An overview of updates to the Irish suckler beef breeding indexes

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Summary

- Breeding indexes are tools, which provide an expected profit value for the progeny of breeding animals by combining individual animal estimates of genetic merit transmitting abilities for a range of performance traits, each weighted by their respective economic importance.
- Irish cattle receive two index values each: 1) a Terminal Index to help identify candidate parents to generate calves for meat production, and 2) a Replacement Index to help identify candidate parents to generate the next generation of replacement heifers for entering the suckler herd.
- Both breeding indexes were recently updated to include new traits (e.g., age at finish, tuberculosis resistance), revised economic weights (to reflect changes in prices and costs of production) and trait-specific weights to reflect their carbon cost. In addition, a new method to evaluate calving difficulty, called a single step genomic evaluation has also been implemented.
- The updates to the Terminal Indexes aims to reduce costs of finishing cattle by reducing feed consumption and finishing age, while increasing the focus on carcass value.
- The updates to the Replacement Index aims to reduce the cost of suckler cows by reducing feed costs, predominantly by selecting for smaller cows and increasing fertility, while concurrently emphasising the importance of generating ‘quality’ and profitable progeny.

Introduction

Breeding indexes are tools that collapse the genetic merit of individual animals for a range of traits into a single value. The emphasis each trait receives in an index directly reflects its contribution to profit – be that either revenue or cost of production. The genetic merit of each trait is estimated from information on the animal itself, its ancestors and its descendants. Because each profit index is the sum of a range of different traits, two animals could achieve the same profit (index) through different avenues; therefore, animals with the same index could have different expected performances for each trait. Thus, farmers and breeders alike must not only select animals on their overall index, but also how the expected performance of the animal for the constituent traits of that index suit the herd in question.

Two indexes are available for Irish suckler beef cattle: the Terminal and Replacement indexes. The Terminal Index ranks breeding animals on the basis of the efficiency and profitability of their progeny in calf-to-beef finishing systems. The Replacement Index ranks breeding animals on the basis of the efficiency and profitability of their female progeny as suckler cows (i.e. easy-calving, fertile and low maintenance requirements), as well as being capable of generating profitable progeny in calf-to-beef finishing systems. Research has indicated the effectiveness of these indexes in improving profitability on Irish beef farms. Twomey et al. (2020) found that suckler cows which ranked higher on the Replacement Index had superior performance across a range of key maternal traits. Furthermore, Kelly et al. (2021) showed that, for each unit change in Terminal Index and Replacement Index value, gross profit per livestock unit increased by €1.41 and €0.76, respectively.

Both beef breeding indexes were last updated in the year 2015 and thus, given price, policy and technological changes since, a comprehensive exercise to revise and future-proof the indexes commenced in 2021. Key elements of these revisions were: 1) derivation of new economic values for each of the performance traits according to prevailing prices, 2) inclusion of new traits, such as *finishing age* and *bovine tuberculosis resistance*, and 3) inclusion of greenhouse gas emissions mitigation associated with improvements in performance traits. The purpose of this paper is to describe these revisions.

Approach used to derive production economic and greenhouse gas emissions values

The economic values for each trait in both breeding indexes were generated using the Teagasc beef farm systems model (Crosson et al., 2006; Taylor et al., 2020), which is a whole-farm budgetary simulation model of Irish suckler beef production systems. The model is initialised by specifying the farm area, percentage of the cow herd calving in each month, breeding policy (natural mating or artificial insemination), cow replacement rate, cattle trading strategy (month/age at sale), as well as the appropriate feeding system and various price variables. Using the French net energy system (Jarrige, 1989) modified for Irish conditions (O'Mara, 1996), animal feed requirements are calculated and, based on herd feed requirements, grass and silage intake is calculated. For the generation of the economic values, the farm system assumed was as described by Taylor et al. (2018) and Teagasc (2020). This suckler beef production system selected was considered to be the current prototype suitable for immediate implementation on farms, and for which evaluation has been completed (by means of systems research experiments at Teagasc, Grange). The modelled spring-calving grass-based production system involved finishing steers and heifers at 22 and 19 months of age, respectively, and was operated at a stocking rate of 165 kg organic nitrogen (N) per hectare. Table 1 outlines the key descriptors for the base scenario.

Table 1. Details of the baseline scenario for derivation of economic values for suckler beef breeding indexes for Irish suckler calf-to-beef production systems

Farm area (ha)	50.0
Number of cows calving	67.8
Weaning weight[1] (kg)	331
Carcass weight[1] (kg)	361
Mature cow weight (kg)	670
Age at first-calving (AFC; months)	24
Grazed grass in the annual feed budget	68%
Grass silage in the annual feed budget	26%
Concentrate in the annual feed budget	6%
Mean annual R3 steer price (€/kg)	4.53
Protected urea price (€/t)	550
Concentrate feed price (€/t)	380
Gross output per ha (€)	1977
Gross margin per hectare (€)	1039
Net margin per hectare[2] (€)	491

[1]Mean of male and female progeny. [2]Excludes land and labour costs

To generate economic values for the performance traits of interest, it was necessary to generate scenarios where the scenario was identical to the baseline scenario with the exception of the trait of interest. The performance of the trait of interest was either increased or decreased within a realistic range, and its economic value quantified by comparing the financial performance of the baseline scenario with the modelled scenario. Thus, the economic value is equal to the change in profitability divided by the biological change in the trait of interest, holding the performance metrics of all other traits constant.

The environmental performance of food production is under increasing scrutiny and, although this encompasses issues such as biodiversity, nutrient surpluses, water quality and ammonia emissions, greenhouse gas emissions are of particular interest at present. Society and consumers are increasingly basing consumption decisions on such issues and therefore, the beef sector must urgently seek to reduce greenhouse gas emissions reductions. There is now also a legislative imperative for greenhouse gas emissions reductions; Ireland has set legally-binding targets to reduce nationally-reported emissions by 51% by 2030. Consequent to the setting of these national level targets, sectoral emissions ceilings were established with agriculture given a reduction target of 25% to be achieved by 2030.

The beef sector can contribute to meeting these emission targets by increasing the biological efficiency of production systems. Improving the genetic merit of the beef herd is key to production efficiency improvements and greenhouse gas emissions reductions. Indeed progress in improving the genetic merit of the national beef herd (Figure 1) is likely to already have had a substantial impact on the greenhouse gas emissions intensity of Irish beef.

With this in mind, a key update to the beef indexes was the inclusion of greenhouse gas emissions (i.e. 'carbon'); such a strategy has already been adopted in the two dairy breeding indexes in Ireland. The approach taken was to assess the impact of a unit change in each performance trait on farm emissions. The Teagasc beef systems model has recently incorporated a greenhouse gas emissions sub-model (Taylor et al., 2020) to quantify emissions from modelled beef cattle production scenarios. Emission sources include enteric fermentation, slurry storage and application, chemical fertiliser application, deposition of excreta from grazing animals at pasture, silage effluent and on-farm diesel use. Emissions from the manufacturing of purchased concentrate feed, chemical fertiliser, diesel and electricity, in addition to nitrous oxide emissions, resulting from N leaching and ammonia volatilisation, are also included. In the present analysis, it was assumed that there was no effect of the different scenarios evaluated on soil organic carbon; thus, effects of soil carbon sequestration or loss were not considered. The greenhouse gas emissions associated with changes in performance for each trait were quantified on a per animal basis, and converted from carbon dioxide equivalents to monetary values by assuming a carbon price of €80/tonne (t). This was considered to be representative of the price paid for carbon on the EU Emissions Trading Scheme (range from €15/t in March 2020 to €100/t in March 2023; Statista, 2023) and is consistent with what has been used in the dairy breeding indexes in Ireland.

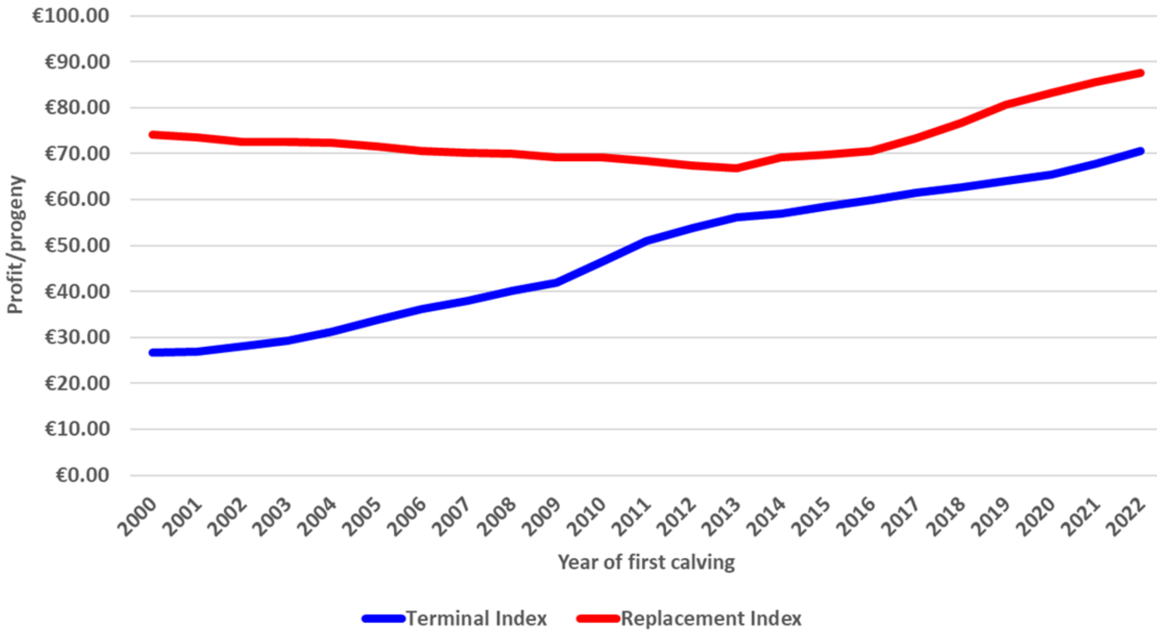

Figure 1. Genetic trends for the Replacement and Terminal Indexes in the Irish beef herd.

New traits included in the Irish beef breeding indexes

Three new traits were included as part of the index updates being; *finishing age*, *TB resistance* and *carcass specifications*.

Reducing finishing age of animals in the Irish cattle herd has been recognised in the Irish Climate Action Plan and the Teagasc Marginal Abatement Cost Curve (MACC) as a cost-effective measure to reduce agricultural greenhouse gas emissions. Animal genetics has a key role to play on reducing finishing age (Berry et al., 2017), with 23-26% of the variability observed in the age of finish within breed being attributable to genetic differences. Including carcass weight in the breeding indexes along with age-at-slaughter ensures that earlier finishing age is not associated with a concomitant reduction in carcass weight. Good progress has been made in reducing finishing age at farm-level in recent years with reductions of almost one week per year achieved between the years 2011 and 2021. Importantly, this has been achieved with almost no reduction in carcass weight (341 kg in 2011 vs. 338 kg in 2021). This has led to a reduction in costs on farms, particularly feed, while retaining output and reducing greenhouse gas emissions. Indeed, it is estimated that, by finishing cattle two months earlier, approximately 430,000 t carbon dioxide equivalents are abated annually. In this present analysis, data were obtained to quantify the effect on carcass weight and traits (conformation and fatness) of each day unit change in finishing age. These data were then used to parameterise the Teagasc beef model, permitting the production and greenhouse gas emissions economic values to be generated.

The herd incidence of bovine tuberculosis (bTB) in Ireland has increased from a historic low of 3.3% in 2016 to 4.3% in 2022 (More, 2023). Bovine TB is a substantial cost to the exchequer (estimated at €2 billion over the past 20 years; More, 2023), and also gives rise to financial hardship on affected herds. Moreover, the trauma inflicted on farm families in the case of culling or depopulation is immeasurable. Recent analysis has indicated that, on average, 7% of cattle in a herd outbreak situation test positive for TB infection. Furthermore, this analysis showed that there is large variation in the likelihood of sire progeny testing positive for TB infection, such that the genetics explained 14% of the likelihood of an animal testing positive. The data used in the TB genetic evaluation include only data from herd-management groups that have several confirmed TB reactors, thus the genetic merit does not solely indicate which bulls have been used in TB hotspots. The TB trait definition can be interpreted as the expected prevalence of TB infection in an animal's progeny where they are exposed to the TB bacterium; the genetic merit for TB typically ranges from 1 to 14%, with lower values more desirable (i.e., expect fewer TB reactors). This data informed the development of a *TB* trait with the updated indexes with an economic weight of -€0.97.

The meat industry have communicated the desired specifications for beef carcasses in respect of weight (between 280 and 380 kg), conformation (greater than O=) and fatness (between 2+ and 4+). Carcass price data has demonstrated that beef price reduces for carcasses outside these specifications and therefore, a new trait, *carcass specification* was included in the revised indexes (e.g. Table 2). The specifications imposed relate to carcass weight, conformation and fat score. The introduction of a minimum (and maximum) carcass fat specification into the index replaced the previously used carcass fat trait, which was assumed to have a linear effect.

Table 2. Price penalties implements for the ‘carcass specification’ trait in the beef index updates. Penalties are expressed in cents per kilogram.

Tier	< 220 kg	220-250 kg	250-280 kg	380-410 kg	410-440 kg	>440 kg
Penalty	45	12	6	3	6	12

Updates to the Terminal Index

The three new traits described above are included in the updated Terminal Index. In addition, the existing traits within the Terminal Index have been updated, as described hereunder.

Carcass gain per day of age

The carcass gain per day of age trait (otherwise known as *carcass weight*) describes the genetic potential of beef progeny to have a heavier carcass at a given age. This trait is expressed as an increase in carcass weight. The economic value was calculated as the increase in prime beef sales per animal finished, accounting for seasonality of beef price, divided by the increase in carcass weight (€4.68/kg carcass). Greenhouse gas emissions associated with carcass weight are captured within the *progeny feed intake* trait.

Progeny feed intake

The progeny intake trait describes the increase in feed intake associated with heavier animals. The economic value generated in this case reflects the dietary proportions and relative feed costs of grazed grass, grass silage and concentrate ration in the feed budget of suckler beef progeny. Thus, the economic value was calculated as increased feed costs divided by increased feed demand (€0.18/kg DM). Greenhouse gas emissions due to each additional kilogramme of feed consumed was valued at €0.06/kg DM.

Gestation length

Gestation length refers to the duration of pregnancy. Gestation length assumed in the baseline scenario is 286 days. The impact of increasing gestation length is to:

- Increase replacement rate as a result of increased barrenness (empty rates). Where suckler cows have a longer gestation length, the amount of time available for breeding is less and therefore, the probability of becoming pregnant is lower. This results in a greater number of cows that are not pregnant at the end of the breeding season. Each day increase in gestation length increases barrenness/replacement rate by 0.24% (Amer et al., 2001).
- Reduce weaning and slaughter weight. Since it is assumed that weaning date and slaughter age is fixed, then longer gestation lengths result in suckler progeny being younger (and lighter) at weaning with this lower weight largely retained to slaughter (Drennan and McGee, 2009).
- Reduce the length of the grazing season for suckler cows. As it is assumed that suckler cows are not turned out to grass in spring until after calving, longer gestations reduces the proportion of grazed grass in the total feed budget, a key factor influencing profitability.

The combination of these three factors means that longer gestation lengths result in, on average, lower profitability. The economic value was calculated as the change in net margin per cow per day increase in gestation length (€3.01/day). The above factors also contribute to an increase in greenhouse gas emissions, and thus a carbon value of €0.03/day.

Calving difficulty

Calving difficulty can range from no assistance to where a caesarean section is required. Calving difficulty can have a substantial impact on farm profitability due to increases in labour costs (farmer and vet) and cow replacement costs (based on cows not going in-calf in the next breeding season due to calving difficulties and a small proportion that die as a result of calving difficulties). Calves that die during calving are not included in this trait, but are captured in a calf mortality trait that is quantified separately. Calving difficulty is partitioned into two components: direct calving difficulty and maternal calving difficulty. Direct calving difficulty describes the level of difficulty associated with the characteristics of the calf itself (e.g. body size and shape) inherited from its sire and dam. Maternal calving difficulty describes the level of difficulty associated the characteristics of the dam giving birth (e.g. pelvic size, calving ability and maternal effects on birth weight) and indicates how easily a sires'/dams' daughters will calve. Updates to the *calving difficulty* economic value included the costs of veterinary call-outs (from a survey carried out and published by the Irish Farmer's Journal), the impact on subsequent performance and updated costs from the bioeconomic model.

Other traits

Other traits included in the Terminal Index include carcass conformation directly (as well as via a minimum specification), polledness, docility, calf mortality, and a breed bonus for Angus and Hereford cattle. All have been updated to reflect changes in prices and costs of production in the past eight years.

Updates to the Replacement Index

The Replacement Index is composed of traits expressed by the female progeny of a breeding animal when that female progeny enters the suckler herd (i.e. the cow traits), as well as the traits expressed by the progeny of that suckler cow when finished to beef. The latter category of traits are the same as those described in the Terminal Index and account for approximately 40% of the total emphasis in the Replacement Index. The remainder of this section describes just the cow traits within the Replacement Index.

Maternal weaning weight

The maternal weaning weight trait describes the impact of suckler cow milk yield on the live weight (and consequently, carcass weight) of her weanling progeny. A recent meta-analysis of the international literature has demonstrated that cow milk yield is a major determinant of calf live weight gain pre-weaning (Sapkota et al., 2020). These findings have indicated that the calf growth response to each additional kilogram of milk is approximately 0.04 to 0.07 kg live weight with the upper end of this range assumed in the analysis to maximise the value of higher milking dams. However, higher cow milk yield is also associated with increased feed energy requirements (Jarrige, 1989; O'Mara, 1996) and economically, this partially offsets the additional live weight advantage of calves from cows with higher milk yield. The additional cow feed energy costs were calculated based on the energy requirement (0.45 UFL) of each additional kg of milk (O'Mara, 1996) and the cost of grazed grass.

Data from livestock marts indicates that there is a premium paid for weanlings at sale (150 to 300 days of age) compared to the prevailing beef carcass price i.e. the price per kg live weight at weaning is greater than equivalent the price per kg live weight at slaughter. This price premium is not captured within integrated calf-to-beef systems and therefore, must be factored in. Thus, the maternal weaning weight economic value was calculated as the increase in output value taking account of a weanling premium minus the cost of added milk production divided by the increase in weaning weight. This equated to €2.71/kg live weight. There is also an increase in greenhouse gas emissions associated with the higher feed demand of suckler cows and progeny where maternal weaning weight (i.e. milk yield) is greater, and this carbon value offset the production value by €0.83/kg weaning weight.

Mature cow live weight

The mature cow live weight trait is based on varying the live weight of the mature cow herd and quantifying the impact of this on feed costs. The value obtained was €0.32/kg live weight. Changes in mature cow live weight also have implications for cull cow carcass weight and associated cull cow value (€3.95/kg carcass). The additional income from sales of heavier cull cows partially offsets the added cost of heavier mature cow live weight; however, the overall impact is to reduce profitability. Replacement heifer live weight also increased accordingly (first calving cows required to be 90% of mature weight immediately post-calving) and this was quantified economically as the increase in heifer feed costs per unit change in cow live weight (€1.27/kg mature cow live weight). Given the increase in feed costs associated with heavier mature cow weight, greenhouse gas emissions also increase with the increase in carbon values calculated as 0.19 and 0.34 per kg cow live weight.

Survival

Survival describes the ability of suckler beef cows to remain in the herd over a number of years. Thus, lower values for survival mean that the heifer replacement rate of a suckler herd is higher than a corresponding herd with higher survival rates. There are multiple effects of lower survival on the profitability of suckler beef production:

- The value of prime beef sales are lower because (1) more of the heifer progeny are needed as replacements rather than being sold as beef, (2) average carcass weight for the herd is lower since more of the progeny are from primiparous (first-calvers) cows, and (3) the 'beef' merit of sires used on first-calving cows (heifers) is lower i.e. selection of sires is prioritised towards calving traits rather than beef (carcass weight and conformation) traits.
- The labour required for primiparous cows is greater, especially at calving time, than that required for multiparous cows.
- Offsetting the reduction in prime beef sales is the increase in sales of cull beef cows.
- The dietary proportions of grazed grass, grass silage and concentrate rations for the farm change because of differences in the numbers of replacement and finishing heifers, which have different feed budget requirements.

Survival was modelled as a change in replacement rate for suckler beef herds with an economic value of €2.22 obtained. There was no greenhouse gas emissions impact obtained; the higher emissions association with retaining heifer progeny for longer in the herd (since first-calvers are assumed to calve at 24 months of age, compared to 'finishing' heifers leaving the herd at 19 months of age) was offset by lower emissions from a lighter herd and progeny (both due to a greater number of first-calvers).

Calving interval

Calving interval describes the length of time between successive calvings for a cow. The target calving interval for a suckler cow herd is 365 days; however, data from ICBF indicates that the average calving interval for suckler cows in Ireland is 390 days. In the longer term, an increase in calving interval results in a different calving pattern for a suckler beef farm; in other words, the mean calving date for the farm will slip. Where mean calving date slips (and assuming it was originally at the optimum date for a particular farm) two factors must be taken into account:

- Weaning and slaughter weights are lower because progeny will be younger (and lighter) at weaning and at slaughter.
- The length of the grazing season for suckler cows is reduced because it is assumed that suckler cows are not turned out to grass until after calving. Thus, the proportion of grazed grass in the total feed budget decreases and feed costs increase.

The overall effect of longer calving intervals is to reduce profitability for suckler beef farms. The analysis was carried out using national breeding data and stratifying herds based on varying percentages of the herd calved in the first 75 days and varying calving intervals. The effect of using industry-based data in the model is to delay mean calving date thus, reducing carcass weights and to increasing feed costs when compared with the baseline Grange research farm scenario. The economic value was calculated as the change in profit divided by the change in calving interval, which equated to €3.55/day increase in calving interval. As with *survival*, there was no greenhouse gas emissions impact obtained for calving interval, with lower emissions from lighter progeny offset by higher emissions associated with longer indoor feeding periods.

Age at first-calving

Age at first calving is the age at which replacement breeding heifers calve for the first time. In economic terms the optimum age at first-calving for seasonal calving suckler beef production systems breeding replacements from within the herd is 24 months (McGee et al., 2022). In this scenario, heifers calving for the first time at 24 months of age and 36 months of age (because of seasonality of calving) were compared. The economic value was calculated as the change in net margin per heifer calving divided by the difference in age at first calving with the resulting value of €1.76/day obtained. Greenhouse gas emissions associated with delay in first-calving were quantified as a carbon value of €0.11/day.

Impact

A key consideration for suckler farmers is the choice of sire and dam for breeding cattle for finishing or for breeding females as suckler cows. It is desirable to select sires that are ranked highly on either the Terminal or Replacement Index depending on the intended use of the resulting progeny. In the beef breeding indexes, star ratings are provided with one-star indicating animals in the bottom twenty percent and five-stars indicating animals in the top twenty percent. The animals used to derive the within- and across-breed star ratings are updated in the first evaluation run every year. In spring 2023, the Department of Agriculture Food and Marine opened the Suckler Cow Efficiency Programme (SCEP), an agricultural scheme, which aims to provide support to beef farmers to improve the environmental sustainability of the national beef cow herd. An important pillar of SCEP is to maintain a high proportion of high-genetic merit animals on-farm defined as calves sired by four- or five-star bulls.

Given that most farmers have a breed preference, it is important that there is a wide availability of sires across breeds that meet this criteria. Figure 2, focusing on the Replacement Index, indicates that, although there is some change in the percentage of sires for the main breeds achieving four- and five-star status, a wide choice of sires remains for each breed. Limousin and Aberdeen Angus remain the most numerous four- and five-star sire breeds, followed by Charolais, Hereford and Simmental.

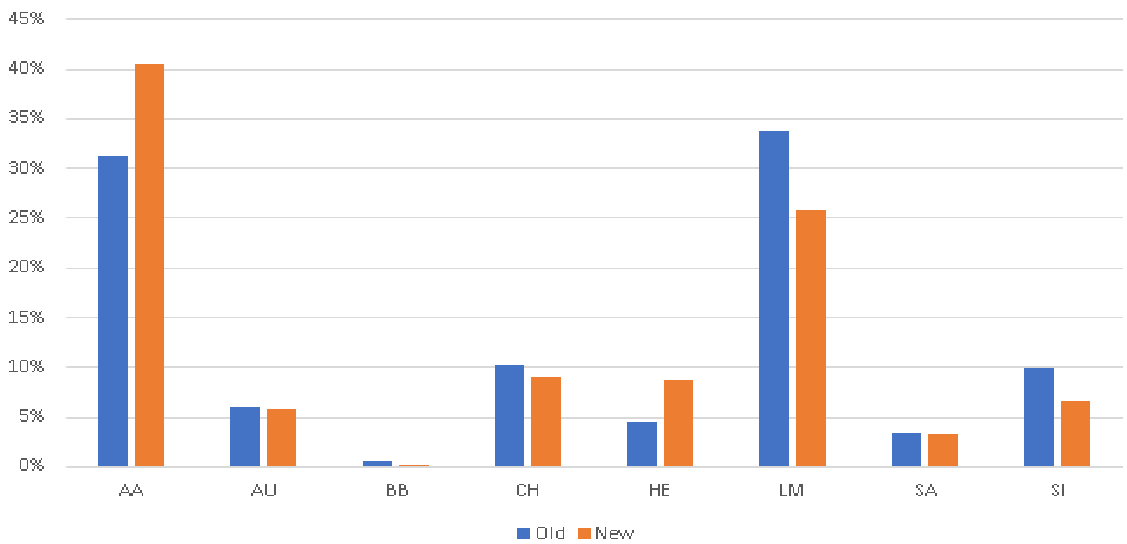

Figure 2. The percentage of male breeding animals which are four- and five-star across breed on the Replacement Index based on the current formulation ("Old") and after the updates presented in this paper ("New") are implemented.

Similarly Figure 3, focusing on the Terminal Index, shows that although there is some change in the percentage of sires meeting four- and five-star criteria, a wide choice of sires remains for each breed, with Charolais and Limousin being the dominant sire breed.

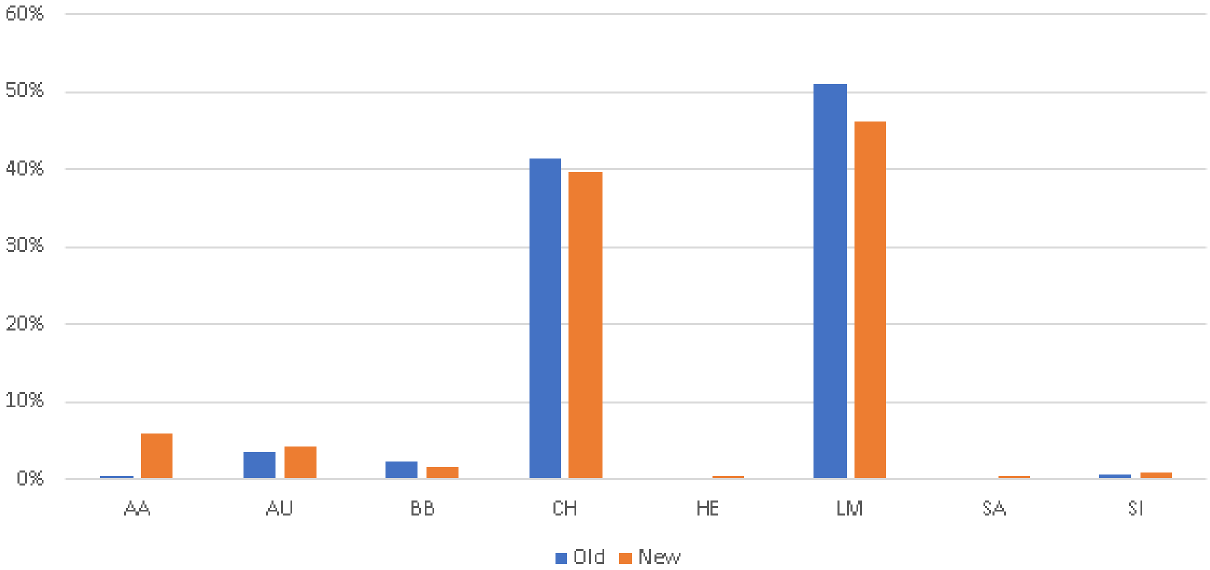

Figure 3. The percentage of male breeding animals which are four- and five-star across-breed on the Terminal Index based on the current formulation ("Old") and after the updates presented in this paper ("New") are implemented.

Summary

The economic values for the beef breeding indexes were previously calculated in 2015 and, in the interim, seismic changes have occurred in the market and policy environment. The farming sector has experienced extraordinary volatility with prices now appearing to have settled at a baseline much higher than heretofore. The policy environment has seen a sharp focus on the environmental footprint of food production with greenhouse gas emissions mitigation seen as a priority area for action. The updated economic values, summarised in Table 3, incorporating price changes and greenhouse gas emission values much better reflect this new situation.

The new economic values are more representative of the impact that advances in production traits have on the profitability of Irish suckler beef production systems. The updates to the Terminal Indexes aim to reduce the costs of finishing cattle by reducing feed consumption and finishing age, while increasing the focus on carcass value, particularly as regards producing carcasses that best meet industry guidelines. The updates to the Replacement Index aim to reduce the cost of suckler cows by reducing feed costs, predominantly by selecting for smaller cows within breed, and increasing fertility. The calf traits within the Replacement Index, will also benefit from the updates to the traits as described in the Terminal Index.

The inclusion of carbon in the breeding indexes has a relatively modest impact on the economic values (on average thirteen percent of the combined economic value is carbon) and on the relative emphasis of traits within the Terminal (six percent of which is carbon) and the Replacement (ten percent of which is carbon) Indexes; however, it creates an additional focus for the index. It provides a message to society in terms of the commitment of the beef sector to reduce emissions and creates a global-first framework for tangibly including environmental variables in a composite breeding index. In future, it is envisaged that direct methane transmitting abilities will be included in the indexes once the data collected is sufficient to capture the full range of animal types (growing and finishing animals, suckler cows) and diets (grass and TMR diets).

Table 3. Summary of economic values, for the traits with the highest emphasis, obtained in the updated analysis for the suckler beef breeding indexes in Ireland

	Economic value	Carbon value	Combined value
Terminal Index			
Direct weight for age (€/kg carcass)	4.68	-	4.68
Progeny intake (€/kg DM)	-0.18	-0.06	-0.24
Gestation length (€/day)	-3.01	-0.03	-3.04
Finishing age	-1.66	-0.26	-1.92
Replacement Index			
Maternal weaning weight (€/kg carcass)	2.71	-0.83	1.88
Mature weight – cow (€/kg live weight)	-0.32	-0.19	-0.51
Mature weight - heifer (€/kg live weight)	-1.27	-0.34	-1.60
Mature weight - cull (€/kg carcass)	3.95	-	3.95
Survival (€/% decrease)	-2.22	-	-2.22
Calving interval (€/day)	-3.55	-	-3.55
Age at first-calving (€/day)	-1.76	-0.11	-1.87

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