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Economic implications for growing wool from using genomic technologies

R.M.W. SUMNER AND R.M. DAVISON[1]

AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton, New Zealand

ABSTRACT

Agricultural commodity products experience marked price trends over time. In the 1980s the balance between returns to growers, before deducting costs, from meat and wool was 46/54. The ratio has now shifted to 83/17. Price increases of the magnitude currently required to redress this imbalance for wool growers may be achievable through genomic technologies. Such technologies could create a demand for biological components extractable from a proportion of the national clip, permit the development of novel fibre types and significantly reduce wool harvesting and husbandry costs. The economic benefits to sheep owners through changing wool characteristics such as fibre diameter or crimp are limited by existing high volume, low profit margin value chains. New technologies which improve wool characteristics and value should be complemented where possible by direct supply relationships between producers and end-users in order to justify their development and to sustain price premiums.

Keywords: wool; economic returns; fleece characteristics; fleece distribution; keratin extraction.

INTRODUCTION

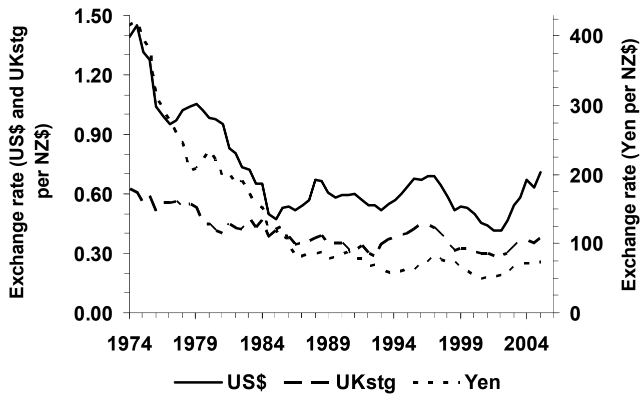
A major motivation for people to engage in a business is the profit margin derived from that business. Pastoral farmers are no different although they also seek a degree of financial security in view of the high capital investment in their farms (Small *et al*., 2005). Any factors that can either increase the sale price of the product or decrease the costs of production will potentially increase profitability and encourage a producer to increase their productivity.

This paper will briefly discuss recent trends in prices received by sheep farmers from the sale of products produced by sheep and the associated costs of production of those products. Extrapolating to the future, we explore whether the potential changes in production achievable through genomic technologies will be sufficient to encourage sheep farmers to increase their profitability by incorporating these new technologies into their businesses.

CURRENCY SHIFTS

New Zealand is a net exporter of products derived from sheep. The prices received by sheep farmers are thus influenced by supply and demand in the countries to where the products are exported, in combination with the relative values of the principal international trading currencies. With a floating New Zealand dollar, significant currency value changes can occur within the production cycle of a particular sheep product. Figure 1 indicates the exchange rate of the New Zealand dollar to the US dollar, UK sterling and Japanese yen over the last 30 years. This volatility is driven by a diverse range of international factors over which New Zealand, and New Zealand sheep farmers in particular, have no control.

FIGURE 1: Exchange rate of the New Zealand dollar relative to US dollar, UK sterling and Japanese yen since January 1974. New Zealand adopted a floating exchange rate on 4 March 1985. (Source: Meat & Wool New Zealand Economic Service).



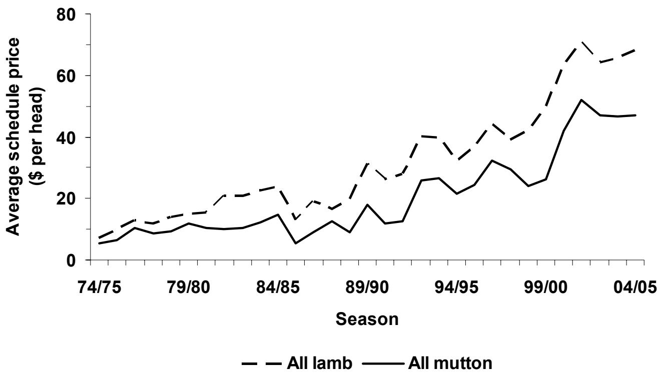
MEAT AND WOOL PRICES

As a result of shifts in currency, and product supply and demand, farm-gate prices for sheep-meat and wool have varied considerably over the past 30 years. Figure 2 shows the average export meat schedule prices for lamb and mutton paid to farmers. Over this time the per head price received for an older sheep sold as mutton has been between 45 and 80% of the price received for sheep

[1] Meat & Wool New Zealand, Economic Service, P.O. Box 121, Wellington, New Zealand

sold as lamb. As lamb prices rise, competition occurs between farmers seeking breeding ewes and processors seeking mutton carcases, the price of adult sheep may increase, whereas the reverse occurs when lamb prices fall. Returns from meat were particularly depressed between 1985/86 and 1992/93 following deregulation within the meat industry.

FIGURE 2: Average export meat schedule price paid to farmers for lamb and mutton since 1974/75. (Source: Meat & Wool New Zealand Economic Service).



The New Zealand wool clip is made up of a diverse range of types varying from super fine Merino with a mean fibre diameter of less than 18 microns (µm) to coarse Drysdale carpet wool with a mean fibre diameter in excess of 40 µm. As mean diameter of a parcel of wool is the key factor that regulates its suitability for a particular end-use, the New Zealand clip is commonly divided into three broad groupings for analytical purposes. These are finer than 24 µm, 25 to 31 µm and coarser than 32 µm referred to as the fine, medium and strong segments respectively. The fine segment is principally Merino wool, the medium segment is principally New Zealand Halfbred and Corriedale wool while the strong segment includes wool from British long wool breeds. Fine wools tend to be used for apparels, medium wools tend to be used for hosiery and knitting yarns while strong wools tend to be used for interior textiles and carpets. While approximately three quarters of the New Zealand clip sold at auction currently has a mean diameter coarser than 32 µm and only 10% is finer than 24 µm, the national clip has gradually become finer over the last 30 years (Figure 3). The amount of wool in the fine segment doubled between 1986/87 and 1992/93.

Fibre diameter is a key factor associated with spinning performance through its influence on the length of yarn that can be spun from a parcel of loose fibre as well as the relative softness of the resultant yarn. As a result finer wools are more suited to a wider range of end-uses than strong wools and receive a higher price. Figure 4 shows the average clean price for wool at New Zealand auctions over the last 30 years for each market segment. There was a marked surge in wool prices of the fine segment in 1988/89 which stimulated the increase in the amount of fine wool produced in New Zealand during the late 1980s (Figure 3).

FIGURE 3: Proportion of the New Zealand wool clip sold at New Zealand auctions in the fine, medium and strong segments. Fine = 24 µm and finer, Medium = 25-31 µm, Strong = 32 µm and coarser. (Source: Meat & Wool New Zealand

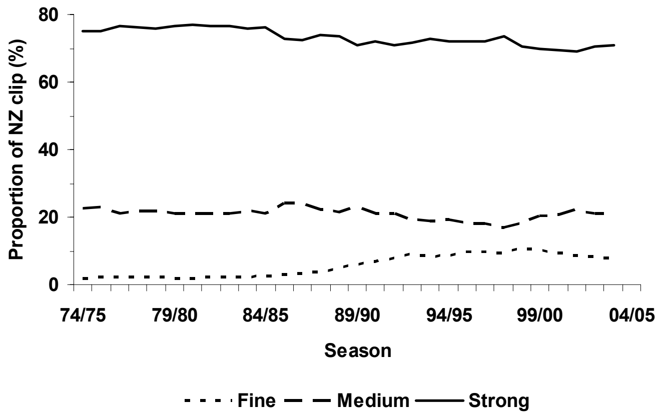


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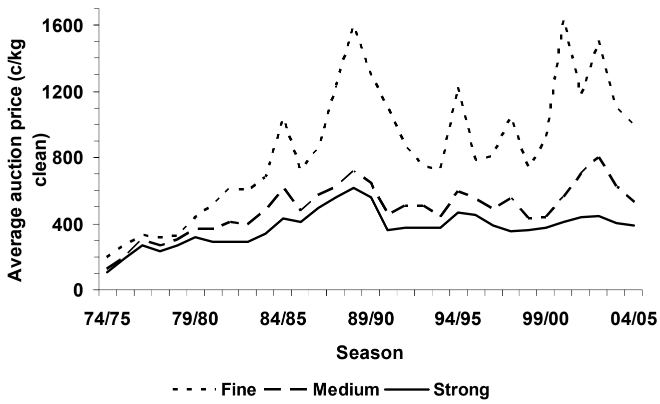
FIGURE 4: Average price (c/kg clean) for new season wool sold at New Zealand auctions by market segment. Fine = 24 µm and finer, Medium = 25-31 µm, Strong = 32 µm and coarser. (Source:



Meat & Wool New Zealand Economic Service).

There was a similar, although smaller peak in prices in 2001/02 with lesser peaks in 1983/84, 1995/96 and 1998/99. Traditionally average prices for the medium segment have tended to be approximately 15% higher than the prices for the strong segment. It is of note that the period during the late 1980s when the fine segment of the clip was increasing, corresponded with a period of lower meat prices (Figure 2) and decreasing

TABLE 1: Average relative economic values of objective wool parameters important in processing based on an average price of 450 c/clean kg of wool (after Maddever *et al.,* 1991).

Parameter	Units	Test method	c/ unit change / clean kg
Bulk	cm^3/g	NZS DZ_8716	6.4
Brightness	Tristimulus Y value	NZS 8707:1984	4.3
Mean carded length	mm (barbe)	NZS DZ_8719	0.3
Medullated fibre	% by number	IWTO-12-64(E)	-0.7
Kemp fibre	% by number	IWTO-12-64(E)	-0.8
Short fibre	% <24 mm barbe	NZS DZ_8719	-2.2
Yellowness	Tristimulus Y-Z value	NZS 8707:1984	-6.5
Vegetable matter	% by mass	IWTO-19-85	-24.5

crossbred sheep numbers. It was also a period when fibre diameter measurement technologies became sufficiently cheap to warrant their use in selection programs. This demonstrates how quickly sheep farmers will respond to market signals in an attempt to maintain their profitability and serves as an indicator of what proportion of sheep farmers (or indeed investors from other industries) might adopt new technologies to fill a niche.

Shorn wool from sheep within an individual flock of sheep is very variable in terms of its fibre dimensions and associated characteristics. Utilizing this variability, wool has traditionally been made into a diverse range of products that have different requirements in terms of fibre dimensions and characteristics required to produce a quality product. Consequently wool is sorted into broad categories with respect to its mean dimensions and characteristics prior to sale. This enables processors to source fibre with particular specifications to suit their needs. With the increasing use of objective measurement to describe lots of wool offered for sale at auction it has been possible, using the New Zealand Wool Board auction database to develop the relative economic value of independent wool characteristics (Maddever *et al.*, 1991). While the mean auction price varied between seasons, the price relativity between different wool characteristics was sufficiently stable to justify breeding decisions. While this analysis cannot be repeated due to the discontinuation of appropriate data collection, it is generally believed that the current price differentials for individual wool characteristic are not dissimilar to those reported by Maddever *et al.* (1991). While only 40% of the New Zealand wool clip is sold at auction, prices paid at auction underpin the prices paid for different types of wool where the fibre is traded outside of the auction system.

The relative economic value for fibre diameter in Maddever *et al.'s* (1991) data was curvilinearly related to fibre diameter with a value of 293 c/unit change/clean kg applying at 20 µm, approximately 33 c/unit change/clean kg applying at 27 µm and approximately 0.2 c/unit change/clean kg applying at 37 µm at the then market indicator of 450 c/clean kg. This marked curvilinearity highlights the economic importance of fibre diameter for fine wools suited for apparel production. In contrast the mean fibre diameter of coarse wools used for carpet production is of limited processing significance with other characteristics being more important (Maddever & Cottle, 1999).

Maddever *et al.'s* (1991) estimates of the average relative economic values for traits other than fibre diameter, that are of importance in processing, based on an average price of 450 c/clean kg, are given in Table 1. Mean carded length and short fibre content, both of which are associated with staple tensile strength, and the presence of vegetable matter are principally influenced by on-farm management procedures. Brightness and yellowness are largely influenced by environmental factors related to the location of the farm in association with the timing of shearing, while bulk, medullated fibre content and the presence of kemp fibre are all directly related to the genotype of sheep being farmed. Instruments to measure fibre curvature had not been developed at the time Maddever *et al.* (1991) undertook their analyses. There are also several other characteristics such as "handle" and crimp definition that are deemed important for processing particular products that buyers assess subjectively because there is no objective measurement procedure available.

FARM PROFITABILITY

The Meat and Wool New Zealand Economic Service regularly surveys a sample of over 500 farms divided into eight classes according to the location, terrain and farming system (Meat & Wool New Zealand Economic Service, 2003). A summary of the basic production parameters pertaining to each class of sheep and beef farms for 2004/05 are given in Table 2.

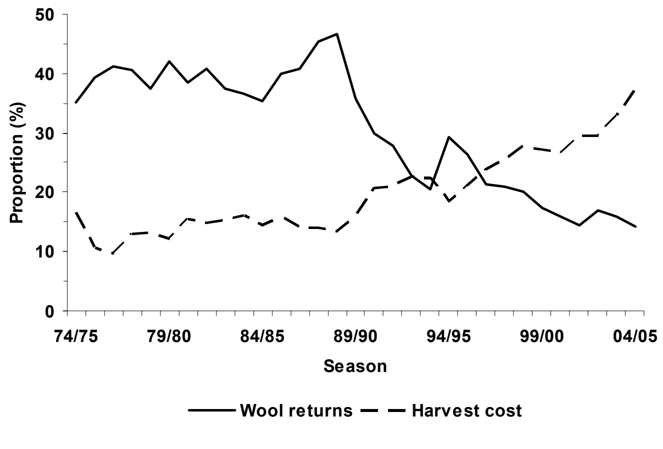
TABLE 2: A summary of provisional sheep production data within Meat and Wool New Zealand farm Survey farms in the 2004/05 production season (Source: Meat & Wool New Zealand Economic Service).

Class	Description	Average area of farm (ha)	Gross farm income ($/su[1])	No of sheep wintered	Proportion of total farm income derived from sheep (%)	Proportion of total farm income derived from wool (%)	Weight of wool produced (greasy kg)	Wool harvesting costs as a proportion of income from wool (%)
1	South Island high country	9,031	46.74	8,722	80.4	48.1	34,342	25.5
2	South Island hill country	1,501	60.02	4,391	80.0	21.8	18,781	30.8
3	North Island hard hill country	738	58.57	4,202	71.6	16.0	20.477	43.0
4	North Island hill country	428	68.95	2,623	59.8	12.2	13,280	40.4
5	North Island intensive finishing	254	86.37	1,535	43.1	7.8	6,962	39.1
6	South Island finishing-breeding	460	79.85	3,307	75.4	15.0	15,613	39.7
7	South Island intensive finishing	247	88.25	3,236	89.3	17.8	18,770	34.7
8	South Island mixed finishing	291	211.03	2,230	26.0	4.8	7,805	29.8
	Weighted average all classes	600	76.67	3,038	65.9	14.3	14,763	37.2

[1] su: stock unit

These data reflect national decreases in the land area used for sheep and beef farming, and in the sheep population, with individual farms becoming larger through amalgamation along with increased intensification. The proportion of wool returns spent on harvesting is associated with breed type and the value of the wool (Figure 5). There has been a clear trend for the proportion of farm income derived from wool to progressively decline over the last 30 years as wool prices have declined relative to returns from other agricultural commodities. Currently Merino wool growers spend approximately 25% of their wool revenue on wool harvesting whereas those farming coarse-wool breeds spend approximately 40 per cent of their wool revenue on wool harvesting.

FIGURE 5: Proportion of farm revenue derived from wool and the proportion of wool revenue spent on harvesting on New Zealand sheep farms since 1974/75. (Source: Meat & Wool New Zealand Economic Service).



RECENT EXAMPLES OF IMPROVING THE PROFITABILITY OF GROWING WOOL

It is well known that once a premium is created and producers adopt the technologies to supply that niche, the new technology becomes the norm and the price differential is gradually eroded. An example of this was the Ultrafine Merino Company in their joint venture with Nippon Keori Kaisha Ltd. (NKK), a worsted spinning mill in Osaka, Japan. The joint venture was established in the late 1980s to use genetics to generate sheep producing fleeces of around 16 µm while still maintaining fleece weight. At the same time it linked the growers with an assured market for the specialty fibre at an assured price. When the joint venture was established there was almost a two-fold advantage in wool returns for wool that met the specifications. Soon other contracts were established in association with the New Zealand Merino Company to produce merino fibre to specification. With more contracts in place the financial advantage in supplying each contract is reduced. New contracts related to different products are needed to supply wools with altered specifications.

There have been several attempts to develop supply contracts based on high bulk wool related to premiums of up to 10% for lines of fleece wool attaining a threshold measurement. Each attempt has been thwarted within a couple of seasons due in part, to the lack of affordable robust technologies for measuring this characteristic. At the same time there was an expansion of breeds of sheep aligned with the production of prime lambs. Most of these breeds tend to produce more bulky wool than the Romney with the result that the bulkiness of the strong segment of the clip has increased by approximately 2 cm^3/g between 1980 and 2002 (Meat & Wool New Zealand Economic Service, unpublished data).

The Drysdale Carpet Wool Co-operative is an example of a group that has been able to maintain a variable premium for coarse heavily medullated "Drysdale type" wool over and above "Romcross type" wool for use as a specialty component for inclusion in carpet wool blends. This premium has been achievable due to a limited volume of wool of the specified type.

Greater changes within the sheep industry will need to be developed to produce significant premiums for wool if the wool industry is to regain its position of importance alongside meat. What opportunities does genomics offer?

FUTURE OPPORTUNITIES TO IMPROVE THE PROFITABILITY OF GROWING WOOL

To achieve 40% of farm income from the sale of wool, as in the 1970s, and encourage farmers to focus on producing a specifiable product, would require a two and a half-fold increase in wool returns. Previous papers in this contract have highlighted several potential opportunities to use genomics to increase the profitability of wool growing in New Zealand. These have included:

- changing individual fibre characteristics of individual fleeces to suit processor's requirements (Forage *et al.,* 2006; Yu *et al.,* 2006; Abbott *et al.,* 2006; Kendall, *et al.,* 2006),
- reducing wool harvesting costs (Scobie, *et al.,* 2006),
- using wool in alternative, novel ways (Plowman, *et al.,* 2006) and
- strengthening industry relationships between the grower and the processor (McDermott, *et al.,* 2006).

Some opportunities potentially offer large gains for a small number of growers. Individually such opportunities would have a negligible effect at a national level, but could transform the industry, provided sufficient niche markets were developed. Other opportunities potentially offer small incremental gains for a large number of growers which would have a measurable effect at a national level. A reduction in fibre variation and increased average staple strength across the national clip, for example, would assist in maintaining competitiveness against synthetic fibres and reduce the need for blending.

Potentially, the opportunity that is likely to have the greatest effect on increasing an individual farmer's returns from wool is the developing technology of protein extraction (Plowman *et al.,* 2006). However, a requirement for production of differentiated wools as feedstocks for specified products has yet to be proven. Protein extraction from wool is, in the foreseeable future, only likely to be an option for a relatively small number of farmers. As such the premiums might be sustained almost indefinitely while the processing technology is patented.

Other than for the case of wool-on leather production, wool must be "harvested" from the sheep before it can be processed into alternative products. Shearing and removing parts of the fleece at different times during the year for the welfare of the sheep imposes a significant cost on all sheep farmers (Table 2). Regardless of the fibre type being produced it is essential that these operations be made quicker and simpler to reduce costs. If shearing time could be reduced by half with the development of sheep that do not require shearing on the belly and points, as suggested by Scobie *et al.* (1999a), there is the potential to reduce harvesting costs by up to 35%, after allowing for a series of fixed costs. While quicker to shear, the resultant fleece would be devoid of a belly with less discoloured pieces around the edges and legs. If wool revenue were reduced by 15% due to the loss of oddments, extrapolation of the data presented in Table 2, indicates this has the potential to "free-up" approximately 5% of farm revenue currently spent by Merino wool growers on harvesting costs and up to 7% currently spent by growers producing strong wool. This equates to a potential annual benefit of approximately $5,500 for an "average" farm. While aiming to remove wool from the lower regions of the body, it will be increasingly important for farmers to aim to maximise the amount and quality of fleece wool growing over the main body area to optimise their economic returns.

The first paper in this contract (McDermott *et al.*, 2006) indicated that regardless of what changes they may engender within the wool clip, there are overarching opportunities associated with establishing new business models linked with tightly aligned relationships within supply chains. Such relationships will potentially be based on the supply of relatively uniform or unique, raw material delivered against established objective specifications. Genomics has a role in reducing variation within individual fleeces and enabling the modification of the harvested fleece to be diverted into alternative end-uses. The research required to develop genotypes resistant to the multiple environmental and physiological drivers of wool variability as well as reduce within-fleece variation is likely to be long-term but would enable incremental progress towards a target.

Assuming other production costs remain unchanged, the relative economic advantages from changing various wool characteristics are indicated by their relative economic values (Table 1). These are however, likely to be underestimated for future enterprises supplying wool for specific manufacturing purposes. While a reduction in mean fibre diameter has the potential to provide the greatest relative return, genomic technologies in the longer term will provide the means for step changes in all economically important fibre attributes. However, many of the characteristics important in processing are related to on-farm management issues. Regardless of the type of wool produced on a farm it is imperative that the sheep be managed and the clip prepared in the best way possible to maximise the advantages present as a result of any changes induced by genomic technologies.

CONCLUSION

Manipulating fleece cover over the body of sheep and thereby reducing shearing and husbandry costs will support all farmers by making sheep farming easier and addressing animal welfare issues that are likely to become more pressing in the future.

It is clearly evident that small changes in individual fleece characteristics will have a limited effect on individual sheep farmer's returns unless they can continue to exploit the differences between their clip and the national clip through the establishment of special relationships with individual processors. However, price premiums are likely to decline with time as previous examples in this industry have illustrated.

As a result of current investment in wool genomics in Australasia, opportunities will be created for additional novel uses for wool, to enable the sheep and wool industries to continue to remain viable businesses in future. The application of such research will support wool production for both niche and commodity markets. Niche opportunities are characterised by low volume, higher value wool but the markets are likely to be more fickle and demanding. Commodity production will continue to absorb the majority of the wool clip for the foreseeable future. These markets are characterised by a high volumes of lower value wool but still present opportunities for more consistent wool types better fitted for specific purposes.

Concluding remarks: Genomics and the future of wool production

A.J. NIXON

AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton, New Zealand

Wool is a natural product from renewable, living systems - grass, microbes and sheep. Several papers in this session have pointed out the consequent high variability and competitive disadvantage of wool in relation to synthetic textiles. Yet the biological basis of wool production now presents an opportunity to capitalise on the huge worldwide development of gene technologies and genetic information for the benefit of sheep farmers.

The preceding technical papers represent feats of gene sequencing, expression analysis, bioinformatics, gene mapping, and functional genomics that themselves depend on a much greater, global enterprise covering many fields of biological science. Each one of the tens of thousands of expressed sequences isolated from wool follicles is being compared with public gene databases, including the human genome. These are the first steps toward identifying the sets of genes that determine fibre characteristics (Yu *et al.*, 2006; Plowman *et al.*, 2006) and fleece distribution (Scobie *et al.,* 2006). The major challenge ahead will be to apply this new knowledge in practical, economically feasible solutions to meet industry needs.

So what might the farming technology of the future look like? Discoveries in sheep genomics can be applied by one of three possible routes; tools for genetic selection, therapeutics, or development of transgenic livestock.

Selection markers can make possible more rapid genetic improvement based on pre-existing variation within flocks. Markers are especially useful for difficult to measure or late developing traits. For example, Scobie *et al.* (2006) showed fleece cover phenotypes of "easy-care" and other sheep do not develop until after one year of age. Although there are currently no commercial markers available for wool traits, Abbott *et al.* (2006) point to several interesting candidates, especially amongst keratin genes, which could be