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1 **Price risk exposure of Australian merinos – is it in the bloodline?**

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6 **Abstract**

7 Sheep producers and their advisors utilise Australian Merino bloodline trial data to guide future
8 sheep breeding objectives and ram selection. To adequately assess the economic outcomes from different
9 bloodlines in the decision making process, there is a need to consider the impact of wool and sheep meat
10 price risk. Using a steady state wether flock model that accounts for the lifetime productivity of 268
11 reported Merino bloodlines and stochastic dependency in weekly wool and sheep meat prices from
12 28/6/2005 to 10/11/2011, Gross Incomes per Dry Sheep Equivalent (GI/DSE) were calculated for a
13 weekly time step. The analysis found that across all bloodlines and market price scenarios, GI/ DSE
14 ranged between \$13.92 and \$67.83, with an overall mean of \$32.60. The individual means of bloodlines
15 across the time series ranged from \$37.46 to \$25.19 GI/ DSE. The coefficient of variation, used as the
16 measure of relative risk for each bloodline, ranged from 0.24 to 0.30 with a mean of 0.25. The analysis
17 showed that a bloodlines exposure to price risk has a curvilinear relationship to fibre diameter and fleece
18 weight. The results from a risk-reward point of view indicate that the majority of Australian Merino
19 bloodlines are risk-inefficient. This suggests Australian sheep producers have a significant opportunity to
20 increase net returns and reduce price risk exposure by identifying and switching to more risk-efficient
21 bloodlines.

22 **Keywords**

23 Wool and sheep meat price risk, sheep bloodline productivity and economics, simulation, risk-
24 efficiency.

25 **Introduction**

26 A key aspect in managing and developing profitable merino bloodlines is the need to give
27 consideration to the uncertainty in the price and quantity of outputs (meat and wool) (Counsell and Vizard
28 1997). In-field sheep productivity trial data are commonly used to compare bloodline performance in
29 decision making by sheep producers and their advisors (Butler 2006), with significant differences being
30 reported in the profitability of different bloodlines (Coelli *et al.* 1996; Coelli and Atkins 2000; Martin *et*
31 *al.* 2010). The economic ranking of different bloodlines has been shown to vary in response to different
32 deterministic wool market price scenarios applied (Martin *et al.* 2010). Atkins and Coelli (1997)
33 investigated the effect of price risk over 14 sale quarters and reported that price risk only produced
34 significant gross margin variations for bloodlines with a wool fibre diameter of less than 20.5 microns.
35 While the majority of studies into bloodline performance have incorporated some uncertainty regarding
36 productivity estimates, the issue of price uncertainty has largely been overlooked and any decision
37 regarding bloodline selection should consider the balance between average returns and variability (Atkins
38 and Coelli 1997).

39 To fully assess the likely economic performance of a bloodline requires the incorporation of price
40 risk and predicted life-time bloodline performance. Given the increasing contribution of sheep meat
41 income to enterprise profitability in Australian merino based production systems (Curtis 2009), there is
42 also a need to incorporate sheep meat price risk into the analysis of bloodline performance.

43 The economic literature relating to risk in agricultural production systems, is generally based on
44 expected utility theory (Hardaker *et al.* 2004). This method assumes that a decision maker aims to
45 maximise their expected utility, and requires some knowledge of the decision maker's personal utility
46 function (Anderson *et al.* 1977). The practical difficulties in establishing such a utility function are
47 substantial (Hershey *et al.* 1982), and various efforts have been made to avoid the need for such a
48 function (Hardaker *et al.* 2004). Antle (1983), for example, argues that dynamic risk neutral models, are
49 more useful in defining the effects of risk in agricultural systems, allowing the decision maker to identify
50 preferable strategies *a posteriori*.

51 The phenotypic diversity of merino bloodlines in the Australian merino flock and the associated
52 uncertainty of sheep meat and wool prices are significant components when selecting an appropriate
53 bloodline from a set of risky alternatives. To analyse these risky alternatives, without the need to specify a
54 decision maker's utility function, an alternative method based on efficiency analysis (Hardaker *et al.*
55 2004) that integrates wool and sheep meat price risk to estimate a risk-efficient frontier (Cacho *et al.*
56 1999) for Australian merino bloodlines is developed. Application of this method will assist decision
57 makers with the identification of a risk-efficient set of bloodlines and thus allow the producer to decide
58 where on the frontier they would like to operate so as to correspond to their current level of risk aversion.

59 **Methodology**

60 Based on a steady state economic model of bloodline performance, this study utilised aggregated
61 results from in-field sheep bloodline production trials (Martin *et al.* 2010), to simulate the effects of
62 stochastic wool and sheep meat prices on bloodline profitability.

63 To account for possible stochastic dependency between price variables (sheep meat and wool),
64 simulations were completed through the use of a historical data set that describes concurrent wool, mutton
65 and merino weaner prices. This method of dealing with stochastic dependency between price variables
66 assumes that the historical data is representative of the future (Hardaker *et al.* 2004). The data set used
67 represented weekly prices over the period of 28/6/2005 to 10/11/2011. Weekly mutton and merino weaner
68 price data is derived from NSW saleyard indicators (MLA various issues), with the wool micron price
69 guides derived from national wool micron indicators (AWEX various issues).

70 *Bloodline economic model*

71 The key economic measure of bloodline performance used in this analysis is the gross income per
72 Dry Sheep Equivalent (DSE) generated in a wether enterprise operating under a steady state. In a steady
73 state system, total numbers are maintained at a constant after sales, purchases and mortalities have been
74 accounted for. Gross Income per DSE at time period t , GI_t , is calculated as;

$$75 \quad GI_t = \frac{TI + \sum_{n=1}^3 WI_n}{SC}$$

76 where n is an index for age, TI is the total trading income per hectare (ha) for a bloodline, WI_n is
 77 the total wool income/ha for age cohort n , and sc is the assumed stocking capacity in DSE/ha. The value
 78 of trading income, TI , is a function of the number of animals being sold and purchased, their weight and
 79 their market value, under a steady state system:

$$80 \quad TI = P_N BWT_1 \beta_{DPW} WNR P_t + S_N BWT_n \beta_{DPM} MP_t$$

81 where P_N and S_N are the number of animals purchased and sold under a steady state condition,
 82 BWT_1 and BWT_n are the liveweights of animals purchased and sold, β_{DPW} and β_{DPM} are the dressing
 83 percentages for merino weaners and wethers, and $WNR P_t$ and MP_t are the market values for merino
 84 weaners and mutton in \$/kg dressed weight at time period t . Prior to incorporation into the bloodline
 85 economic model, the trait data reported in Martin, Atkins *et al.* (2010) are transformed into absolute
 86 numbers for each bloodline using reported deviations and trait means (Table 1).

87 **Insert [Table 1](#) near here**

88 The body weight of each particular age cohort is determined from the derived body weight of a
 89 bloodline, which is taken as the Standard Reference Weight (SRW) of a bloodline and is assumed to
 90 correspond to the 3 year old cohort, and is then adjusted for expected maturity. In this analysis we assume
 91 $BWT_1 = 0.7SRW$, which, in turn, assumes purchased merino weaners have been uninhibited in growth to
 92 the point of purchase. The number of animals purchased or sold under a steady state system, P_N and S_N ,
 93 are calculated as follows:

$$94 \quad P_N = \frac{sr}{1+(1-\gamma)+(1-\gamma)^2+\dots+(1-\gamma)^{n-1}} \text{ and } S_N = P_N(1-\gamma)^{n-1}$$

95 where sr is the stocking rate in head/ha, and γ is the mortality rate across all age groups. The
 96 stocking rate, sr , for each bloodline was standardised for their DSE rating which is determined by their
 97 relative metabolic size (Freer *et al.* 2007).

$$98 \quad sr = \frac{50^{0.75} sc}{SRW^{0.75}}$$

99 Total wool income for a bloodline is the sum of the calculated wool income from each age cohort.
100 The calculated wool income for each age cohort, WI_n , is a function of the quantity of wool expected to be
101 grown, its fibre diameter and the wool price at time t .

$$102 \quad WI_n = N_n FW_n WP_t$$

103 where N_n is the number of sheep in age cohort n , FW_n is the fleece weight for age cohort n in kg
104 clean wool/hd, and WP_t is the wool price in \$/kg clean at time period t . In this analysis both the calculated
105 fleece weight and fibre diameter for each age cohort is adjusted for the derived annual change in fibre
106 diameter and clean fleece weight with age (Martin *et al.* 2010). The fleece weight for each age cohort is
107 calculated from the derived clean fleece weight of a bloodline, CFW , which is assumed to correspond to
108 the production from the 3 year old cohort. This is then adjusted for a bloodlines clean fleece weight
109 stability measure, $CFWST$. Mathematically this is represented as:

$$110 \quad FW_n = CFW \left(1 - \frac{CFWST}{100}\right)^{3-n} \text{ subject to } n \leq 3$$

111 The wool price, WP_t , for each simulation is calculated using micron price guides and a predicted
112 clip basis for 17 to 26 micron wool over the analysed period. To calculate non-whole point micron prices,
113 MPG_{FD} , a cubic spline was used to interpolate between whole point micron price guides, as well as
114 extrapolate outside of the whole point micron price guides. Such that,

$$115 \quad WP_t = MPG_{FD} CB_{FD}$$

116 where CB_{FD} is the predicted clip basis estimated for different clip fibre diameters from data
117 published by Counsell (2002), and allows for the reduction in average clip value due to the lower value of
118 oddments such as pieces, bellies, locks, stain and other miscellaneous wool found in a typical clip.

$$119 \quad CB_{FD} = -0.0054FD_n^2 + 0.2705FD_n - 2.4083$$

120 where FD_n is the fibre diameter in microns of age cohort n . The fibre diameter for each age
121 cohort is calculated from the derived fibre diameter of a bloodline, which is taken as the Mean Fibre
122 Diameter (MFD) of the bloodline and assumed to correspond to the 3 year old cohort. This is then
123 adjusted for the bloodlines fibre diameter stability measure, $FDST$. Mathematically, this is represented as:

124 $FD_n = MFD + FDST(n - 3).$

125 The bloodline economic model is implemented and solved using Matlab (Mathworks_Inc 2013).
126 The simulation involves the analysis of 268 Merino bloodlines reported in Martin, Atkins *et al.* (2010),
127 and the use of 477 historical price scenarios for concurrent mutton, merino weaner and wool prices that
128 occurred over the period of 28/6/2005 to 10/11/2011. During this period the 19 micron premium ranged
129 between 4.2% and 36.6% and averaged 15.6%, whereas the 21 micron premium ranged between 0.3%
130 and 10.1% with an average of 3.5%. Table 2 provides summary statistics for the sheep meat and wool
131 prices used in this analysis. The included correlation matrix indicates positive correlations between
132 mutton and merino weaner prices over the period used in this analysis. Positive correlations also exist
133 between wool prices and sheep meat prices, indicating the need to account for stochastic dependency
134 between the price variables used in the analysis.

135 **Insert Table 2 near here**

136 **Results**

137 Analysis of the mean Gross Income per DSE for each bloodline and its variation, measured as the
138 standard deviation and coefficient of variation of Gross Income per DSE, indicates that bloodlines vary in
139 their risk-efficiency (Figure 1 **a & b**). Across all bloodlines and market price scenarios, income per DSE
140 ranged between \$13.92 and \$67.83 per DSE, with an overall average of \$32.60 per DSE. The mean
141 income per DSE for bloodlines ranged from \$37.46 to \$25.19 with a mean of \$32.56. The standard
142 deviation for mean income per DSE for bloodlines ranged from \$9.50 to \$7.03 and averaged \$8.20. The
143 data presented in Figure 1a indicates that a frontier to the risk-efficiency of bloodlines exists when
144 measured in absolute terms (grey line which links all risk-efficient bloodlines), where standard deviation
145 is used as the proxy for risk. Risk-efficient bloodlines are those that are not dominated by other bloodlines
146 in terms of maximising their profit and minimising their measure of risk. Table 3 indicates the mean
147 production characteristics of the risk-efficient set of bloodlines for different levels of risk aversion in
148 sheep producers. The identified risk-efficient bloodlines were evenly grouped into high, moderate and
149 low risk aversion sets. The low risk aversion set of bloodlines maximise returns regardless of the absolute

150 variation in returns (found furthest to the right on the frontier), whereas the high risk aversion set of
151 bloodlines are found furthest to the left along the frontier and maximise returns while minimising risk.

152 **Insert Figure 1 near here**

153 **Insert Table 3 near here**

154 Results indicate that sheep producers with low risk aversion should choose bloodlines from the
155 risk-efficient set that are finer in FD, heavier in CFW and lighter in BWT. Whereas sheep producers with
156 high risk aversion should choose bloodlines from the risk-efficient set that are broader in FD, lighter in
157 CFW and heavier in BWT. However, when risk is measured in relative terms as the coefficient of
158 variation (cv) of returns (Figure 1b), two bloodlines are found to dominate all others (top left corner), as
159 they achieve higher returns with less variation of returns. The results indicate that cv of returns ranged
160 from 0.24 to 0.3 with a mean of 0.25.

161 The key measures of bloodline productivity (being FD, CFW and BWT) indicate a curvilinear
162 relationship with both mean bloodline returns and risk (Figure 2). The data indicates that FD has the
163 strongest influence on both bloodline risks and returns, followed by CFW and BWT. There is a tendency
164 for bloodline returns to increase with increasing fleece weights, however, the two most risk efficient
165 bloodlines (based on relative risk) maintain slightly above average fleece weights, with both intermediate
166 fibre diameter and body weights when compared to the available population.

167 **Insert Figure 2 near here**

168 **Discussion**

169 The method presented here allows sheep producers and their advisors to consider the risk profile
170 of different bloodlines when making decisions regarding the future breeding direction of a flock. The
171 application of the methodology to Australian merino bloodlines, in this instance, allowed the
172 identification of risk-efficient bloodlines. Once risk-efficient sets of bloodlines are identified, sheep
173 producers can select their optimal bloodline based on the profit they wish to generate and the risk they are
174 willing to accept. This process allows sheep producers to trade off some risk for expected returns
175 (Hardaker *et al.* 2004). It also allowed the production characteristics of those risk-efficient bloodlines to

176 be indicated, which would enable producers with varying degrees of risk aversion to more easily identify
177 appropriate bloodlines for future purchase or breeding.

178 The results suggest that a bloodlines risk profile is linked to fibre diameter and fleece weight, and
179 to a lesser extent body weight. The curvilinear relationship that exists between fibre diameter and risk is
180 somewhat consistent with the findings of Atkins and Coelli (1997) who suggested that only finer
181 bloodlines had significant increases in their variability of returns. Although, this analysis did indicate that
182 risk is minimised when bloodlines have a fibre diameter around 20 microns. The results also indicate a
183 relationship between fleece weight and risk profile, with increasing fleece weight reducing the riskiness
184 of the bloodline, especially at lower fibre diameters. This finding is also consistent with Atkins and Coelli
185 (1997) who found that higher fleece weight bloodlines had lower coefficient of variations of gross margin
186 returns at the same fibre diameter.

187 Although there is an indication that increasing fleece weight increases mean income, there is no
188 clear indication that fibre diameter or mature body weight influences Mean Income. However, the ranking
189 of bloodlines on a risk-efficiency basis is driven by the combination of productive factors driving
190 profitability. In particular, the effect of fleece weight in determining both mean income and variability of
191 returns, and fibre diameter in determining return variability through its expression of higher price
192 variability at lower fibre diameters (Table 2). Overall, the risk-reward profiles indicate that the majority
193 of Australian merino bloodlines are risk-inefficient (i.e. do not lie on the frontier or are dominated by
194 more profitable and/or less risky bloodlines) and sheep producers may either increase returns while
195 maintaining return variability or maintain returns and reduce return variability by switching to more risk-
196 efficient bloodlines.

197 Given the differences in bloodline risk-reward profiles when measured using standard deviation
198 as an absolute measure of risk, versus coefficient of variation as a relative measure of risk, the results
199 indicate that the mean return (i.e. mean gross income) is a greater determinant of risk-efficiency than
200 absolute risk. The results also indicate the need to balance between fleece weight and fibre diameter so as

201 not to excessively increase the variability of returns when breeding objectives focus strongly on fibre
202 diameter reduction in lieu of increasing or maintaining fleece weight.

203 This analysis does not consider all the traits and reported differences between bloodlines such as
204 fibre diameter cv, wool style, length, colour and staple strength (Casey *et al.* 2010). However Atkins and
205 Coelli (1997) found that the additional measures of quality traits such as style, staple length, colour and
206 tenderness contributed less than 1% to bloodline profitability. The importance of these measures in
207 defining wool prices changes overtime, so it would be expected that they may have an increasing
208 influence on bloodline profitability and may warrant inclusion in future analyses. In addition, with an
209 increasing proportion of the Australian merino flock moving towards self-replacing systems with very
210 few wethers making up the national flock structure (Curtis 2009), there is also a need to expand this
211 analysis to consider the dynamics of ewe performance in assessing the risk-reward profile of bloodlines.

212 The method applied to identify risk-efficient sets of bloodlines from which a decision maker
213 chooses, is limited by the assumption that the decision makers subjective probability distributions for
214 wool and sheep meat prices are identical to those historical prices used (Hardaker *et al.* 2004). This may
215 not always be the case in future markets. However, the methodology presented still provides an easily
216 applied method of identifying risk-efficient bloodlines from which sheep producers may choose
217 appropriate bloodlines for their level of risk aversion, if decision makers also define their expected future
218 wool and meat price variation as part of the analysis.

219 **Acknowledgements**

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221 providing access to Australian Merino Bloodline data and reviewing an early draft of this paper.

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266
267

268 **Tables & Figures**

269 **Table 1: Summary of production characteristics for 268 Merino bloodlines (derived from Martin et**
270 **al. (2010)).**

| Summary Statistics | Fibre Diameter (um) | Clean Fleece Weight (kg) | Body Liveweight (kg) | Fibre Diameter Stability (um/yr) | Clean Fleece Weight Stability (%/yr) |
|--------------------|---------------------|--------------------------|----------------------|----------------------------------|--------------------------------------|
| Mean | 19.59 | 4.18 | 51.2 | 0.48 | 5.17 |
| Standard Deviation | 1.03 | 0.24 | 2.06 | 0.32 | 2.14 |
| Maximum | 22.04 | 4.77 | 57.0 | 1.43 | 13.97 |
| Minimum | 16.74 | 3.41 | 47.1 | -0.80 | -2.94 |

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Table 2: Summary of historical wool and sheep meat price data from 28/6/2005 to 10/11/2011

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(Sources: (AWEX various issues; MLA various issues)). Price statistics are in cents/kg carcass weight for

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merino weaners and mutton prices, and cents/kg clean for micron price guides.

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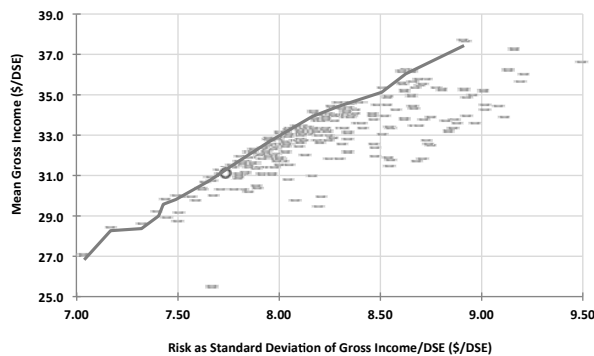
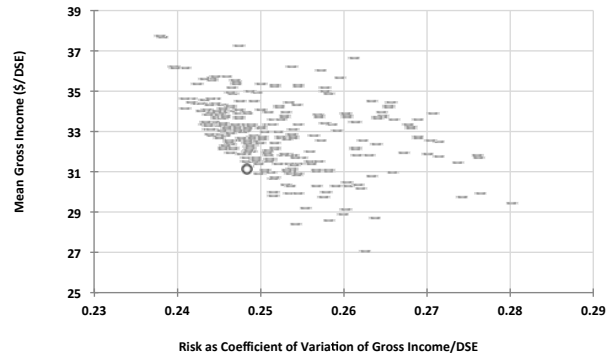
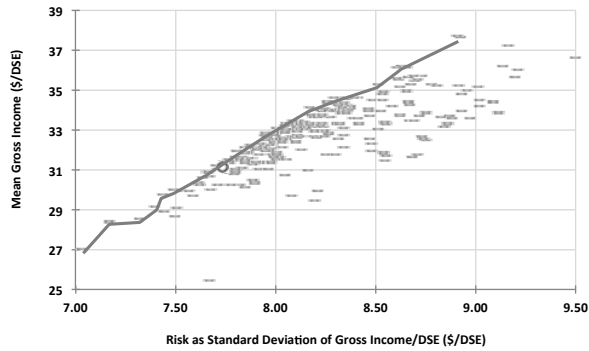
| Correlation Matrix | Sheep meat | | Wool Fibre Diameter and Micron Price Guides | | | | | |
|---------------------------------|------------|---------------|---|-------|-------|-------|-------|-------|
| | Mutton | Merino Weaner | 17 | 18 | 19 | 20 | 21 | 22 |
| Mutton | 1.000 | | | | | | | |
| Merino Weaner | 0.949 | 1.000 | | | | | | |
| 17 | 0.606 | 0.614 | 1.000 | | | | | |
| 18 | 0.573 | 0.581 | 0.977 | 1.000 | | | | |
| 19 | 0.559 | 0.540 | 0.921 | 0.960 | 1.000 | | | |
| 20 | 0.487 | 0.439 | 0.829 | 0.870 | 0.965 | 1.000 | | |
| 21 | 0.542 | 0.492 | 0.826 | 0.865 | 0.958 | 0.993 | 1.000 | |
| 22 | 0.573 | 0.528 | 0.838 | 0.871 | 0.956 | 0.986 | 0.997 | 1.000 |
| Summary Statistics | | | | | | | | |
| Mean | 219 | 309 | 1409 | 1264 | 1098 | 952 | 900 | 869 |
| Standard Error | 4.6 | 4.5 | 14.3 | 12.2 | 9.5 | 8.4 | 8.1 | 7.6 |
| Median | 191 | 286 | 1315 | 1206 | 1069 | 922 | 882 | 855 |
| Standard Deviation | 100 | 98 | 312 | 267 | 208 | 184 | 178 | 167 |
| Coefficient of Variation | 46 | 32 | 22 | 21 | 19 | 19 | 20 | 19 |
| Minimum | 49 | 132 | 1063 | 900 | 779 | 684 | 657 | 648 |
| Maximum | 467 | 598 | 2525 | 2189 | 1769 | 1588 | 1522 | 1461 |

277

278

a)

b)



279 **Figure 1: Risk-reward for Australia merino bloodlines, a) Absolute risk measured as Standard**
 280 **Deviation of Mean Gross Income, and risk-efficiency against Mean Gross Income per DSE; b) Relative Risk**
 281 **measured as coefficient of variation of Mean Gross Income against Mean Gross Income per DSE.**

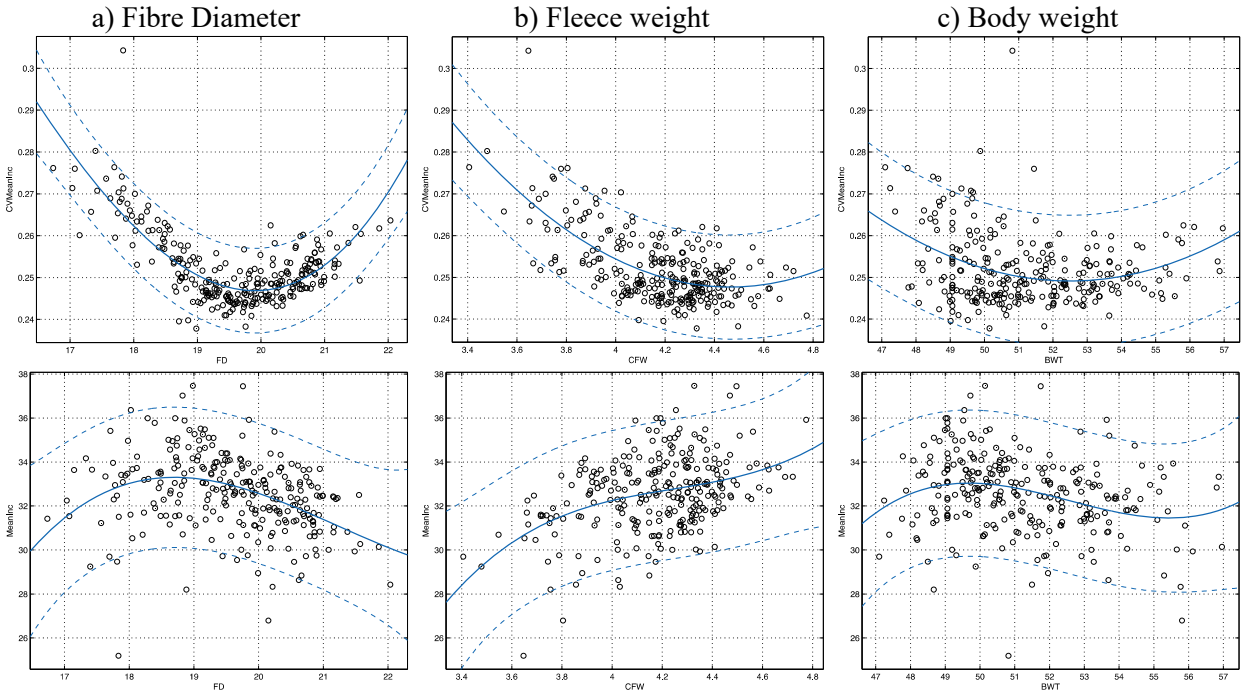
282

283 **Table 3: Mean productive characteristics of absolute risk-efficient bloodlines in relation to the degree**
 284 **of a decision makers risk aversion.**

| Descriptor | Degree of Risk aversion | | |
|---|-------------------------|----------|--------------------|
| | Low (Risk neutral) | Moderate | High (Risk averse) |
| Wool Fibre Diameter (microns) | 19.4 | 19.6 | 19.9 |
| Fleece Weight (kg clean/head) | 4.3 | 4.2 | 4.0 |
| Mature Body Weight (kg liveweight) | 50.2 | 51.3 | 51.9 |
| Stocking rate (head/ha) | 8.0 | 7.8 | 7.8 |
| Trading Income (\$/ha) | -3.48 | -3.50 | -3.51 |
| Wool Income (\$/ha) | 281 | 261 | 241 |
| Mean Gross Income (\$/DSE) | 34.7 | 32.1 | 29.7 |
| Standard deviation of Mean Gross Income (\$) | 8.4 | 7.9 | 7.5 |
| Coefficient of Variation of Mean Gross Income | 0.242 | 0.246 | 0.253 |

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Figure 2: Relationships between bloodline a) Fibre Diameter, b) Fleece weight, and c) body weight;

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and gross income (\$Gross Income/DSE) and risk (measured as standard deviation of Mean Gross

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Income/DSE) with fitted regressions and 95% confidence intervals shown (dotted line).

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