EBI2005, EBI2006, EBI2007 and EBI2008, was 0.350, 0.113, 0.072, 0.074, 0.079, 0.061 and 0.066, respectively. The decrease in heritability of the breeding goal over time is due to the increased emphasis on low heritability traits such as calving interval and survival.

Correlations between sire proofs

A total of 2,710 AI sires with a reliability for milk yield of at least 70% were used to determine, using correlation analyses, the effect of changes in the EBI over the years on the ranking of sires. The correlations among sire RBI and the various EBI's is detailed in Table 23. The low correlation between the RBI and EBI (in particular the most recent EBIs) is due to increased emphasis on calving which is unfavourably correlated with milk production, the only traits included in the RBI.

Table 23. *Correlations between sire proofs (n=2710) for RBI and the various EBIs over the years*

Index	RBI	EBI2000	EBI2004	EBI2005	EBI2006	EBI2007
EBI2000	0.87					
EBI2004	0.59	0.86				
EBI2005	0.58	0.59	0.85			
EBI2006	0.51	0.79	0.95	0.98		
EBI2007	0.13	0.48	0.82	0.85	0.90	
EBI2008	0.35	0.66	0.92	0.94	0.97	0.97

Impact of change in breeding goal on response to selection and relative emphasis

Genetic and phenotypic (co)variance matrixes with categories of traits evaluated together in a multi-trait analysis were obtained from the respective parameters included in the genetic evaluations. Genetic correlations between traits not evaluated together were estimated from correlations between EBVs of sires of moderate to high reliability. The genetic and phenotypic parameters are summarised in Appendix 1.

The P, G and C matrixes required for analysis using selection index theory were derived from the respective genetic and phenotypic parameters assuming a progeny group size of 100 for all traits. Traits included in the breeding goal were identical to those included in the selection index and only a single trait for calving interval and survival (parameters were based on the average across lactations) were used. These matrices were also used to derive the weighting factors as well as the standard deviation of the breeding goal and selection index.

Response to selection

An annual response to selection of 0.22 standard deviations of the selection index was assumed. The response to selection in the individual traits are summarised in Table 25. The standard deviation of the breeding goal was 25, 69, 83, 90, 96, 116 and 129 for the RBI, EBI2001, EBI2004, EBI2005, EBI2006, EBI2007 and EBI2008, respectively; the respective standard deviations of the index (assuming a progeny group size of 100) was 24, 60, 66, 76, 82, 95 and 106. The response to selection based on the responses per trait from selection on each breeding goal and the economic values of the EBI in 2008 assuming 0.22 standard deviations per annum are €10.81, €15.39, €19.79, €22.15, €22.51, €23.02 and €23.33 for the RBI, EBI2001, EBI2004, EBI2005, EBI2006, EBI2007 and EBI2008, respectively.

The top 100 AI sires (of at least 70% reliability for milk production; n=2710) were ranked on each index separately and their mean predicted transmitting abilities calculated; the results are summarised in Table 26.

The response to selection in fat and protein yield with the EBI is lower than selection on the RBI due mainly to the large emphasis on calving interval which is unfavourably correlated with fat and protein yield (Appendix 1). The mean genetic merit of the top 100 sires for fat and protein yield for the EBI2008 is half that of the top 100 sires on RBI; however, what is important to remember is that genetic evaluations for milk production in Ireland are based on a standardised 305-day lactation and therefore does not account for a potentially shorter lactation length (and thus a potentially lower yield) of cows calving later in the year under a seasonal calving system which is not currently reflected in the sire's genetic merit for milk production. One could argue that the deficit in difference in genetic merit could be met, if not surpassed, by longer lactation lengths of a more fertile population following selection on the EBI. The RBI was expected to increase (i.e., unfavourable) calving interval in the population by 0.46 days/year which is in contrast to the expected reduction (i.e., favourable) decline of -0.83 days/year with selection on the EBI2008; the effect is even greater when looking at the top 100 sires ranked on EBI2008. Furthermore, the greater increase in functional survival with selection on the EBI will result in a more mature herd which may subsequently result in greater herd yield for the same number of cows, as well as facilitating herd expansion. The RBI was selecting towards larger cows while the most recent EBIs are selecting towards smaller cows. The inclusion of fertility in the EBI is likely to minimise any effect of selection for lower cow weight on lower body condition score.

The response to selection from selection on the current EBI for the traits included in the EBI were almost all in the favourable direction with the exception of calf mortality, progeny carcass fat score and locomotion score (Table 25) all of which have a low relative emphasis in the EBI (Table 27). Work in currently underway at Moorepark to investigate the effect of selection on EBI on trait not routinely measured such as periparturient immune function and health, hoof disorders, and feed intake and efficiency as well as detailed fertility measures.

Relative value and relative contribution

Cunningham and Tauebert (2007) described alternative methods to measure the change in selection indexes over time. To date most countries describe the change in relative emphasis in an index over time as the economic value times its standard deviation divided by the sum of the absolute values of these products and then multiplied by 100 (Van Radan, 2002). The change in relative emphasis in the Irish indexes over time is summarised in Table 29 and the change in relative emphasis at the sub-index level is illustrated in Figure 1. With time the relative emphasis on milk production has been reduced due to both increased importance of non-production traits as well as the introduction of new traits into the index (i.e., the sum of the emphasis on each trait must add to 100 and thus the inclusion of new traits will reduce the emphasis on the traits already included in the index). From 2004 calving interval and protein constituted each around one quarter of the emphasis within the EBI.

Nonetheless, the relative emphasis statistic proposed by VanRanden (2002) implies a genetic standard deviation change in each trait which is not necessarily true (Table 25). Cunningham and Tauebert (2007) defined "relative value" as the percent reduction in the total economic value of genetic change in all traits if the particular trait is omitted. Unlike the calculation of relative emphasis by Van Raden (2002) this approach accounts for the covariances between traits as well as different responses to selection for each trait. It is also independent of whether or not the trait has actually been measured and included in the index. The relative value for the j^{th} goal trait is

$$RV_j = \frac{b'G_j}{b'Pb} \cdot v_j \cdot 100$$

where

P is the phenotypic (co)variance matrix for the measured traits

G_j is the j^{th} column of the phenotypic x genetic (co)variance matrix b is the vector of index weights for the measured traits

v_j is the economic weight on trait j

Cunningham and Tauebert (2007) defined the relative contribution of the j[th] trait as the percent reduction in total economic value of overall genetic gain if that trait was omitted from the index (i.e., not physically measured) and may be calculated as:

$$RC_j = 100 - \sqrt{\frac{b'Pb - \frac{b_j^2}{P_{jj}^{-1}}}{b'Pb}} \cdot 100$$

where

b is the vector of index weights for the measured traits

P_{jj}^{-1} P is the j[th] diagonal element of the P^{-1}

Both the relative value and relative contribution of each trait were calculated for the different Irish indexes using the genetic and phenotypic parameters in Appendix 1 and the economic values in Table 24. The results are detailed in Tables 28 and 29.

The relative value of 20% on fat yield in the RBI (Table 28) means that if fat yield was not included in the RBI then genetic gain in RBI would be reduced by 20%; the relative value of -12% on milk yield in the RBI means that if milk yield was omitted from the RBI (or the economic value set to missing) then the total genetic again in the RBI would be 12% greater. The largest relative value in the most recent EBIs is on calving interval which is followed by protein yield and survival. The relative value estimated using the Cunningham and Tauebert (2007) method is similar to the method suggested by VanRaden (2002) for most traits with the exception of calving interval where the relative value is considerably higher than the relative emphasis figure. This is due to a combination of reasons namely the consideration of correlations in the method of Cunningham and Tauebert (2007) as well as the fact that one standard deviation change in all traits is not assumed in the method of Cunningham and Tauebert (2007). For example, in the EBI2008 calving interval is expected to improve by 0.1 genetic standard deviation while protein yield is expected to increase by 0.043 genetic standard deviations.

The relative contribution of most traits in Table 29 is low due primarily to the correlations between traits. For example, the relative contribution of fat yield is low because it is strongly correlated with protein yield, amongst others (Appendix 1) implying the selection for protein yield will results in a correlated response in fat yield even if fat yield was not physically measured.

Table 24. *Summary of the economic weighting factors on the different traits for the RBI and EBI's*

Index / trait†	Const.	MILK kg	FAT kg	PROT kg	PROT %	CIV	SUR	DCD	MCD	GEST	MORT	CWT	CCONF	CFAT	CULL	LOCO	SCS
RBI	100	-0.014	0.36	1.64	74												
EBI2001		-0.08	0.86	5.7		-2.07	11.4										
EBI2004		-0.08	1.5	5.22		-7.09	10.77										
EBI2005		-0.076	1.5	5.22		-7.09	10.77	-2.96	-1.48	-4.47	-2.58	0.92	3.93	-6.14	0.04		
EBI2006		-0.084	1.55	5.27		-7.17	10.8	-2.96	-1.48	-4.52	-2.58	1.38	5.99	-4.49	0.04	1.13	-55.48
EBI2007		-0.085	0.96	5.36		-10.87	10.51	-3.26	-1.73	-6.85	-2.85	1.38	10.32	-11.71	0.04	1.13	-55.48
EBI2008		-0.09	1.26	6.91		-11.97	11.17	-3.65	-1.73	-7.54	-2.85	1.38	10.32	-11.71	-0.5	1.13	-57.21

†RBI = relative breeding index; EBI2001= economic breeding index in 2001; EBI2004= economic breeding index in 2004; EBI2005= economic breeding index in 2005; EBI2006= economic breeding index in 2006; EBI2007= economic breeding index in 2007; EBI2008= economic breeding index in 2008; MILK kg = milk yield; Fat kg = fat yield; PROT kg = protein yield; PROT% protein percent; CIV = calving interval; SUR = survival; DCD = direct calving difficulty; MCD = maternal calving difficulty; GEST = gestation length; MORT = calf mortality; CWT = progeny carcass weight; CCONF = progeny carcass conformation; CFAT = progeny carcass fat score; CULL = cull cow carcass weight; LOCO = locomotion score; SCS = somatic cell score.

Table 25. *Response to selection for the different traits from selection on the RBI or different EBI*

Index / trait†	MILK kg	FAT kg	PROT kg	CIV	SUR	DCD	MCD	GEST	MORT	CWT	CCONF	CFAT	CULL	LOCO	SCS
RBI	42.8	2.8	2.4	0.46	0.03	0.01	0.00	-0.05	-0.04	0.9	-0.07	-0.01	0.83	0.01	-0.06
EBI2000	31.7	2.4	2.2	0.13	0.13	-0.04	-0.02	-0.04	-0.03	0.7	-0.06	0.00	0.48	0.00	-0.05
EBI2004	-2.9	1.6	1.3	-0.51	0.16	-0.09	-0.07	-0.03	0.00	0.2	-0.02	0.02	-0.12	0.00	-0.07
EBI2005	-0.2	1.5	1.2	-0.50	0.17	-0.19	-0.16	-0.05	0.04	1.4	0.03	0.01	0.16	0.00	-0.09
EBI2006	-5.2	1.2	1.0	-0.53	0.18	-0.18	-0.15	-0.04	0.04	1.9	0.05	0.01	0.32	-0.01	-0.07
EBI2007	-29.1	0.1	0.2	-0.92	0.19	-0.23	-0.19	-0.02	0.07	1.4	0.09	0.02	-0.19	-0.01	-0.07
EBI2008	-20.0	0.5	0.6	-0.83	0.19	-0.23	-0.19	-0.03	0.07	1.2	0.06	0.02	-0.36	-0.01	-0.08

†For abbreviations see Table 24

Table 26. *Mean predicted transmitting ability for a range of traits of the top 100 sires ranked on each index separately*

Trait	RBI	EBI2001	EBI2004	EBI2005	EBI2006	EBI2007	EBI2008
Milk yield	258	261	138	170	121	-51	79
Fat yield	15	14	11	12	11	2	7
Protein yield	13	12	8	9	8	1	6
Fat %	0.1	0.08	0.11	0.11	0.12	0.09	0.08
Protein %	0.09	0.07	0.07	0.07	0.07	0.06	0.06
Calving interval	0.9	-0.59	-2.66	-2.18	-2.61	-5.29	-3.85
Survival	-0.28	0.72	1.31	1.13	1.21	1.8	1.57
Direct calving difficulty	0.07	-0.33	-0.5	-0.93	-0.91	-1	-1.08
Maternal calving difficulty	0	0.02	0.09	0.16	0.18	0.34	0.28
Gestation	-0.12	-0.34	-0.34	-0.56	-0.49	-0.6	-0.7
Calf mortality	0.08	-0.08	-0.03	-0.16	-0.12	-0.06	-0.11
Cull cow carcass weight	0.33	-1.82	-3.54	-2.08	-1.84	-3.68	-4.3
Progeny carcass weight	1.4	0.6	-0.6	1	1.4	-0.2	-0.6
Progeny carcass conformation	0.06	0.1	0.18	0.16	0.2	0.35	0.26
Progeny carcass fat	0.05	0.07	0.11	0.09	0.08	0.14	0.14
Locomotion	-0.37	-0.28	-0.24	-0.27	-0.24	-0.15	-0.2
Somatic cell count	0.04	0.04	0.04	0.04	0.01	0	0.02
Overall type	-0.59	-0.87	-1.29	-1.13	-1.23	-2.01	-1.56
Overall mammary	-0.51	-0.7	-1.08	-0.93	-0.97	-1.6	-1.25
Overall feet & legs	-0.4	-0.32	-0.41	-0.44	-0.51	-0.78	-0.57
Dairy composite	-0.28	-0.49	-0.84	-0.77	-1.06	-2.18	-1.37
Body composite	-0.24	-0.54	-0.81	-0.75	-0.97	-1.84	-1.24

Table 27. *Change in relative emphasis for each trait calculated using the method of Van Raden, (2002).*

Index / trait†	MILK kg	FAT kg	PROT kg	PROT %	CIV	SUR	DCD	MCD	GEST	MORT	CWT	CCONF	CFAT	CULL	LOCO	SCS
RBI	15%	14%	50%	20%												
EBI2000	21%	8%	43%		10%	18%										
EBI2004	17%	12%	31%		27%	14%										
EBI2005	13%	10%	25%		22%	11%	3%	1%	4%	1%	7%	1%	2%			
EBI2006	13%	9%	23%		20%	10%	3%	1%	3%	1%	10%	2%	1%	0%	1%	4%
EBI2007	11%	5%	21%		27%	9%	3%	1%	5%	1%	9%	3%	2%	0%	1%	3%
EBI2008	11%	6%	23%		26%	8%	2%	1%	4%	1%	8%	3%	2%	2%	1%	3%

†For abbreviations see Table 24

Table 28. *Change in relative value for each trait.*

Index / trait†	MILK kg	FAT kg	PROT kg	PROT %	CIV	SUR	DCD	MCD	GEST	MORT	CWT	CCONF	CFAT	CULL	LOCO	SCS
RBI	-12%	20%	75%	17%												
EBI2000	-19%	16%	95%		-2%	11%										
EBI2004	2%	16%	46%		25%	12%										
EBI2005	0%	13%	38%		21%	11%	3.3%	4.2%	0.8%	-0.4%	7.8%	0.7%	-0.4%	0.0%		
EBI2006	2%	11%	30%		21%	11%	3.0%	3.8%	0.6%	-0.3%	14.3%	1.7%	-0.2%	0.1%	2.2%	-0.4%
EBI2007	12%	1%	6%		48%	10%	3.5%	6.2%	0.3%	-0.6%	9.5%	4.2%	-1.0%	0.0%	2.5%	-0.4%
EBI2008	8%	3%	17%		43%	9%	3.6%	6.1%	0.4%	-0.5%	7.3%	2.7%	-1.2%	0.8%	1.8%	-0.4%

†For abbreviations see Table 24

Table 29. *Change in relative contribution for each trait.*

Index / trait†	MILK kg	FAT kg	PROT kg	PROT %	CIV	SUR	DCD	MCD	GEST	MORT	CWT	CCONF	CFAT	CULL	LOCO	SCS
RBI	1.6	1.3	9.4	3.5												
EBI2000	9.0	0.8	21.7		2.0	4.4										
EBI2004	12.7	1.4	16.3		13.5	4.6										
EBI2005	5.7	1.4	11.9		8.0	1.6	1.1	1.7	0.0	0.0	0.2	1.0	0.1	0.0		
EBI2006	5.8	1.2	10.5		6.9	1.3	0.9	1.6	0.0	0.0	0.6	1.1	0.2	0.0	1.1	0.1
EBI2007	5.6	0.1	8.5		11.2	1.1	1.0	2.3	0.0	0.1	0.3	1.4	0.1	0.0	0.9	0.1
EBI2008	5.7	0.2	10.8		10.9	1.1	1.0	2.2	0.0	0.1	0.3	1.0	0.1	0.0	0.8	0.0

†For abbreviations see Table 24

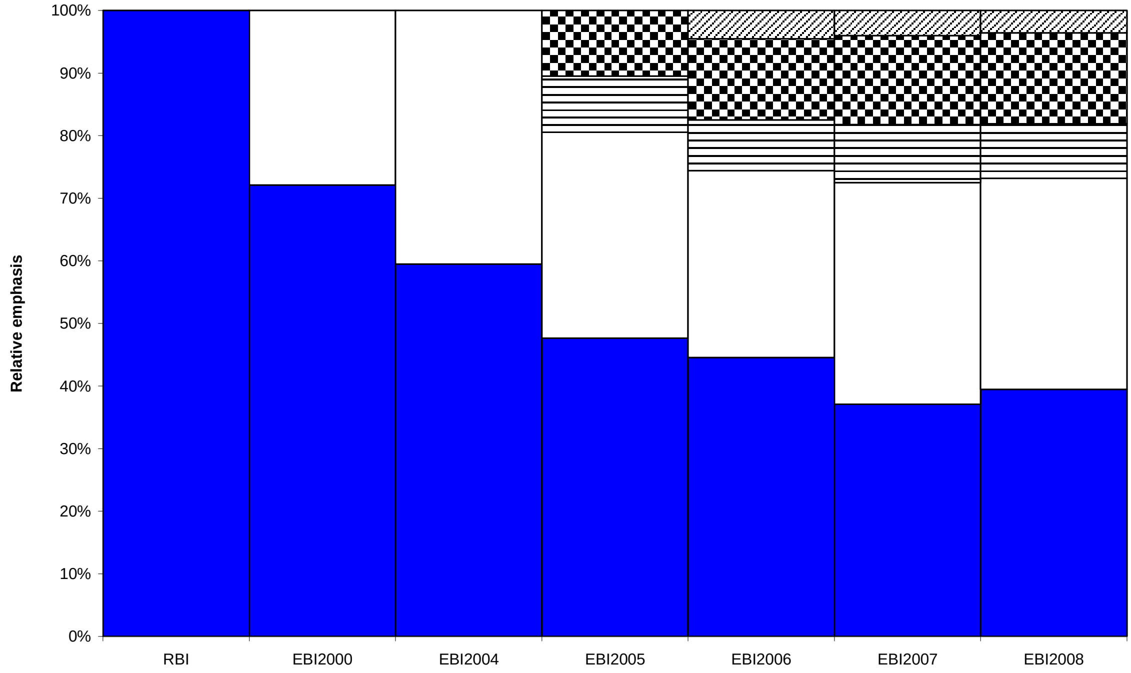

Figure 1. *Change in relative emphasis for each subindex calculated using the method of Van Raden, (2002). Dark shaded=milk production; white=fertility &s survival; horizontal lines = calving performance; checked = beef performance; diagonal = health.*

FUTURE DEVELOPMENTS

- *Genetic parameters should be re-estimated.* For some traits it has been a considerable time since genetic parameters were estimated despite the addition of new data, including data from other breeds and changes to the data editing criteria and models of analysis as well as changes to the data in the database (e.g., changed breed fractions). Genetic parameters should be re-estimated

- *Use of insemination data*. Mating and pregnancy diagnosis data has been recorded on a large scale since 2005 and will soon be recorded electronically by almost all AI technicians in Ireland. DIY operators also have the option to submit data to the ICBF database. These data will be incorporated into genetic evaluations through use in data editing (e.g., cow served within 150 days should be included in the genetic evaluations for calving interval where previously a calving interval >600 was set to missing) and through use in a multi-trait analysis of fertility as well as potential use in INTERBULL MACE evaluations

- *Test-day model.* Most countries have changed their genetic evaluations for production traits (included somatic cell count) to a test-day model which better accounts for environmental (e.g., management/climatic effects specific to one day) as well as allowing different lactation profiles for each cow/sire. Heritability estimates for milk production traits generated from test-day model also tend to be greater than traditional lactation models thereby increasing the emphasis on cow data in the estimation of breeding values for cows. However, test-day models require larger computational demands. Nonetheless, the usefulness of test-day models should be investigated for Ireland

- *"Omic technologies"*. The development of methodologies to derive genomic estimated breeding values from genome wide dense marker maps as well as from individual markers/genes has the potential to increase the accuracy of breeding values with limited phenotypic data. This is particularly a benefit for young test sires, foreign sires with no daughters in Ireland as well as for individual cows (i.e., potential bull dams)

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APPENDIX 1

Trait[†]	Milk kg	Fat kg	Prot kg	Protein%	CIV	SUR	DCD	GEST	MORT	MCD	CWT	CCONF	CFAT	CULL	SCS	LOCO
σ_g	463.74	17.41	13.30	0.12	8.49	2.80	2.66	2.34	1.60	1.49	21.63	0.98	0.70	17.56	0.21	2.09
h^2	0.35	0.35	0.35	0.35	0.04	0.02	0.28	0.20	0.05	0.10	0.54	0.59	0.31	0.40	0.11	0.07

[†] MILK kg = milk yield; Fat kg = fat yield; PROT kg = protein yield; PROT% protein percent; CIV = calving interval; SUR = survival; DCD = direct calving difficulty; MCD = maternal calving difficulty; GEST = gestation length; MORT = calf mortality; CWT = progeny carcass weight; CCONF = progeny carcass conformation; CFAT = progeny carcass fat score; CULL = cull cow carcass weight; LOCO = locomotion score; SCS = somatic cell score.

Trait	Milk kg	Fat kg	Prot kg	Protein%	CIV	SUR	DCD	GEST	MORT	MCD	CWT	CCONF	CFAT	CULL	SCS	LOCO
Milk		0.81	0.95	-0.14	0.19	0.07	0.02	0.00	0.06	0.02	0.10	0.00	-0.05	0.13	-0.06	0.21
Fat	0.58		0.86	0.03	0.17	0.13	0.00	0.00	0.06	0.00	0.10	0.00	-0.03	0.12	-0.04	0.17
Prot	0.80	0.74		0.08	0.18	0.13	0.01	0.01	0.06	0.01	0.10	0.00	-0.03	0.15	-0.05	0.20
Protein%	-0.33	0.08	0.01		-0.06	0.01	-0.02	0.00	0.02	-0.02	0.02	0.00	0.00	0.06	0.07	-0.09
CI	0.56	0.44	0.46	-0.27		0.00	0.05	0.15	0.02	0.05	0.03	0.00	0.00	0.07	0.03	0.05
SUV	0.00	0.00	0.00	0.17	-0.20		-0.03	0.01	-0.02	-0.03	0.03	0.00	0.00	0.07	-0.05	0.00
cd	0.20	0.13	0.10	-0.15	0.29	-0.16		0.02	0.36	0.60	0.01	0.00	0.00	0.03	-0.01	0.01
gest	0.20	0.05	0.12	-0.17	0.26	-0.13	0.26		0.06	0.08	0.13	0.00	0.00	0.00	0.00	0.00
mort	-0.06	-0.20	-0.11	-0.07	-0.05	0.04	0.18	0.16		0.30	0.10	0.00	0.00	0.00	0.00	0.00
mcs	-0.20	-0.20	-0.20	0.14	-0.27	0.01	-0.50	-0.23	-0.31		0.01	0.00	0.00	0.03	-0.01	0.01
CWT	0.26	0.19	0.27	-0.07	0.15	-0.14	0.10	0.06	-0.01	-0.11		0.41	-0.12	0.26	-0.03	0.05
C CONF	-0.47	-0.44	-0.48	0.11	-0.30	0.26	-0.09	0.01	0.18	0.17	0.49		-0.06	0.02	0.00	0.00
C FAT	-0.21	-0.13	-0.17	0.15	-0.29	0.15	-0.19	-0.19	0.00	0.22	-0.29	-0.16		-0.23	0.00	0.00
Cow Wt	0.39	0.36	0.34	-0.15	0.33	-0.21	0.24	0.23	-0.01	-0.22	0.57	0.04	-0.65		-0.03	0.05
SCC	0.20	0.19	0.23	0.02	0.18	-0.23	0.09	-0.01	-0.05	0.03	0.01	-0.21	-0.09	0.00		-0.01
LOCO	0.04	-0.11	-0.05	-0.11	0.10	0.10	0.13	0.00	0.10	-0.20	0.02	-0.16	-0.07	0.07	-0.06	

Phenotypic correlations above the diagonal and genetic correlations below the diagonal