Institution: University of Edinburgh and SRUC, Scotland's Rural College

Unit of Assessment: 6

Title of case study: The Profitable Lifetime Index (£PLI) is a reliable basis for genetic improvement of dairy cattle productivity, health, welfare, longevity and environmental impact.

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

Impact: Economic / animal health and welfare / environment: Improved profitability and sustainability of the UK dairy industry.

Significance: The use of the Profitable Lifetime Index (£PLI) increased the profitability of the dairy sector by an estimated £634M in 2008-2013 and reduced the greenhouse gas emissions from the sector by an estimated 8.4%.

Beneficiaries: Dairy producers, breeding companies, general public/environment, dairy cattle welfare and health.

Attribution: Drs Wall, Mrode (SRUC), and Brotherstone (UoE), Profs. Coffey, Simm, Stott, Veerkamp, Oldham (SRUC), and Woolliams (UoE/Roslin)

Reach: UK dairy industry. Tools developed, such as the routine recording of body condition score, and using these data in national genetic evaluations, have been widely adopted internationally, including in major dairy genetics exporting countries such as the USA, Canada, the Netherlands and New Zealand.

2. Underpinning research (indicative maximum 500 words)

This Research is attributed to (Drs Wall (Researcher, employed 2001-onwards), Mrode (Senior Geneticist employed 2005-onwards), and Brotherstone (researcher, UoE employed 1982-2011), Profs. Coffey (Team Leader, employed 1998-onwards), Simm (Academic Director, employed 1983-onwards), Stott (Group Manager, employed 1983-onwards), Veerkamp (Researcher, employed 1991-2004), Oldham (Principal researcher, employed-onwards), and Woolliams (Group Leader, UoE/Roslin employed 1977-onwards), UK dairy cattle genetic improvement programmes focussed mainly on milk production traits with clear negative impacts on cow health, welfare and fertility, and thus economic performance. The research team, collaborators and dairy industry opinion formers identified that broader breeding goals were needed, encompassing production but also addressing animal health and welfare, and other industry goals. A significant programme of research was initiated over 25 years ago with both government and industry funding. This led to improvements in knowledge and successively updated dairy cattle breeding tools, with those elements of research and impact reported here occurring in the relevant REF impact period.

Research (from 1993 onwards) focused on two main areas:

- Establishing the biological, environmental and economic consequences of selection for milk production, including testing for unforeseen consequences of selection [3.1]. This was achieved by: (i) comprehensively measuring and comparing the performance of cows selected for high milk solids yield with control line cows in our Langhill experiment - the world's longest running dairy cattle selection experiment; and (ii) estimating genetic correlations among traits of interest, from both Langhill [3.2] and UK dairy industry data [3.3]. This work identified that selection for production had a major impact on body condition score change, which in turn, affected reproductive performance. As a result, the UK was the first country in the world to routinely record body condition scores in dairy herds and was the first to use this information in national genetic evaluations for dairy cow fertility.
- Developing new 'breeding goals' – identifying the most appropriate combination of traits to select for, and their relative economic importance – and developing genetic improvement tools to allow selection for these breeding goals [3.3, 3.4, 3.5]. This

included: (i) developing genetic and statistical methodology for predicting genetic merit in new breeding goal traits, or proxies for them, including longevity, fertility, body condition score, udder health and calving ease, and (ii) producing successive versions of a new selection index, the Profitable Lifetime Index (£PLI), which provides a single score to identify animals with the highest genetic merit for overall economic performance in breeding goal traits.

The research provided evidence on the optimal design of breeding schemes and produced practical selection tools (e.g. estimated breeding values for new traits in dairy cows and new statistical models to enhance accuracy of selection decisions [3.3, 3.4]) and the new £PLI [3.5], which has become widely used in the UK. The index framework developed allows subsequent additions as new traits are identified and become economically significant.

Further work established valuable environmental co-benefits in terms of greenhouse gas emissions [3.6].

Wider programme on dairy cattle fertility and health involved colleagues from Universities of Nottingham (Prof A Flint) and Reading (Dr R J Esslemont).

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

3.1 Veerkamp, R F, Simm, G, & Oldham, J D (1994). Effects of interaction between genotype and feeding system on milk production, feed intake, efficiency and body tissue mobilization in dairy cows. Livestock Production Science, 39: 229-241. http://dx.doi.org/10.1016/0301-6226(94)90202-X

3.2 Veerkamp, R. F., & Brotherstone, S. (1997). Genetic correlations between linear type traits, food intake, live weight and condition score in Holstein Friesian dairy cattle. Animal Science, 64: 385-392. http://dx.doi.org/10.1017/S1357729800015976

3.3 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. http://dx.doi.org/10.3168/jds.S0022-0302(03)74023-5

3.4 Mrode, R, Pritchard, T, Coffey, M and Wall, E (2012). Joint estimation of genetic parameters for test-day somatic cell count and mastitis in the United Kingdom. Journal of Dairy Science. 95 (8): 4618-4628. http://dx.doi.org/10.3168/jds.2011-4971

3.5 Stott, AW, Coffey, MP and Brotherstone, S (2005). Including lameness and mastitis in a profit index for dairy cattle. Animal Science. 80: 41-52. http://dx.doi.org/10.1079/ASC40520041

3.6 Wall, E, Simm, G and Moran, D (2010). Developing breeding schemes to assist mitigation of greenhouse gas emissions. Animal. 4: 366–376. http://dx.doi.org/10.1017/S175173110999070X

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

The major impact of this research is improved profitability and sustainability of the UK dairy industry. Adoption of these new indexes has improved production, fertility and economic performance of dairy cattle. Cattle now live longer (from 3.4 years in 2004 to 4.3 years productive life in 2009). Cow fertility has improved (average calving interval has decreased from 431 days in 2008 to 423 days in 2012) and health (somatic cell scores, an indicator of the incidence of mastitis, have decreased from 206,000 cells/ml in 2008 to 198,000 cells/ml in 2012) with milk yields still increasing (8,765 litres/cow/annum in 2008 vs. 9,091litres/cow/annum in 2012).

The economic benefit of selection on the versions of £PLI produced as a result of this research are estimated to be around £634M over the period 2008-2013 [5.10]. Also, the changes to the sector brought about by the new selection indexes and breeding goals have cumulatively reduced greenhouse gas emissions per breeding animal by an estimated 1.4% (reduction in CO_2 equivalent) per annum.

Pathways to Impact

The versions of the £PLI index developed in this REF period have become very widely used in the UK dairy industry, allowing selection of those breeding animals best suited to UK needs from the massive international pool available. The vast majority of dairy cows in the UK are bred using artificial insemination (AI), to bulls which rank highly on £PLI. It is the combination of high AI use, and the selection of high £PLI bulls by AI companies which underpins most of the impact. Additional, smaller gains arise from farmers selecting the best available AI bulls, and breeding replacement heifers from the highest ranking £PLI cows.

We have worked to support the dairy industry levy bodies (currently DairyCo) in encouraging widespread uptake by breeding companies and farmers, via many workshop and conference presentations and with articles for websites, the farming press, and other media activity. The use of the tools we have developed has helped dairy producers in the UK become more sustainable, helping them to breed animals that are more profitable, fertile, healthy, have longer productive lives, and reduced greenhouse gas emissions per unit of milk produced.

Our research led to lifespan being included in the national dairy breeding goal (which became £PLI in 1999) in 1995. This was the first move away from a production-only breeding goal for UK dairy farmers. £PLI was further upgraded in 2003 with the inclusion of health traits (somatic cell counts from milk as an indicator of mastitis/udder health, and locomotion as an indicator of lameness), and in 2006 with the inclusion of fertility traits; traits that were all identified as important and researched by our group.

Genetic evaluation – the process of predicting the genetic merit of animals from pedigree and performance data (milk yield, growth, disease incidence etc.) and, recently, molecular genetic data - is a mathematically complex, internationally scarce, but key enabling technology in delivering the impact described. We established Edinburgh Genetic Evaluation Services (EGENES) in 2005. It provides livestock genetic evaluation and data handling services, and has helped to accelerate the transfer of research results into industry practice. EGENES has been contracted by DairyCo to provide genetic evaluations for the UK dairy population since 2005. The close partnership between our researchers, EGENES and DairyCo in research, translation via genetic evaluation services, and supporting knowledge exchange with users, has been instrumental in achieving impact.

International Impact

The approaches and methodology employed have influenced practice internationally via Interbull – the international agency for quality assurance and technical developments in cattle genetic evaluations; see: www.interbull.org. For example, the genetic evaluation of body condition score which we pioneered has since been adopted in 15 other major dairying countries, including Canada, the Netherlands and USA and our methods for including body condition score as a predictor of dairy cow fertility have been mirrored in national routine evaluations for fertility in Belgium, Ireland, the Netherlands, New Zealand, South Africa, Spain and the UK.

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

5.1) Marco Winters (Head of Genetics at DairyCo, marco.winters@dairyco.ahdb.org.uk) DairyCo fund and disseminate the national dairy genetic evaluations and have been responsible for the implementation of research findings into practice. http://tinyurl.com/lm3rdnn

5.2) Dr David Garwes (former research project manager, Defra, currently DairyCo consultant, djgarwes@tiscali.co.uk). Many of the research findings described were commissioned by Defra and managed by Dr Garwes. http://tinyurl.com/lxa3cly

5.3) Wall et al. 2003. Introducing a UK Fertility Index [http://tinyurl.com/o72986c]. This article relates to an annual meeting of the British Cattle Vet Assoc. and describes the launch of the fertility index to UK dairy farmers.

5.4) DairyCo Breeding+ [http://tinyurl.com/qf5ggxm] The hub for routine provision of breeding values (and selection indexes) to UK dairy farmers.

5.5) Swanson, G. and Mrode, R. (2001). Reduction in mastitis incidence from selection for reduced Somatic Cell Counts - good or bad? [http://tinyurl.com/oqzhc5u]. Presentation to the British Mastitis Conference on how selection on somatic cell counts can be used to genetically select for mastitis reduction.

5.6) Winters, M. (2008). Develop mastitis resistance by exploiting genetics [http://tinyurl.com/olgdmu6] Article describing how selection on somatic cells has impacted on mastitis resistance.

5.7) 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. [http://tinyurl.com/odkfa99]

5.8) Winters, M. (2010). Is dairy cow fertility a lost cause? DairyCo Technical Note [http://tinyurl.com/q38y6z6] Technical note showing how the genetic decline in dairy cattle fertility has been turned around since the introduction of the fertility index as part of routine national genetic evaluations.

5.9) Performance of UK Holstein-Friesian cows for a range of production and fitness traits (2000-2012). [http://tinyurl.com/paaqk54] National statistics for milk recorded pedigree Holstein-Friesian cows showing how traits have changed over the past decade.

5.10) Pritchard, T., Coffey, M., Mrode, R. and Wall, E. (2013). Understanding the genetics of survival in dairy cows. Journal of Dairy Science. 96 (5): 3296-3309. Peer reviewed publication quantifying the improvement in dairy cattle survival. http://dx.doi.org/10.3168/jds.2012-6219