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Sheep industry structure and genetic improvement

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ABSTRACT

The sheep industry consists of a nucleus or ram-breeding sector that accounts for 1-2% breeding ewes and a commercial sector that relies on the ram-breeding sector for the supply of flock rams. The rate of genetic change in the whole industry is dictated by the rate of genetic gain in the nucleus sector. Increasing the size of the nucleus sector has little affect on genetic gain but increases the costs of genetic improvement. Industry structure is determined by the behaviour of breeders and farmers but there is often little individual incentive for these players to alter their practices despite overall benefit to the industry. The advent of performance recording, open-nucleus breeding schemes and the introduction of new sheep breeds have all resulted in modifications to the NZ breeding industry structure. The introduction of new biotechnology, notably DNA and cloning technologies could markedly alter future industry structure.

Keywords: Sheep; performance; industry data.

INTRODUCTION

Most livestock industries have a structure that comprises at least two tiers – in the sheep industry this involves a nucleus tier that produces flock rams for breeding purposes and a commercial tier that utilizes sires bred in the nucleus to produce offspring for commercial production of lambs and wool. The relative size of the nucleus tier, its composition and the manner in which it interacts with the commercial tier have major implications for the profitability of the sheep industry, its opportunity for systematic advance and its flexibility to enable a quantum leap in performance. This paper addresses some of these issues in a New Zealand context.

RELATIVE SIZE OF THE NUCLEUS AND COMMERCIAL TIERS

Consider an "average" commercial flock of 10,000 ewes with rams used for three years at a mating ratio of 1:75 ewes. Such a commercial flock would require some 45 new rams to be recruited each year. Suppose these rams were supplied from a single ram-breeding (or nucleus) flock with 150% lambing. Allowing the nucleus flock to cull half of its ram progeny, the nucleus would need to comprise about 120 ewes in order to supply the required number of rams. This size would represent a little more than 1% of the total number of ewes represented in the nucleus and commercial enterprises. Depending upon the mating ratios, ram longevity and nucleus opportunity for culling rams, the required nucleus size is between 0.2% and 5% of total ewes. In a national context comprising 32 million breeding ewes in New Zealand, somewhere between 64,000 and 1.6 million breeding ewes are required to meet the requirements for flock rams. The current nucleus size is likely between 350,000 and 750,000 breeding ewes.

Changing the size of the aggregate national nucleus, within the limits identified in the previous paragraph, has little impact on the rate of genetic gain or on the accumulation of inbreeding. However, genetic gain relies on the ranking of animals followed by selection of animals with above-average genetic merit and culling of below-average performers. For many traits, animals can only be ranked following the objective measurement of performance, requiring individual identification and performance recording. For traits that are sex-limited, of low heritability, or measured late in life, measurement of relatives can add considerably to the accuracy of evaluation. This requires the collection of pedigree information. Pedigree and performance recording incurs direct costs in ear tags and data services, as well as indirect costs such as labour to undertake these extra tasks. The size of the nucleus therefore has greater impact on the industry cost of improvement than it has on the industry rate of genetic gain. The total costs can be minimized by ensuring that performance recording is limited to the animals that truly comprise the nucleus.

STRUCTURE OF NUCLEUS

The nucleus is not a single flock entity, but a collection of flocks of varying sizes and breeds. In New Zealand, the average performance-recorded flock comprises some 300 ewes, with a significant number of flocks exceeding 1,000 recorded ewes. These flock sizes provide ample opportunity for selection. In contrast, some nucleus sectors in other countries, such as the UK are characterized by flocks of 100 or fewer ewes, considerably limiting their opportunity for selection. In those circumstances, it is imperative for some of the flocks to operate collectively, with across-flock progeny-testing or sire reference schemes, in order to achieve genetic progress. Garrick (1991) describes analytical aspects of such across-flock evaluations. The impact of some across-flock breeding plans on genetic gain was shown by Blair (1989) to vary according to the trait and breeding strategy adopted. Accounting for costs as well as genetic gain demonstrates that optimal strategies of industry improvement do not necessarily result from across-flock schemes.

In New Zealand, the nucleus sector includes a significant number of small-sized flocks, particularly in terminal sire and less popular breeds (Stewart and Garrick, 1996). Many of these flocks have not typically utilized national performance recording schemes. However, continued demand for objective measures of farm performance (pasture covers, soil tests, financial performance) has led to increased adoption of performance recording by industry. Further demand for objectivity and economies of scale are likely to reduce the influence of small nucleus flocks as large "branded" or franchise-based breeders increase their dominance in the industry.

In practice, only a fraction of the nucleus tier contributes directly to genetic progress in the national flock. Analysis of pedigree records in the nucleus tier demonstrates that many of the nucleus flocks simply purchase rams from other nucleus flocks (Stewart and Garrick, 1996) and sell the resultant male offspring, such flocks are often called 'multipliers'. In total, there are perhaps 1,000 flocks contributing to the nucleus (and multiplier) sector, with less than 100 having a dominant influence on the commercial population. In encouraging adoption of improved practices and new technology in the nucleus sector, strategies that concentrate efforts on this minor grouping will provide far greater return on R & D investment than treating all flock owners equally.

The long-term nature of genetic improvement is reflected in the considerable delay between selection in the nucleus and the sale of product from resultant offspring in the commercial tier. This time lag introduces a major difficulty in improvement programmes. In a stable economic environment, market signals provide a useful indication of the attributes that should be changed in the future. However, in practice, markets change quickly in response to fashion, media pressure and changes in consumer attitudes. In the 1970s to 1990s dual-purpose sheep producing lamb and wool were the mainstay of New Zealand sheep farming. These two commodity products provided approximately equal contributions to farm income. In recent years there has been gradual erosion of wool value relative to lambs and some new traits have quite suddenly become important to farmers or to the marketplace.

Increases in farm scale and the numbers of stock units per farm worker has increased interest in easy-care attributes that reduce the work of farming sheep. These traits have included reduced face cover, ease of lambing, mothering ability, reduced dagginess, and increased disease resistance. In future, new traits may target animal welfare aspects (Scobie *et al*., 1997). Changes in the market place have lead to the introduction of new traits that have been implicated as determinants of future profit from a processor or consumer perspective. These include wool bulk (Clarke *et al*., 1999), eye-muscle area and lean meat yield (Waldron *et al*., 1991).

A major strength of having a nucleus distributed over many flocks is that each breed and each flock within a breed has its own breeding objectives. Although many share a common theme, there are enough outliers to provide some security in relation to changes in market requirements. For example, there are currently breeders that are selecting for resistance to internal parasites, selecting for resilience to internal parasites or ignoring internal parasitism in their breeding objective (Breeding Matters, 1994). Similarly some breeders are selecting for facial eczema resistance (Towers *et al*., 1983) while others ignore this trait. The development of the Drysdale breed would not have occurred without some breeders demonstrating an interest in the niche markets that might result from the production of medullated wool fibres.

In many countries, the nucleus consists entirely of registered animals, a registration barrier limits entry of animals, preventing rapid growth in the nucleus. This is not the case in New Zealand, where the widespread adoption of open-nucleus breeding schemes to improve reproductive performance in the 1960s and 1970s led to unregistered animals dominating the performance-recorded sector. The introduction of different breeds into the nucleus can occur in two different ways. A new breed can be introduced (by migration) and maintained in its own right, or a new breed can be crossed with existing animals to create a new so-called composite breed. Both of these approaches have been adopted in New Zealand, although the most successful introductions have tended to result in the development of new composites. The creation of the Corriedale, NZ half-bred, Coopworth and Perendale are examples of simple composites. At present, new composites are being developed, often incorporating East Friesian, Finnish Landrace, Texel or Dorset breeds. It remains to be seen whether these breeds result in new "labelled" breeds.

The introduction of these new breeds has seen some breeders rapidly increase the size of their nucleus, through immigration of crossbred or composite animals. In many cases, these introductions originate from a small genetic base. Perceptions of breeders regarding these animals often reflect an individual sire rather than attributes of the breed as a whole. The opportunity breeders have to access a large pool of commercial animals for their nucleus is particularly valuable when the breeding objective changes suddenly and a quantum leap in performance attributes is required. However, such introduction of animals creates challenges for recording systems and will result in biased rankings of animals unless the screening criteria used in the selection of these animals is properly accounted for.

PERFORMANCE RECORDING IN NUCLEUS

The information needs for genetic improvements are largely dictated by the nature of the breeding objectives in the nucleus flocks. Traits with high heritabilities and few systematic environmental influences that can be easily measured on all individuals at a young age will be readily amenable to selection with little benefit from sophisticated technology. This includes characteristics such as fleece weight and post-weaning gain. Traits measured late in lifetime, such as longevity, or measured in only one sex, such as litter size, benefit from the inclusion of information from relatives. This is particularly so when the trait has low heritability, such that individual performance provides little reliable indication of genetic merit. In these cases, the collection of pedigree information and the use of sophisticated statistical techniques will markedly increase the rate of gain from selection.

Some characteristics require specialized off-farm equipment for measuring phenotype, such as for fleece yield and mean fibre diameter in wool samples, enzyme concentrations as in gamma-glutamyl transferase for facial eczema, faecal egg count or ELISA antibody assays for parasite resistance, or CAT-scanning of individual muscle tissues for changing body composition. In these cases, selection cannot occur at that time when the sample is collected, necessitating the recording and analysis of information in advance of the selection process.

The act of performance recording does not, in itself, result in genetic progress. Progress occurs as a result of selection for economically important traits. If long-term market signals are to encourage genetic progress, it is important that any financial reward for nucleus animals is directed at superior individuals and not simply at those that are performance recorded.

STRUCTURE OF COMMERCIAL SECTOR

The commercial sector in New Zealand has traditionally been linked to the nucleus sector via the transfer of straight-bred rams that have predominantly been used in commercial flocks to mate ewes of the same breed. An exception is the use of terminal sire breeds. Ram buyers have tended to remain loyal to their ram breeders, such that the entire industry can be viewed as a number of separate pyramids, each pyramid involving a ram-breeding nucleus at the top, linked to a number of commercial farmers via ram sales. A selection of only 60 of the larger performance-recorded ram breeding flocks meets the ram requirements of about _ of the entire national commercial flock (Garrick, 1996). From time-to-time there has been some perturbation of this otherwise stable structure: these are described below.

During the 1970s some commercial flocks screened high performing sheep into a nucleus flock to meet their requirements for flock rams (Rae, 1977). This open-nucleus concept is no longer popular for a variety of practical and economic reasons, e.g. those associated with disease risks, recording costs and genetic lags between nucleus and commercial flocks (Garrick, 1993). From a genetic improvement standpoint, the open-nucleus structure is of little advantage compared to closed-nucleus flocks making real progress for the traits of interest to commercial farmers.

Some commercial farmers have created and maintained multiplier flocks for the purpose of reducing the costs and efforts involved in ram purchase. A few relatively high-performing ewes are individually identified and mated to perhaps one elite ram purchased each year. The above-average sons for some simply measured performance are then used as flock sires.

A significant change to the structure of the commercial industry has occurred recently as a result of the decline in wool price relative to the value of lambs, and the perceived opportunities from the introduction of genes from breeds that exhibit high fecundity and precocious puberty, notably the Finnish Landrace and the East Friesian. These breeds have been concurrently introduced into both nucleus and commercial flocks, often through the use of first-cross flock rams. The resulting commercial offspring are therefore _ Finn or _ East Friesian. It remains to be seen as to the long-term effect of these introductions on the structure of the commercial sector. There are at least five options for using these newly introduced breeds and each will have different implications on the structure of the commercial sector. These options are outlined below.

The motivation for commercial farmers to introduce new breeds is typically related to strengthening performance of a particular trait, such as fecundity. In practice, every breed or cross is likely to have both strengths and weaknesses, and it is only by trialing the animals under their own production and economic circumstances that farmers pay adequate attention to the weaknesses. This may take several years, as some weaknesses may not become apparent until a significant proportion of the flock has been changed to a new breed or cross. If the animals fail to provide an appreciable lift in productivity, farmers will likely discard the new animals and return to their traditional breeds. At the other extreme, they may be so taken by the new animals that they totally upgrade their flocks to the new breed. Between these extremes are three options that involve the continued use of animals that have some genes sourced from the new breed. To some extent the choice among these three options will be dictated by the behaviour of ram breeders with respect to the new breeds. Ram breeders may create a “stabilized” composite that involves some fractions of two or more breeds, and begin supplying commercial farmers with these crossbred rams for use in commercial flocks. This occurred in the development of the Coopworth and Perendale breeds. Alternatively, commercial buyers may prefer to continually source rams for outcrossing, thereby recreating crossbred animals. This approach would be favoured if heterosis contributed significantly to performance, or if industry demand covered too wide a spectrum of composites to justify ram breeders providing of all of these combinations. Considerable management and production advantages can also result from this approach if farmers integrate the system across different classes of country, as has traditionally occurred in parts of the UK. The final option involves continued backcrossing and selection to introgress desired genes from the new breed and incorporate them into the traditional breed.

PERFORMANCE RECORDING IN COMMERCIAL FLOCKS

Some commentators believe that the industry would gain marked benefit from the collection of phenotypic information on all commercial progeny. The rate of genetic progress in ram-breeding flocks is directly linked to the accuracy of selection and this increases as more information is available for ranking animals. However, if extra information comes at the expense of any delay to the age at which selection can take place, increase to the generation interval will erode some or all of the benefits from increased accuracy. Even if there is a net benefit in genetic gain from adding information on commercial animals, there may be a greater increase to the cost of collecting the information than can be justified by the increase in returns from higher genetic gain. Optimal breeding programmes are seldom characterized by the maximum achievable rate of gain – they must reflect compromise between costs, benefits, selection accuracy and generation interval. This increase in costs may not be a factor if the commercial producers are prepared to collect the information and pay the associated costs for their own benefit, and provide ram breeders with "subsidized" access to the commercial records. This is the situation currently enjoyed by artificial breeding companies in the dairy industry, whereby most commercial animals are performance recorded at the commercial farmers' expense.

Information from commercial animals will only contribute to the evaluation of animals if records are available on contemporary animals and if non-genetic factors can be accounted for. In practice, commercial data often lacks relevant environmental information (such as date of birth) and has been subject to preferential treatment (e.g. higher feeding levels to a subset of animals) and records are not available on all contemporaries (e.g. poorer animals may be sold store).

DETERMINANTS OF STRUCTURE

The structure of the industry is determined by the joint behaviour of many different players – notably the ram breeders and the ram buyers. Both of these parties are limited in their options based on their perceptions about the reaction of the other party.

The requirement of some quality assurance schemes for individual identification, recording of contemporary animals and the collection of animal treatments and subsequent product information (such as meat quality) will reduce the barrier between the ram breeding and ram buying tiers.

Technology can have considerable influence on industry structure. For example, DNA methods for parentage analysis allow pedigree recording on otherwise extensive properties. The advent of electronic tags and computer-assisted recording (such as using electronic scales) will facilitate the collection of performance records, which previously was labour intensive and acted as a barrier for entry to the ram breeding sector.

The development of technologically-based tests of performance (such as DNA gene tests) could revolutionize current industry structure as animals might be segregated at an early age on the basis of fitness for purpose. For example, animals with propensity for producing heavier fleeces, or resisting parasites may be allocated to production systems where those attributes were of greatest financial reward.

Cloning offers the greatest potential to change existing industry structure. Commercial farmers desire "even" lines of animals; often selecting rams that have similar appearance. Contrary to widespread belief, the use of cloned rams need not significantly reduce the phenotypic variation observed in offspring, nor introduce serious inbreeding problems. However, it could result in a major proportion of the current ram breeding sector being "by-passed" by commercial farmers if they can cost-effectively source clones of proven sires for flock mating.

Scientific modelling of industry structure can identify the genetic and financial implications of various structures. There is very little information available to objectively quantify the existing NZ sheep industry structure for use in these models. The recognition of an optimal structure will not necessarily provide any motivation for individual players to modify their practices to move the structure towards the optimum. Finally, the commercial interests of individuals, such as ram breeders, are more influenced by their relative competition with other ram breeders currently in business than by the theoretically optimal performance. In breeds where there has been little acceptance of technological innovation, there is no motivation to be as good as one can be, only motivation to be better than average.

There is increasing interest among some ram breeders to increase their level of vertical integration, both with their ram clients and with the processors and marketers of their resultant products. This structural change has already been adopted in some pig and poultry breeding arenas and would likely lead to change in breeding objective from a production to a market focus. The success of such a venture remains to be seen.

CONCLUSIONS

Industry structure has a major influence on profitability and the rate at which the industry can change in order to seek enhanced products or production processes and increased future productivity. This is particularly important in an economic environment characterized by continuous erosion of commodity prices, along with an increasing demand for compliance, via resource management acts, occupational safety and health, QA schemes, animal welfare etc.

Improved industry structure will result in increased industry profitability but this will not necessarily be associated with increases in the profitability of individual breeders or commercial farmers. In particular, the contribution to industry profit of the small group of leading nucleus breeders is not adequately reflected in market returns for their rams.

Existing industry structure is not easy to quantify, but improved structures can be readily identified by modelling and the use of other analytical tools. However, there are many barriers in achieving modifications to structure to increase industry performance. Entrepreneurial farmers and breeders have been responsible for minor shifts in structure in recent decades. Research and development advances are likely to be the major contributors to quantum structural changes in the long-term.

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