Jointly selecting for fibre diameter and fleece weight: A market-level assessment of the QPLU$ Merino breeding project

Stuart Mounter[1,2], Garry Griffith[1,2] and John Mullen[3]

Abstract

The QPLU$ Merino breeding project began in the early 1990s. The aim of the project was to demonstrate the efficiency of using a selection index to achieve breeding objectives. A number of selection lines were created from three strains of Merino sheep. During the ten-year course of the project, selection of each line was undertaken using an index based on measurements of fleece weight and fibre diameter. Different emphases were placed on each trait in each selected line. This paper estimates the potential aggregate returns of the project to the Australian sheep and wool industries using an equilibrium displacement model.

Key words

Australian sheep and wool industries, equilibrium displacement model, cross-commodity relationships, R&D evaluation

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[1]NSW Department of Primary Industries, Armidale, NSW, 2350.

[2]School of Business, Economics and Public Policy, University of New England, Armidale, NSW, 2351.

[3]NSW Department of Primary Industries, Orange, NSW, 2800.

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Pat Taylor, Kevin Atkins and Luke Silvester (formerly)

NSW Department of Primary Industries, Orange, NSW, 2380.

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Introduction

Together, fleece weight and fibre diameter (micron) account for approximately 90 per cent of the value of a fleece. Hence, determining the appropriate emphasis to place on selecting for each of these traits is an important decision for Merino wool producers (Taylor *et al*. 2007 p.15).

The focus of the Trangie QPLU$ Merino breeding project was on simultaneous selection for both of these traits. Five selection lines were created within the project based on fine, medium and broad wool bloodlines from the Merryville, Haddon Rig and East Bungaree studs, respectively. Different emphases were placed on the selection of each trait (Table 1). An industry line, selecting for visual characteristics, was also established, as were randomly bred (Control) lines for each strain (Casey 2007 pp.24-25). The ten-year selection period ended in 2004.

Table 1: QPLU$ selection lines

Strain	Breeding Line	Breeding Objective
Fine	8% MP	Equal emphasis on reducing fibre diameter and increasing fleece weight
Fine	Control	Random mating to maintain a line that represents the original population
Medium	3% MP	Maximise increase in fleece weight and maintain fibre diameter
Medium	8% MP	Equal emphasis on reducing fibre diameter and increasing fleece weight
Medium	15% MP	Maintain fleece weight and maximise reduction in fibre diameter
Medium	Industry Line	Reduce fibre diameter by 0.5 micron, increase fleece weight and improve/maintain wool quality and conformation
Medium	Control	Random mating to maintain a line that represents the original population
Broad	8% MP	Equal emphasis on reducing fibre diameter and increasing fleece weight
Broad	Control	Random mating to maintain a line that represents the original population

The results of the observed changes in the traits for each selection line were presented at an open day in 2007 and documented in open day proceedings (Pope 2007). Included in the proceedings are estimates of the changes in fleece values and gross margins associated with each of the QPLU$ outcomes.

This objective of this paper is to provide an initial market-level evaluation of the potential returns from the commercial adoption of QPLU$ selection practices by Merino sheep producers. The analysis evaluates the potential returns from each of the five breeding projects listed as 3% MP, 8% MP and 15% MP in Table 1. Each selection line was obtained using an index of fleece weight and fibre diameter.[1] The percentage figures apply to the micron premium (MP) on which the selection lines are based and represent different emphases on fleece weight and fibre diameter (Pope 2007).[2]

Clean fleece weight (CFW) and mean fibre diameter (μm) comparisons between the selection and control lines of the QPLU$ program are presented in Table 2. The data, collected in 2005, were obtained from a random sample of mixed age ewes born between 2000 and 2003 inclusive (Taylor *et al*. 2007 p. 8). All of the flocks were managed under experimental conditions. Compared to the control lines, all 5 MP selection lines recorded fleece weight gains and reductions in fibre diameter.

Table 2: Clean fleece weight and mean fibre diameter of mixed age adult ewes

Strain	**Fine Wool**		**Medium Wool**					**Broad Wool**	
Trait	**8% MP**	**C**	**Ind**	**3% MP**	**8% MP**	**15% MP**	**C**	**8% MP**	**C**
Clean fleece weight (kg)	4.4	3.4	5.4	5.4	5.4	4.9	4.7	6.0	5.0
Mean fibre diameter (μm)	19.4	20.3	20.9	21.3	20.3	18.9	22.0	23.0	25.4

Three additional scenarios included in the evaluations provide more conservative or lower bound (LB) estimates of the potential benefits from successfully selecting for fleece weight and fibre diameter. For each of the fine, medium and broad wool lines it is assumed that a 1-micron reduction in fibre can be achieved whilst maintaining fleece weight. Although, changes in a number of other traits, such as staple strength, style and reproduction are reported in the open day proceedings, they are not included in the current analysis. The focus here is on the potential industry gains from selecting for fleece weight and fibre diameter.

[1] Indexes allow for genetic selection based on multiple traits rather considering individual traits separately (Pope 2007).

[2] The likely response of a breeding objective to selection can also be represented through the use of micron premiums. For example, a '15% MP index' refers to extra returns of 15% for wool that is 1 micron finer (Pope 2007).

Methodology

Alston *et al*. (1995) argue that economic surplus as a measure of welfare is the preferred method to evaluate industry level returns from agricultural research. Equilibrium displacement models (EDMs) have often been used for this purpose (e.g. Mullen *et al*. 1989; Mullen and Alston 1994; Zhao, *et al*. 2001; Hill *et al*. 2001; Zhao *et al*. 2003). EDMs are partial equilibrium, comparative static models that depict an industry in equilibrium at two distinct points in time.

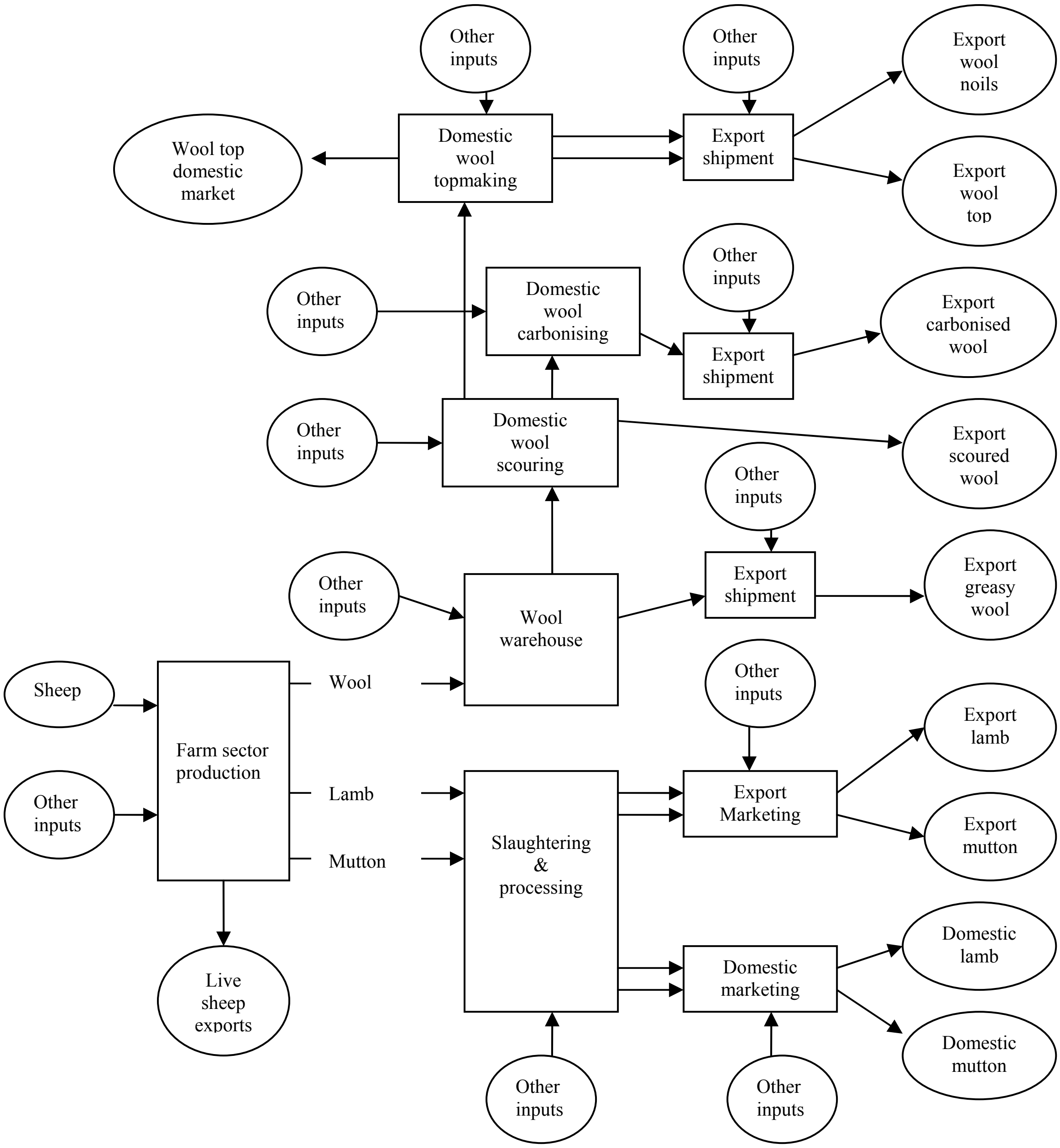
Disaggregation of an industry within an EDM framework enables the estimation and comparison of the annual total returns from R&D investments and the distribution of the returns among the various industry sectors and markets. The industry structure is represented by a system of general functional form demand and supply equations defining equilibrium in all markets. The impact of a new technology in an industry sector is modelled as a vertical parallel shift of the supply curve in the market in which the R&D is assumed to occur. When an exogenous shift displaces the initial equilibrium, the resulting market price and quantity changes allow changes in industry benefits, and changes in benefits to different market segments, to be estimated. These are calculated as changes in "producer surplus" and "consumer surplus" using standard formulae.

This paper employs an EDM of the Australian sheep and wool industries developed by Mounter *et al*. (2007a) to estimate the potential annual returns from the QPLU$ project. The Australian sheep and wool industries comprise numerous market segments. A simplified representation of this structure is depicted Figure 1.

In the EDM the national flock is separated into Merino sheep and non-Merino sheep. The Merino portion is divided according to agricultural zone and production enterprise within each zone. For example, breeding intention splits Merino ewes in the high rainfall and wheat-sheep zones into Merino and non-Merino lamb producing enterprises. Merino sheep not used for breeding purposes (i.e. Merino wethers and Merino hoggets) are classified as dry sheep and are combined as a single enterprise in each zone.

The production of Australian wool is separated into four main fibre diameter categories that correspond to Australian Bureau of Statistics wool export categories. These are 19 micron (μm) and finer, 20-23 μm, 24-27 μm and 28 μm or broader.

Figure 1: Model Structure



Vertical disaggregation of the wool industry includes the warehousing, export and domestic early-stage processing sectors. Vertical disaggregation of the sheepmeat sector post farm gate consists of processing and marketing sectors. The processing sector undertakes all slaughtering and processing activities necessary to produce lamb and mutton for the export market and carcasses of lamb and mutton for sale to domestic retailers. The domestic marketing or retail sector processes the carcasses and packages the products for sale to final consumers. This sector comprises supermarkets, butchers and integrated abattoir or independent boning rooms that undertake the same process.

As is typical in EDM analysis, all sectors are assumed to maximise profit and all production functions are assumed to exhibit constant returns to scale. Extensive sensitivity analysis has been undertaken to account for any uncertainty over specified parameter values in the EDM (Mounter *et al*. 2007b). Interested readers are referred to Mounter *et al*. (2007a) for further details on the model.

Modelling QPLU$ Outcomes

The following example illustrates the gains from QPLU$ selection for the medium wool 3% MP scenario. The control values and measured QPLU$ outcomes for the medium wool 3% MP scenario are reproduced in Table 3.

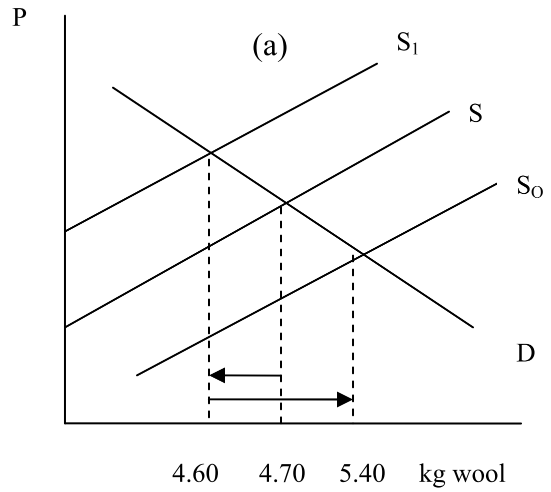
Table 3: Clean fleece weight and mean fibre diameter of mixed age adult ewes: Medium wool 3% MP

	Medium wool 3% MP	Medium wool Control
Clean Fleece weight (kg)	5.4	4.7
Fibre diameter (micron)	21.3	22.0

The impacts of QPLU$ are twofold, there is an increase in fleece weight and a reduction in fibre diameter. In the absence of QPLU$ selection the individual per/kg adult fleece weight is 4.7 kg, as represented by the control line. For medium wool bloodlines clean fleece weight (CFW) decreases by 3% for every 1 micron decrease in fibre diameter (Atkins *et al*. 2007). Hence, without QPLU$ the cost of a 0.7 micron reduction in fibre diameter is a 2.1% reduction in CFW (3% x 0.7), shown as a decrease in CFW from 4.70 kg to 4.60 kg in Figure 2. If conservatively we were to say that QPLU$ achieves a reduction in fibre diameter without a loss in CFW, the benefits from QPLU$ are the increase in fleece weight from 4.60 kg to 4.70 kg. This represents the medium wool lower bound (LB) scenario. For the 3% MP QPLU$ scenario CFW increases to 5.40 kg. Hence, the benefits from QPLU$ are the fleece weight gains from 4.60 kg to 5.40 kg.

In recent years there has been an industry trend towards finer wool production. The average fibre diameter of the national Merino wool clip has fallen by approximately 1 micron from 1994/95 to 2006/07 (AWTA 2007). Therefore, the benefits of the QPLU$ outcomes corresponding to fibre diameter reductions of approximately 1 micron and less are solely the result of increased wool production, as pre-existing price incentives have delivered a similar industry outcome over a similar passage of time.

Figure 2:



It's reasonable then to assume any reductions in fibre diameter greater than 1 micron can be attributed to QPLU$ selection. Finer wools attract market premiums that need to be considered in the evaluations. However, accounting for any associated price premiums would require a multiple market analysis with separate prices and quantities specified for each micron wool type under consideration. Unfortunately the EDM used in this analysis does not offer that degree of product differentiation. Different wool types within the EDM are aggregated across micron categories. For example, medium wool is classified as Merino wool 20µm - 23µm inclusive, with an aggregate average price. An implication of the aggregation is that the cost reductions in production are attributed to all micron types in a specified category, rather than relating to the specific mean fibre diameters listed for the QPLU$ scenarios in Table 2.

This limitation does not inhibit the analysis, as the intention is to determine the potential aggregate benefits from industry adoption of QPLU$ breeding practices. Although conducted on a trial basis at Trangie in NSW, expectations are that the QPLU$ outcomes are not restricted by agricultural region or micron, and results should be readily transferable to commercial producers. The only exceptions to this are dual purpose and meat sheep flocks that would select largely on carcass and reproduction (Taylor, P. 2008, pers. comm.).

Adoption and QPLUS Wool Production Gains

Technology adoption in the sheep and wool industries is perceived to be low (see for example, Butler *et al*. 1995; Robertson and Wimalasuriya 2004), particularly in comparison to other agricultural industries. QPLU$ surveys indicate a 25% rate of adoption among commercial producers (Taylor, P. 2008, pers. comm.). Based on previous studies, anecdotal evidence and scientific opinion, Vere *et al.* (2005) assumed a 20% rate of new technology adoption in the sheep industry. A 20% level of adoption is also assumed for the QPLU$ evaluations in this study. Information relating to the rate at which QPLU$ is taken up by commercial breeders was not available for this analysis. Therefore, it is assumed the 20% level of adoption occurs simultaneously.

The gains from genetic research are cumulative over time. Consequently, the gains in wool production associated with QPLU$ selection are incremental. The ram contributes 50% of genes to the progeny and approximately 40% heritability (i.e. the proportion of the sires superiority passed to the progeny) (Taylor, P. 2008, pers. comm.). Hence, given a reported 0.80 kg gain in wool production as in Figure 2, the additional wool production per generation of QPLU$ sheep can be calculated as:

0.80 kg x 0.5 (gene contribution) x 0.4 (heritability) = 0.16 kg

Therefore, the wool production gains from first generation QPLU$ sheep are 0.16 kg. Typically, Merino ewes are joined when they reach 2 years of age. First generation ewes joined to QPLU$ rams produce second generation QPLU$ sheep that grow an additional 0.16 kg x 2 = 0.32 kg. Third generation sheep would produce an extra 0.48 kg and so on. The proportions of each generation in the adult population determine the overall increase in wool production in any particular year. For example, at the end of a 10 year period the flock would consist of fifth generation QPLU$ sheep, fourth generation QPLU$ sheep and so forth. The proportions of each QPLU$ generation in the adult population over time were modelled in EXCEL to calculate the cumulative increments in wool production over a 10 year time frame.[3] The results are presented in Table 4. In years 1 and 2 of the breeding program there are zero gains in adult wool production as it takes 2 years for a sheep to reach adult age.[4] The gains in wool production are based on a 90% lambing percentage and the proportions of QPLU$ sheep in the flock in any particular year. For instance, 31% of the flock in year 3 are estimated to be 2 year old QPLU$ sheep.[5] The extra wool production in year 3 for the medium 3% MP line is:

[3] The calculations are based on the most recent ABARE estimates of flock composition by age reported in Martin *et al.* (2004).

[4] This is a simplification for the purposes of this analysis. In reality there would be some gains as sheep are first shorn as hoggets (12 months of age).

[5] The other 69% do not produce additional wool as they are the original ewes on which the selection lines are based.

0.16 kg x 31% = 0.050 kg.

The final row of Table 4 indicates that, depending on the individual scenario, QPLU$ sheep, on average, produce an extra 0.28 kg to 0.55 kg CFW at the end of the 10 year breeding program.

Table 4: Additional Wool Production (CFW): QPLU$ Scenarios

Adult Ewe Wool Production Change (kg)	Fine Wool 8% MP	Medium Wool 3% MP	Medium Wool 8% MP	Medium Wool 15% MP	Broad Wool 8% MP
Year 1	0	0	0	0	0
Year 2	0	0	0	0	0
Year 3	0.071	0.050	0.058	0.039	0.077
Year 4	0.121	0.084	0.099	0.066	0.130
Year 5	0.191	0.133	0.156	0.104	0.205
Year 6	0.255	0.178	0.208	0.139	0.275
Year 7	0.330	0.230	0.269	0.179	0.355
Year 8	0.386	0.269	0.315	0.209	0.415
Year 9	0.453	0.316	0.370	0.246	0.488
Year 10	0.517	0.360	0.421	0.280	0.556

QPLU$ Gains and EDM Supply Shifts

The base equilibrium data specified in the EDM are average annual prices and quantities for the period 2002/03 to 2004/05. Quantities of wool within the model are specified in greasy weights. Hence, the CFW QPLU$ gains are converted into greasy fleece weight equivalents (GFWE) using appropriate yields for each line (Taylor *et al*. 2007 p. 10).

There is a basis for scaling down experimental gains as they tend to be greater than commercial gains (Davidson and Martin 1965; Alston *et al*. 1995 pp.339-40). In this analysis additional wool produced under commercial conditions is assumed to be two-thirds of the experimental QPLU$ gains.

In the EDM the adoption of new technologies are modelled as downward shifts in supply representing a reduction in the costs of production. For each evaluation scenario it is necessary to determine the appropriate percentage shift in supply to implement in the

EDM. Converting experimental gains in yield into industry-level cost savings is not always simple (Alston *et al*. 1995 pp.339-40). A proportionate horizontal supply shift in the quantity direction (J shift) can be translated into a proportionate vertical supply shift in the price direction (K shift) using the expression $K = J/\varepsilon$, where ε is the elasticity of supply. However, as pointed out by Alston *et al*. (1995 p.61), it must be done so with a degree of caution as very elastic or very inelastic linear supply curves may provide unrealistic results. Alston *et al*. (1995 p.322), reasoning that long-run elasticities for most agricultural products are >1 and short or intermediate-run supply elasticities are probably close to 1, advocate using a supply elasticity of 1. A comprehensive review of wool supply response can be found in Griffith *et al*. (2001). Empirical estimates differ considerably and the interpretation of wool supply estimates should be treated with caution for several reasons. Firstly, differences in datasets make comparisons difficult and estimates can vary markedly depending on the methodology implemented or functional form chosen in econometric estimation. Secondly, almost all published elasticities were estimated in an era of wool market price stabilisation. As Griffith *et al*. (2001) acknowledge it is possible that price elasticities of supply may be higher in an unregulated than in a regulated market. However, a medium term supply elasticity of 1 for Merino wool in Australia is not inconsistent with estimates used in other recent studies (Sinden *et al*. 2004; Vere *et al*. 2005).

Continuing with our 3% MP medium wool example (Figure 2), the average QPLU$ wool production gain in year 10 is 0.36 kg. On a CFW basis this equates to a 7.8% increase in production (4.96 - 4.60)/ 4.60 = 0.078. Commercial gains, estimated as two thirds of the experimental gains, are 5.3%. The greasy fleece weight equivalent commercial gains are 3.8%.[6] Based on the quantities specified within the EDM, wool production falling within the medium fibre diameter category is 267.00 kilo tonnes (kt). Given a 20% rate of adoption, approximately 53.4 kt of this amount can be designated as achieving increased wool production gains due to QPLU$ breeding practices. The additional medium wool produced is 2.05 kt (53.40 kt x 3.8%) which equates to an overall 0.77% gain in medium wool production (2.05 kt / 267.00 kt).

Following Alston *et al*. (1995), QPLU$ production gains are converted into equivalent vertical supply shifts through the relationship $K = J/\varepsilon$, where $\varepsilon = 1$. Therefore, in this example the proportionate vertical supply shift in the price direction (K shift) is equal to

[6] Calculated using specified yields for each line (Taylor *et al*. p10).

the proportionate horizontal supply shift in the quantity direction (J shift), K = J = 0.77%. Supply shifts for each of the other scenarios were derived in the same manner.

Industry Returns

The magnitude of the supply shift calculated in the previous section is based on the additional gains achieved in year 10 of the breeding program. As such, the potential industry returns estimated from the EDM refer to year 10 benefits of the program. The wool production gains in each of the preceding years (listed in Table 4) were used to estimate the potential industry returns in each of those years. The total potential industry returns associated with each QPLU$ breeding program over a 10 year period are summarised in Table 5. The lower bound total potential returns for the fine, medium and broad wool lines are listed in Table 6.

The total 10 year benefits presented in Table 5 and Table 6 relate to an assumed 20% simultaneous adoption rate of selecting for fibre diameter and fleece weight traits by wool producers of either, fine wool, medium wool or broad wool.

Table 5: Economic Surplus Changes over a 10 Year Period ($million): QPLU$ Scenarios

	Fine 8% MP	Medium 3% MP	Medium 8% MP	Medium 15% MP	Broad 8% MP
Sheep & wool producers	19.0	14.1	17.3	17.0	2.2
Overseas consumers	33.2	22.7	27.7	27.3	3.5
Domestic consumers	1.7	1.6	1.9	1.9	0.2
Rest of industry	2.9	2.2	2.7	2.6	0.4
Total	56.8	40.6	49.7	48.9	6.3

Table 6: Economic Surplus Changes over a 10 Year Period ($million): Lower Bound Scenarios

	Fine LB	Medium LB	Broad LB
Sheep & wool producers	7.9	8.5	0.5
Overseas consumers	13.8	13.7	0.8
Domestic consumers	0.7	1.0	0.1
Rest of industry	1.2	1.3	0.1
Total	23.5	24.4	1.5

Not surprisingly the largest returns are associated with an industry-level cost reduction relating to fine wool. Wool with a fibre diameter of 19 microns or less comprises around one third of the national clip and typically receives a higher price than medium and broad wool types.

As the 8% MP selection objective is consistent across all three wool lines, it is possible to estimate the potential total returns from a 20% adoption of QPLU$ practices by producers of all Merino wool types. The potential industry gains in this instance are estimated as $112.8 million over a 10 year period.

Conservative lower bound estimates indicate that a reduction in fibre diameter of 1 micron without an associated loss in fleece weight would generate an additional $24 million in industry returns over a 10 year period for the fine and medium wool strains (Table 6). The potential industry gains across all wool types over 10 years are $49.4 million.

Concluding Remarks

This paper estimates the potential returns to the sheep and wool industries from 20% adoption by Australian Merino sheep producers of QPLU$ genetic selection objectives. The estimated total benefits over a 10 year period are calculated for different selection emphases on fibre diameter and fleece weight across fine, medium and broad wool categories. The results suggest industry returns over a 10 year period of $6 million to $57 million dollars depending on the trait selection emphases and the category of wool production in which the adoption is assumed to occur.

The combined potential benefits over a 10 year breeding program that deliver a 1 micron reduction in fibre diameter across all wool categories, without compromising fleece weight, are estimated to be close to $50 million. A common QPLU$ selection objective across all wool categories, that places equal emphases on reducing fibre diameter and increasing fleece weight, has the potential to deliver additional industry returns of $113 million over 10 years. In all instances, sheep and wool producers receive approximately one-third of the total industry returns.

The results contained in this paper are preliminary estimates, as the study has a number of limitations. Details on the costs involved in the QPLU$ breeding program are not included in the analysis. As such, comparison of the monetary returns from the different scenarios can only be made under the assumption that the investment costs required to implement the supply curve shifts are the same.

Price premiums associated with a reduction in fibre diameter are not accounted for within the EDM. Hence, the industry returns estimated for each of the scenarios in this analysis may be underestimated, particularly for the finer end of the market and for the QPLU$ scenarios involving a reduction in fibre diameter of 2 or more microns.

The results presented here are based on average 2002/03 - 2004/05 prices and quantities. This time frame corresponds with a period of low micron premiums for fine wool. Taylor *et al*. (2007) estimated mean fleece values for each of the selection lines under low micron premium and high micron premium market scenarios. Their calculations suggested that under a low micron premium scenario there was little variation in fleece values among the medium wool lines. In this case, fleece values were determined by weight rather than fibre diameter with the 8% MP scenario producing higher fleece values than the 3% MP and 15% MP scenarios. The industry returns for the medium wool lines (Table 5) reflect similar conclusions. Conversely, the responses between the medium wool fleece values varied significantly under a high micron premium market scenario, with much higher premiums for finer micron wools (Taylor *et al*. 2007). This implies that the industry returns estimated in this analysis are conservative representations of the potential gains.

Finally, the partial equilibrium nature of the model does not account for economic benefits or spillovers to other industries that emanate from the introduction of QPLU$ selection practices in the Australian sheep and wool industries.

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