Institution: The University of Edinburgh

Unit of Assessment: UoA5: Biological Sciences

To be cross referred to UoA6: Agriculture, Veterinary and Food Science

Title of case study:

09. Dairy farm profitability is enhanced by the application of quantitative genetics.

1. Summary of the impact (indicative maximum 100 words)

Impact on productivity, the economy and the environment: UK dairy farmers can select the best animals for breeding using analysis of a wide range of traits, leading to improved productivity, greater efficiency and reduced environmental impact, because of UoE research creating a **UK Test Day Model (TDM**) and an overall **Profitable Lifetime Index (PLI)**

Beneficiaries: The principal beneficiary is the dairy industry, specifically dairy farmers who are able to generate higher profits. This has benefits for UK consumers and the economy by keeping milk prices lower. The reduction in greenhouse gas emissions associated with more efficient dairy farming practices has global benefits.

Significance and Reach: The genetic evaluation system enabled by the PLI and TDM has resulted in a financial benefit to the UK dairy industry of an estimated £440M over the period 2008-2013.

Attribution: The quantitative genetic research was led by Dr Sue Brotherstone and Professor Bill Hill of the School of Biological Sciences, UoE, with colleagues at Roslin Institute (UoE; UoA6) and SRUC (also returned with UoE in UoA6) as described below.

2. Underpinning research (indicative maximum 500 words)

UoE has carried out much of the research and development underpinning genetic evaluation systems for livestock in the UK. The research has been a collaborative programme between researchers at the School of Biological Sciences (UoE5; Brotherstone, Hill, White) and at the Roslin Institute and SRUC (UoA6). The research which underpins this impact case study is the underpinning quantitative genetics research led by Brotherstone, which has provided the techniques and statistical models that have been applied to provide productivity and profitability analyses for the UK dairy industry. This research underpins effective genetic evaluation in livestock, which requires a quantitative genetic statistical model in which phenotypic variance is compartmentalised into environmental and genetic effects.

In 1998 Sue Brotherstone and Bill Hill established techniques for routine genetic evaluations for dairy herd *lifespan* in the UK [1]. Brotherstone also showed for the first time how a random regression model could be used to evaluate traits measured just once on an animal [2], for example, *udder composite* and *locomotion*. This paved the way for research into variance traits which are measured only once but which change over time, such as energy balance and body condition.

Research by Brotherstone & White into an improved genetic evaluation model for dairy cattle *productivity* (i.e. milk production levels) published in 1999/2000 initially concentrated on milk yield and derived a method of modelling the lactation curve for UK dairy cows [3]. Variance components necessary for genetic evaluation were estimated for cows in lactations 1 to 3. This allowed development of a test day, random regression model for production traits which uses daily ('test day') production data, providing the ability to account for environmental effects on each test day and to model genetic variation in individual lactation curves (i.e. a 'Test Day Model' or TDM). Subsequent research extended the work to the fat and protein content of milk using a multivariate system, which involved the estimation of over 800 genetic and environmental variance components. Brotherstone also developed methods of accounting for both pregnancy [4] and heterogeneity of variance in the model and derived a method of incorporating lactations 4 and 5 into the evaluation system. This resulted in a UK-herd-specific TDM which delivers more accurate genetic evaluations for production, allows genetic evaluations for lactation persistency to be calculated and enables lactations in progress to be easily incorporated into the system.

Further research by Brotherstone in collaboration with SRUC and the Roslin Institute (genetics researchers Coffey, Woolliams, Wall, and economist Stott) considered other indices that could be used to improve genetic evaluation, demonstrating that there is wide genetic variation in these traits and therefore scope for selection. She produced genetic parameters for locomotion, which is used as a predictor of lameness [5] and provided fertility parameters in collaboration with colleagues at SRUC and Roslin [2, 6]. Stott provided the economic evaluations to convert genetic indices to profitability measures.

All research cited here was undertaken by UoE: Led by Dr Sue Brotherstone, Senior Research Fellow in the School of Biological Sciences (1982-retired 2011) with substantial contributions from Professor Bill Hill, School of Biological Sciences (1965-2002; now Senior Honorary Professorial Fellow), PDRA Ian White (1996-retired 2012), Dr Huw Jones (Biosciences KTN) contributed to paper [2]. Other UoE collaborators at SRUC and Roslin Institute are named above; SRUC led the work in paper [6].

3. References to the research (indicative maximum of six references)

1. Brotherstone, S., Veerkamp, R.F. and Hill, W.G. (1998). Predicting breeding values for herd life of Holstein-Friesian dairy cattle from lifespan and type. *Animal Science* **67,** 405-411. doi: http://dx.doi.org/10.1017/S135772980003280X. **18 Scopus citations at 21/10/2013.**
2. Jones, H.E., White, I.M.S. and Brotherstone, S. (1999). Genetic evaluation of Holstein Friesian sires for daughter condition-score changes using a random regression model. *Animal Science* **68**, 467-475. Web of Knowledge Accession Number: WOS:000080023800015. **52 Scopus citations at 21/10/2013.**
3. Brotherstone, S., White, I.M.S. and Meyer, K. (2000). Genetic modelling of daily milk yield using orthogonal polynomials and parametric curves. *Animal Science* 70, 407-415. Web of Knowledge Accession Number: WOS:000087576100005. **77 Scopus citations at 19/09/2013.**
4. Brotherstone, S., Thompson, R. and White, I.M.S. (2004). Effects of pregnancy on daily milk yield of Holstein-Friesian dairy cattle. Livestock Production Science **87**, 265-269. doi: 10.1016/j.livprodsci.2003.07.014. **12 Scopus citations at 21/10/2013.**
5. Stott, AW, Coffey, MP and Brotherstone, S (2005) Including lameness and mastitis in a profit index for dairy cattle. Animal Science 80, 41-52. doi: http://dx.doi.org/10.1079/ASC40520041. **19 Scopus citations at 21/10/2013.**
6. Wall, E, Brotherstone, S, Woolliams, JA, Banos, G and Coffey, MP (2003) Genetic evaluation of fertility using direct and correlated traits. Journal of Dairy Science. 86, 4093-4102. PubMed ID: 14740850. **94 Scopus citations at 21/10/2013.**

4. Details of the impact (indicative maximum 750 words)

Improvements in livestock production are the result of selection practised by breeders who aim to select and breed from the “best” individuals. Before selection decisions can be made, an accurate genetic evaluation of the animal must take place. In the dairy cattle industry, genetic evaluations take place three times per year and the results are used by breeding companies and by farmers to improve the genetic merit of the national herd.

The techniques established by UoE researchers for routine genetic evaluations for dairy herd lifespan in the UK [1] allowed farmers for the first time to select for both longevity and milk production. The inclusion of breeding values for lifespan gives improved selection decision; before this, dairy farmers selected only for high production, which had negative impacts on cow health and welfare and thus on profitability.

This innovation was the first stage in development of the Profitable Lifetime Index (**PLI**), a widely-used tool provided by DairyCo (a levy-funded, not-for-profit organisation working on behalf of Britain's dairy farmers) which is proven to relate to actual profitability on the farm. The PLI is made up of the traits most strongly linked to profitability and identifies bulls that pass these traits onto their daughters. Since its introduction the PLI has been updated a number of times building on the original production and lifespan parameters which were produced in collaboration between Brotherstone and Hill providing the genetic parameters and SRUC colleagues providing the economic analyses [1-4]. Updating has incorporated lameness [5] and fertility [6]. The traits now included in the PLI are production (milk yield, fat and protein composition of milk), lifespan, type traits (udder conformation and locomotion), fertility, and somatic cell counts [a,b]. The UoE research by Brotherstone described above has provided the underlying parameters and genetic indices for production traits (through the UK Test Day Model) [3,4] and has contributed substantially to the lifespan [1,2], fertility [2,6], and the locomotion type traits [5] that are used in genetic evaluation to derive the PLI for UK dairy cattle.

The UK **TDM** provides the Production component of the PLI [b], which accounts for around 45% of the weighting given to the different traits included in the PLI. The UK TDM has dramatically improved genetic evaluations for milk and its components by allowing data to be adjusted for herd management and environmental effects that change over time, and by accounting for genetic differences in the shape of the lactation curve. The UK moved to this model for the calculation of genetic indexes for production in 2005 and the impact has been felt throughout the assessment period [b]. Milk yields have increased as a result of improved selection utilising TDM assessment: 15% higher per cow per annum in 2011/12 compared to 2003/4; the increase in milk yield in Holsteins from 1980 to 2012 is approaching 60%, with improved genetic selection estimated to have accounted for around half of this improvement [b,c] The multivariate system for assessing the fat and protein content of milk allows the identification of the best cattle to breed depending on the type of milk the offspring would produce. So, cheesemakers desire cows bred to produce milk with a high fat and protein content whereas milk producers desire cows bred to produce high volumes of milk with less emphasis on content. Improved genetic analysis for milk production using the TDM therefore also increases the efficiency and profitability of specialist producers.

Genetic evaluation systems are vital for the efficiency and competitiveness of the UK livestock industry. The benefits from genetic progress in livestock populations are well documented. For example Moran *et al*. [d] showed that animal genetic improvement is expected to deliver public good rates of return between 11% and 18%, far in excess of the recommended Treasury rate of return for public investment (3.5%). Total benefit from dairy cattle genetic improvement in the UK from 1980 to 2009 has been calculated as £2.42 Billion; the introduction of the new TDM in 2005 and improved PLI as a result of UoE research suggest such economic improvements would be sustained or accelerated, equating to £440M over the REF period [e].

The benefits of genetic evaluation also extend into environmental impact. Jones *et al* [f] showed that past selection on production traits in UK livestock has resulted in a decrease in the livestock population through higher productivity per cow, and hence an average 1.4% per year reduction in greenhouse gas production per unit of food produced. In addition, increased longevity and improved fertility through better breeding selection reduces the number of replacement females which need to be reared (e.g. a 2% fall in the size of the national herd was recorded between 2010/11 and 2011/12 [c]), and thus results in reduced greenhouse gas emissions. Data on emissions for more recent periods than the Jones *et al*. evaluation are not available but this environmental benefit will have continued during the impact census period.

5. Sources to corroborate the impact (indicative maximum of 10 references)

The Tiny URLs provide a link to archived web content, which should be accessed if the original web content is no longer available.

a) Head of Genetics Group, DairyCo, can corroborate the importance of TDM and PLI to the industry and the impact of UoE research.

b) DairyCo documentation on Test Day Model and use of genetic indices: http://www.dairyco.org.uk/resources-library/technical-information/breeding-

genetics/breeding-briefs/ or http://tinyurl.com/nkv4p2r

c) DairyCo Average Milk Yield Statistics (2012): http://www.dairyco.org.uk/resources-library/market-information/farming-data/average-milk-yield/ or http://tinyurl.com/nmkzsky.

d) Corroboration of quoted economic value of genetic improvement tools: Moran, D., Barnes, A. and McVittie, A. 2007. The rationale for Defra investment in R&D underpinning the genetic improvement of crops and animals (IF0101). Final report to DEFRA.

e) Corroboration of quoted profitability benefits to UK dairy industry: Amer, P.R., Wall, E., Nuhs, J., Winters, M. and Coffey, M.P. 2011. Sources of benefits from genetic improvement in the UK dairy industry and their impacts on producers and consumers. Interbull Bulletin No 43, Stavanger, Norway.

f) Corroboration of quoted environmental benefit through reduced greenhouse gas emissions: Jones, H.E., Warkup, CC., Williams, A. and Audsley, E. 2008. The effect of genetic improvement on emission from livestock systems. In Proceedings of the European Association of Animal Production, 24-27 August 2008, Vilnius, Lithuania, Session 5.6, p28. DEFRA report on this project is available.