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REALISING GENETIC IMPROVEMENT FOR THE EXTENSIVE LIVESTOCK INDUSTRIES AS A WHOLE

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SUMMARY
This paper examines some aspects of the overall performance of livestock improvement systems, first asking what we mean by the term "system". Variation in behaviour of agents within the system is examined, and some tentative conclusions about the nature of such systems, and scope for their management, proposed.

INTRODUCTION
In discussions of livestock genetic improvement, one theme focusses on improvement at a whole of industry or country level (eg. Hill, 1971; Smith, 1978; Hammond, 2006), and the term "system" or something similar is sometimes used. In general such discussion is descriptive, retrospective and focussed on averages, often leading to reasoning in support of various forms of collective action. In this context, "collective" means activities funded, initiated, managed etc. via mechanisms or agencies acting on behalf of often large numbers of individual enterprises.

A frequent observation is that rates of genetic improvement are less than what is technically possible, and that this can be attributed at least partly to various forms of market failure negatively impacting individuals' incentives to invest in recording and to select somehow optimally. In turn, this thinking has underpinned various forms of collective investment into aspects of livestock genetic improvement in many countries (Amer et al, 2012).

This paper is an attempt is made to explore the nature of such systems, and to ask whether taking a "systems perspective" can help achieve some different outcomes.

This general perspective rests on some important assumptions, including:

- Agents (individuals or organisations within the system) will respond to the availability of knowledge, tools etc by adopting and implementing them relatively immediately and uniformly
- Interactions or interdependencies between tools and/or agents are either minimal or benign in their effects (which ironically is not unlike assuming that all genetic variation is additive, or that at least we can ignore interactions)
- Information flow is such that all agents have perfect information about the future in a form relevant to whatever decisions they are able to make.

These are all heroic assumptions. Where this heroism is recognised, the usual response is to propose some form of collective or even government intervention, which usually takes the form of subsidising the cost of some system input(s). A common example is that government or industry funds are used for R&D and E, which in essence means making some of the raw materials of genetic improvement – knowledge, tools and skills – either free or cheap.

Embedded in these assumptions is the expectation (hope?) that market returns will be sufficient to fund the risky investments that for example sire breeders must make.

We can identify some aspects of the system through simple questions.

a) What comprises the system?
In the livestock industries, the components that are interacting include: bull- and ram-breeders in breeds within the breeding sector, commercial producers, finishers, processors, retailers, service

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providers to these sectors (including research and development organisations), and consumers.

b) How do agents interact?

Agents interact via the sale of packages of genes (mainly sires) and their derivatives (commercial stock and their products). There are many sellers and buyers in most livestock system markets. What do prices for genetic material tell us about information flow in beef and sheep?

Data relevant to this question is incomplete. However, Van Eeenanam (2012) analysed sales data from a number of Angus studs, and found clear relationships between price paid and bulls' merit, with r-squared in the 15-35% range, regression coefficients for the indexes in use at time of $40-70 per index point when stud bulls sales are excluded. Walkom (pers. comm.) analysed sales data from a number of ram breeding flocks, and found r-squared values in the range 35-45% and regression coefficients of price on index of $45-120. Analysis of Angus herd average prices indicates an r-squared of 45% for herd average bull price on herd average $Index merit.

So, some information is being exchanged and used in at least some transactions. With more data, a greater understanding of the variation in this exchange, whether it is changing over time, and longer term trends in market share could be examined.

c) Are the agents all aiming for the same things?

It is possible to examine variation in breeders' attitudes and behaviour around breeding objectives. A survey approach, such as in the MERINOSELECT Breeding Goals Survey (MLA, 2012) reveals more variation in the weighting proposed for individual traits amongst breeders within a wool type category than between categories. A more analytical approach, involving calculating correlations between response vectors amongst breeders, reveals similar variation in realised breeding direction in Angus cattle (Lee, 2014) and Merino sheep (Swan, pers. comm.)

QUESTIONS ABOUT LIVESTOCK IMPROVEMENT SYSTEMS

This brief overview suggests that there is a system of interacting and diverse agents. What questions can be asked of such systems? Smith (1978) is an example of studies highlighting the fact of differing perspectives within such systems – the question really being "what are agents trying to achieve?"

- differences between individual breeders and the national or industry
- differences between different sectors in an industry

In most countries and industries, the general response to these differences has been the establishment of some form of national or industry-level evaluation, with either mandatory or voluntary participation. Such evaluation, especially when based on BLUP methods, has lead or contributed to, increases in rates of genetic progress. Depending on the interaction between the information generated by the evaluation and aspects like bull registration, such initiatives can effectively override differences in perspectives, but this may come at some political and financial cost. Amer *et al* (2012) examined returns from genetic improvement in beef cattle in several countries, and identified a range of approaches differing widely in apparent cost per animal, but less so in outcome.

The general question of aims leads inevitably to the specific question of breeding objectives and hence indexes. National evaluation systems such as BREEDPLAN, Sheep Genetics and ADHIS invest significant resources into developing "industry" objectives, usually with inputs from breeders and others in industry, but may also provide scope for customised indexes. As breeders' confidence in breeding technologies grows, the situation can arise, and seems to be arising more frequently, where some breeders wish to innovate by making and demonstrating genetic progress for new traits. By definition this leads to a situation where only some breeders have information on the new traits, which in turn means that the less innovative breeders are automatically at a disadvantage if indexes are modified to include the new traits.

This question of different views on objectives (and hence on indexes) in turn leads to the question of how to value outcomes of the system. If there is some national objective, but a significant portion of industry is pursuing objectives correlated at less than 1 with the national objective, should the national objective be used to value improvement? And the question of how to value outcomes leads to the question "how to improve those outcomes?"

RESPONDING TO GAPS – LEAVE IT TO THE MARKET?

One way of viewing the establishment of industry-wide genetic evaluation systems is that they are primarily meant to provide information, enabling a market in genetic material to function with greater efficiency. This outcome seems to develop, but slowly and unevenly (Van Eenennaam, 2012). This outcome alone provides a strong basis for some form of collective investment: objective information available to buyers and sellers is necessary for an efficient market. Such information is also a necessary condition for genetic improvement, but is not sufficient on its own. In the absence of direct payments for genetic improvement itself, Amer (pers. comm.) has noted that the primary incentive for breeders to make genetic progress is possible future market share. This incentive would appear to be the driver for dairy breeding companies, who operate in competitive markets in multiple countries, and pig breeders (Knap, 2014). It is not obvious whether beef and sheep breeding businesses in Australia are sufficiently scaleable to make growing market share a realistic goal for all but a minority of enterprises.

Another form of investment in information is via the calibration of genomic tests. This service is provided in the US dairy industry (and hence effectively, globally) by the USDA, and in the Australian beef and dairy industries by the respective industry funding bodies. This initiative has the beneficial effect of enabling informed investment in genetic information products, but raises the interesting question of who pays for the performance data required for the calibration. If such information is collected for other purposes, as is the case for some traits in dairy, this may partly obviate the problem, but where this is not the case, funding data collection becomes yet another dilemma poised around "who benefits, who pays?"

These are two forms of collective intervention, but on their own, they may not generate much overall improvement. What might we need to understand in order to do better?

RESEARCHABLE QUESTIONS – FIRST ORDER

The fundamental level of research must always be focussed on analysis of genetic variation, including new methods. Having accurate descriptors of animals' genetic merit is absolutely essential for efficient selection and the efficient operation of the market for genes (or the animals that carry and transmit them).

The next level of analysis is where we start to understand the behaviour of the "system" and its components. Industry databases now offer scope to analyse what individual enterprises have done – including tracking selection differentials, accuracies achieved, levels of linkage and resulting flows of information between enterprises, and directions of selection. Tools have been developed for such analysis, such as Takestock (Johnston, pers. comm.), but as yet they are not being used systematically to help design interventions (such as new services and products).

Reverter *et. al* (2011) provided an example of preliminary analysis of the network properties of the meat sheep genetic improvement system, and suggested further steps. Similarly, Charteris *et al* (2001) suggested the use of agent-based modelling to explore both the properties of livestock improvement systems, and potentially to explore through simulation the effects of different interventions.

RESEARCHABLE QUESTIONS – DESIGN AND COORDINATION

The bigger questions are around issues such as:

- If we can identify information gaps, should they be filled, and if there is a cost, who pays and how?
- If we assume that all system behaviours ultimately depend on decisions at the individual enterprise level, can we "nudge" them in any way (Thaler *et al*, 2008). For example, if relying on market premiums to incentivise bull- and ram-breeders, and we know that those premiums are imperfect signals, should someone add some sort of rewards for "good behaviour" – things like additional recording, sampling new bloodlines, strengthening linkage, or even simply making faster progress?
- And ultimately, who monitors system behaviour and develops responses? This is ad hoc in Australia, relying on varying inputs and capacities of organisations such as MLA, breeds, ABRI, previously CRCs, and breeders, each with their own constraints. The problem is that this ad hoc system appears to be associated with opportunity costs running into hundreds of millions over the medium term.

CONCLUSIONS

Charteris *et al* (2001) proposed that livestock improvement systems could usefully be examined using the perspective of Complex Adaptive Systems (CAS), where a CAS exhibits "strong interactions among its elements so that current events influence the probability of many kinds of later events". The brief discussion here suggests that there is merit in that recommendation. Already it is clear that there is considerable variation at the level of individual enterprise (agent in CAS language) behaviour and at least some inter-agent interactions.

It is not so clear how to tackle system-wide coordination and management (research using the CAS framework might generate useful ideas for this), but it seems highly likely that in the absence of any such coordination that overall performance will fall short of what seems possible (although what we think is possible may reflect ignorance on important inherent limits of such systems). Responding through some sort of central control seems politically unlikely, so the search must continue for ways to do better. Simply piling up raw materials (new knowledge), ensuring accurate EBVs and Indexes and other types of current R&D may unfortunately be necessary but not sufficient.

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