Title of case study: C: Incorporating novel data-driven approaches into cattle genetic improvement programmes leads to better animal performance and overall economic gains

1. Summary of the impact

Underpinning Research: Using novel methods to integrate data from multiple sources, our research revealed that fitness traits related to production, including fertility, survival to productive age and reductions in culling for non-production reasons, of dairy and beef cattle are more heritable than previously thought, and can be selected for in genetic improvement programmes.

Significance and Reach of Impact: We worked with key industry partners including the Agriculture and Horticulture Development Board (AHDB) and pedigree societies such as the British Limousin Cattle Society to develop tools to enhance genetic and genomic evaluations for key production and fitness traits. Results of these evaluations are published for 95% of all dairy bulls marketed for artificial insemination in the UK and for 65% of the current UK milking herd every month, informing mating decisions on farms across the UK.

Using this data-enhanced genetic understanding has resulted in more accurate selection and thus faster rates of genetic gain in key traits; for example, data from 2019 shows that dairy cows produced milk for 4-6 months longer in their lives than they did in 2013. The present net economic value of these accelerated rates of genetic gain across the UK national cattle herd is estimated at between GBP60,000,000 – GBP80,000,000 per year for the dairy industry and approximately GBP24,000,000 per year for the beef industry, over and above the gains described in REF2014. AHDB estimates the accelerated rates of genetic gain to be worth GBP750,000,000 over the next 5 years.

2. Underpinning research

The Challenge: Maximising cattle productivity using industry data
The UK beef and dairy industries are continually under pressure to sustainably increase productivity. Our research on the genetic basis of production and fitness traits has underpinned genetic cattle improvement programmes since the 1990s. In REF2014/6/1h, we showed that fitness traits, such as predictors of udder health and calving ease, could be combined with production traits in a weighted index that allows farmers to rank bulls according to the value of their genetics to the future profitability of their production system; the Profitable Lifetime Index (£PLI). This was adopted across the UK dairy industry by 1999 and continues to be a key selection tool, with new research findings routinely incorporated into it.

Since REF2014, we have discovered that routinely collected government, abattoir, British Cattle Movement Survey (BCMS) and individual animal data constitute a valuable but untapped additional resource for enhancing genetic improvement programmes. This has led to a step-change in the power of these programmes via the following two innovative steps:
1. Development of new data systems that enable integration of data from multiple sources
2. Application of these new systems to understand the heritability of additional production and fitness traits, to underpin further genetic improvement in cattle.

New data systems underpinning genetic improvement in cattle.
In order to make full use of these various data sources, it was necessary first to develop novel methods to enable cleansing and merging of structurally disparate and unstructured datasets. To this end, we developed new algorithms and data systems (rules and logic) [3.1]. We then harnessed these systems to analyse the heritabilities of new and existing cattle traits in a much larger, and thus better-powered, dataset, to generate more reliable predictions of offspring traits to aid selection of animals for breeding. This improved reliability of prediction has enabled new traits to be added to genetic improvement programmes, and existing traits to be understood at a finer resolution.

This innovative use of multiple data sources represented a step-change as, prior to 2015, genetic relationships between individual animals were only available for animals registered with a pedigree breed society, which accounts for less than 40% of UK dairy cows and only 10% of UK beef cattle. In addition, beef genetic evaluations were based largely on phenotypes collected by a small number of farms representing less than 5% of the total UK beef population. Our research enabling integration of data from multiple sources means that information from 4,000,000 *more* animals, with linked pedigree and phenotype information, are now available for research and genetic improvement programmes [3.1].

Data-driven advances in understanding the heritability of production and fitness traits

Using these data-enhanced systems of both genetic and phenotypic information, we have explored the genetics of a broad array of traits that underpin efficiency and sustainability of dairy and beef systems. This research has enhanced understanding of, for example:

- **Animal survival and female fertility:** Previously, genetic evaluations for cow longevity were based on a series of early life predictors, and other indicators of dairy cow health were largely limited to predictions of udder health based on udder conformation and somatic cell counts, and leg health based on leg conformation score. By contrast, our new data systems have allowed us to develop an improved understanding of the genetic control of survival across the lifespan as well as wider health traits in dairy [3.2; 3.3] and beef [3.1] cattle, enabling generation of more accurate genomic predictions for these traits [3.1].
- **Carcass and efficiency traits:** By merging BCMS and abattoir data, we showed that carcass weight, finishing age, carcass fat and muscle are all heritable traits in beef cattle [3.4]. In dairy cattle genetic improvement, we used the same data, combined with predictions of cow liveweight generated from our research herd [3.5], to study the genetics of, and produce evaluations for, maintenance and feed efficiency in the national herd.

Traits such as those related to survival over the lifespan and carcass performance had previously been considered difficult to incorporate into breeding programmes, due to being complex, difficult to measure or of low heritability. Using novel data science approaches to integrate government, abattoir and private datasets to better understand these heritabilities, we have shown that these traits are in fact sufficiently heritable to be amenable to selection. This has led, for the first time, to the development of genetic and genomic tools to select for these traits, and inclusion of many of them in overall selection indices for dairy (£PLI) and beef animals.

3. References to the research

[3.1] Moore, K.L., Moran, A., Mrode, R., Coffey, M. (2018). Using Commercial Data and Genomics to Improve Female Fertility and Calf Survival of Limousin beef cattle in the UK. *Proceedings of the World Congress on Genetics Applied to Livestock Production*, 11.65

[3.2] Pritchard, T., Coffey, M., Mrode, R., Wall, E. (2013). Understanding the genetics of survival in dairy cows. *Journal of Dairy Science*, 96(5), 3296-3309. doi: 10.3168/jds.2012-6219

- [3.3] Pritchard, T., Coffey, M., Mrode, R., and Wall, E. (2013). Genetic parameters for production, health, fertility and longevity traits in dairy cows. *Animal*, 7(1), 34-46. doi: 10.1017/S1751731112001401

[3.4] Moore, K.L., Mrode, R., Coffey, M. (2017). Genetic parameters of Visual Image Analysis primal cut carcass traits of commercial prime beef slaughter animals. *Animal* 11: 1653-1659. doi: 10.1017/S1751731117000489

[3.5] Banos, G., Coffey, M. (2012). Prediction of liveweight from linear conformation traits in dairy cattle. *Journal of Dairy Science*, 95(4), 2170-2175. doi: 10.3168/jds.2011-4838

Key grants

Beef research projects Innovate-UK 100971 Dairy research project BBSRC reference BB/N018567/1; Innovate-UK 101090

4. Details of the impact

Economic impact

Our research described above has led to improved efficiency of UK beef and dairy production, which translates to significant economic benefits. A model based on publicly available data collected by AHDB and previously published methodology [5.1] estimated that the benefit of being able to select for additional traits is worth between GBP60,000,000 and GBP80,000,000 per year for the dairy industry and GBP24,000,000 per year for the beef industry, based on genetic change at industry level. Furthermore, AHDB projects that: "*Using industry data sources and genetic trends from population data we produce, the changes described in the ICS are estimated to be worth an additional GBP750,000,000 over the next 5 years.*" [5.2a]. This economic impact is derived from 1) the availability of novel genomic tools based on our research, 2) uptake of these tools by farmers, and 3) consequent improvements in cattle performance, as described below.

Impact on cattle farming industry: Novel tools available for farmers

Our findings that more key production and fitness traits are amenable to genetic improvement than previously realised have led to the development of more comprehensive suites of tools that are now being used by farmers to make informed breeding decisions.

Working together with key industry bodies, including AHDB, Signet (the breeding services arm of AHDB) and the British Limousin Cattle Society (BLCS), we have developed, and routinely release, genetic selection tools, chiefly Estimated Breeding Values (EBVs), to help farmers rank the genetic merit of animals, i.e. predict whether offspring will have desirable traits, and therefore make the best-informed decisions on which animals to use for breeding the next generation [5.2 a, b, c]. These EBVs are generally combined into a weighted index to help rank animals for selection across a range of traits (e.g., £PLI in dairy cattle; **Figure 1**). The process of producing these individual trait results and overall rankings is part of the routine national genetic evaluations.

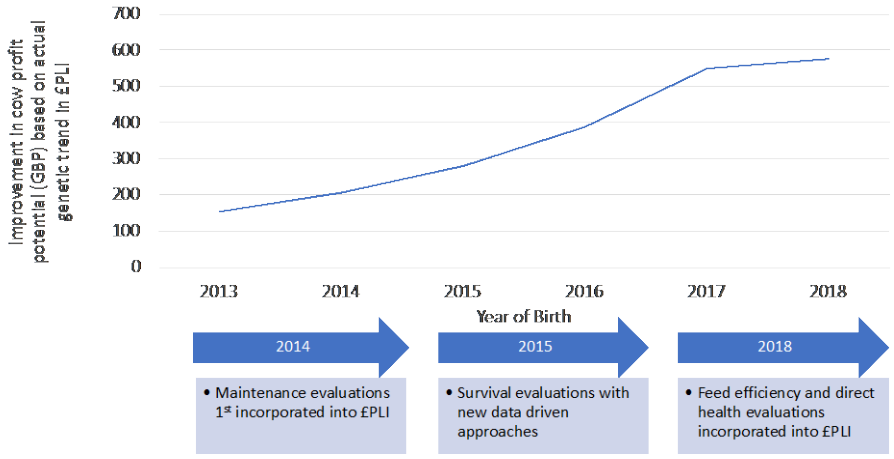

Figure 1. Increased profit potential of animals selected by our data-driven tools, incorporating our research for ranking animals on their genetic merit £PLI

In the UK, AHDB is the independent national source of genetic evaluations, breeding indices and analysis for all major breeds of dairy cattle. The Head of Animal Genetics at AHDB confirms the role of our research in their services: "*Without the research that SRUC has undertaken on methods to integrate new data for the development of new genetic evaluations, we would not have had many of the transformations we have introduced since 2013 in our national genetic and genomic evaluation systems. These results are used across the industry through individual bull, cow and herd reports.*" [5.2a]. Furthermore, AHDB's Beef Breeding Projects Manager highlights the impact of our data-driven tools they promote and deploy in the industry: *"SRUC research has helped show that we can integrate data from a range of sources which has been instrumental in the tools and services we provide to UK beef industry leading to real change in the industry.*" [5.2b].

Overall, as a result of incorporating traits identified through our data-driven research, the number of traits included in routine genetic evaluations has risen from 9 traits across 5 breeds in 2013, to up to 38 traits across 9 breeds in 2019 [5.3]. The most widely used tools developed from our data-driven research include:

- **EBVs for carcase weight, carcase conformation and fat class, days to slaughter and average daily carcass gain** (available since 2017). These form a key component of AHDB's

National Beef Genetic Evaluations, a programme they promote to farmers as "*Helping you breed for the traits you get paid for*" [5.4.a] as well as their Better Returns knowledge transfer programme, which encourages producers to identify where improvements can be made in terms of cost reduction, environmental impact and animal performance [5.4b]. In addition, AHDB Dairy publishes a Dairy Carcase Index (since 2018) to help farmers select for improved carcases in the dairy herd [5.5], where 55% of commercial beef originates. The BLCS Technical Manager notes that the ability to select for these key performance traits "*presents an essential and critical resource to exploit at a time when positive margins are becoming increasingly difficult to achieve through good practice alone, and at a time when market instability demands rapid response to change*" [5.2c].

- **Tools to improve lifetime survival of dairy and beef cows:** In 2015, building on our research elucidating the genetic control of full (as opposed to productive) lifespan, AHDB incorporated the prediction of survival across the full lifespan of dairy animals into this EBV [5.6] and updated the survival component in £PLI. Similarly, for beef cows, following our demonstration that lifetime fertility is heritable, in 2017, the BCLS introduced cow lifetime fertility into their genetic improvement programme [5.2c; 5.7].

Impact on cattle farmer practice: uptake of the data-enabled tools

The genetic/genomic information enabled by these tools has permeated the UK dairy and beef cattle herd through widespread use of artificial insemination (AI; used for 90-95% breeding in the dairy herd). Use of AI allows farmers to take advantage of the best bull genetics, as 95% of the sellers of semen in the UK comply with AHDB's Dairy Semen Code of Advertising [5.2a]; a scheme that ensures the most comprehensive suite of national genetic evaluations available at the time has been performed on the marketed semen and the results provided as part of advertising. Thus, by providing farmers with clear, up-to-date and easily comparable data on the genetic merit of the marketed semen, the Code of Advertising ensures that genomic information is built into farmers' semen-buying decisions.

AHDB data shows that farmers have indeed shifted towards relying on genomic information in their breeding decisions. Before genomic evaluations were introduced in 2012, farmers typically purchased semen from older bulls whose genetic merit was estimated through the performance of their daughters milking in the national herd (average age of bull: 5 years). Genetic evaluations make the same accuracy of estimation of genetic merit possible for younger bulls, and farmers have switched to buying their semen instead: semen from young bulls accounted for 70% of all inseminations in the UK in 2020, compared with less than 25% in 2013 [5.8]. Using younger bulls has the additional benefit of shortening the interval between generations, further accelerating the rates of genetic gain.

In addition, AHDB provide individual herd reports for 65% of the national dairy herd, i.e. to 800,000 milking cows at any one time [5.2a], enabling farmers to see the genetic potential of the cows in their herd to select the best individuals for breeding. Thus, at these farms, information from genetic evaluations informs the selection of both the males (predominantly through AI) and females for breeding.

Another demonstration of the uptake of our tools comes from a recent increase in sire recording in beef cattle passports. Historically, only 23% of beef cattle passports contained a record of the animal's sire (its biological father). Without this information, genetic evaluations cannot be done. In 2019, AHDB launched a campaign called "Shout About the Sire", with the explicit purpose of increasing sire recording so that farmers can reap the benefits of the national beef evaluations, which incorporate our data-enabled tools. After just 1 year, sires were recorded in approximately 32% cattle passports. The AHDB Beef Breeding Projects Manager notes that: *"This demonstrates the growing importance commercial beef farmers are placing on incorporating breeding information into their animal management."* [5.2b].

Impact on cattle performance and productivity

The above described widespread uptake of the data-driven genetic evaluations in both beef and dairy cattle has resulted in improved rates of genetic gain in breeding. The impact of faster rates of

genetic gain is most clearly observed in the dairy industry, as in the beef industry the generation interval of 8 years creates time-lag between a breeding decision and an improved carcass. In dairy cattle, uptake of our data-driven tools has led to the following improvements:

- **Dairy cow survival** has improved such that in 2019 cows were producing milk for an average of 4-6 months longer than in 2013 (corresponding to 0.3 of a lactation), as they were less likely to be culled for non-production reasons such as poor health or fertility [5.9].
- **The overall value of each bull to the production system** can be derived from the trends in £PLI since 2013 to quantify the overall economic benefit of the ongoing genetic change **(Figure 1**, [5.9]). The current value of £PLI indicates that each daughter of a bull available in 2020 was approximately GBP313 more profitable than a daughter of a bull available in 2013.

The value of this impact has been recognised in prestigious national awards for our unit [5.10a, b] with the Royal Association of British Dairy Farmers citing our research as "*invaluable in helping our farmers produce cows that are productive, profitable, healthy and providing a product the consumer wants."*

5. Sources to corroborate the impact

[5.1] Amer, P R., Wall, E., Nühs, J., Winters, M. and Coffey, M. P. Sources of benefits from genetic improvement in the UK dairy industry and their impacts on producers and consumers. *Interbull Bulletin* No. 44. Stavanger, Norway, August 26 - 29, 2011.
[5.2] Evidence for industry incorporation of our tools in their services a. Letter of Support from AHDB Head of Animal Genetics b. Letter of Support from AHDB Beef Breeding Projects Manager c. BLCS article in Somerset Country Gazette, 10th February 2018
[5.3] AHDB Dairy: Dairy Breeding and Genetics website
[5.4] AHDB/Signet promotion of our data-enabled tools a. AHDB website on National Beef Genetic Evaluations b. AHDB Guide "Choosing bulls for Better Returns", 2019
[5.5] Dairy Carcase Index factsheet, AHDB Dairy (published in 2019)
[5.6] Lifespan Index factsheet, AHDB Dairy (published in 2019)
[5.7] New Limousin Genomic Breeding Values (gEBVs) brochure by Limousin Breed Society (2017); including new gEBVs for survival and dam fertility.
[5.8] Tweet by AHDB Head of Animal Genetics showing 70% young bull inseminations (June 2018)
[5.9] UK Genetic Evaluation results on AHDB Dairy website (screenshot from Holstein breed page in December 2020 provided as an example)
[5.10] Awards in recognition of impact a. Queen's Anniversary Prize 2017 b. Princess Royal Award, 2020