Author(s): Behrendt, K.

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

Karl Behrendt[AB]

[A] Graham Centre for Agricultural Innovation (Charles Sturt University and NSW Department of Primary Industries), Charles Sturt University, School of Agricultural and Wine Science, Orange, NSW 2800, Australia.

[B]Author for correspondence: email: kbehrendt@csu.edu.au

Abstract

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

Keywords

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

Introduction

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

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

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

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

Methodology

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

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

Bloodline economic model

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

$$GI_t = \frac{TI + \sum_{n=1}^{3} WI_n}{sc}$$

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

$$TI = P_N BWT_1 \beta_{DPW} WNRP_t + S_N BWT_n \beta_{DPM} MP_t$$

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

Insert Table 1~~**Table 1**~~ **near here**

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

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

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

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

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

$$WI_n = N_n FW_n WP_t$$

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

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

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

$$WP_t = MPG_{FD} CB_{FD}$$

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

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

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

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

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

Insert Table 2 **near here**

Results

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

Insert Figure 1 **near here**

Insert Table 3 near here

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

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

Insert Figure 2 **near here**

Discussion

The method presented here allows sheep producers and their advisors to consider the risk profile of different bloodlines when making decisions regarding the future breeding direction of a flock. The application of the methodology to Australian merino bloodlines, in this instance, allowed the identification of risk-efficient bloodlines. Once risk-efficient sets of bloodlines are identified, sheep producers can select their optimal bloodline based on the profit they wish to generate and the risk they are willing to accept. This process allows sheep producers to trade off some risk for expected returns (Hardaker *et al.* 2004). It also allowed the production characteristics of those risk-efficient bloodlines to be indicated, which would enable producers with varying degrees of risk aversion to more easily identify appropriate bloodlines for future purchase or breeding.

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

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

Given the differences in bloodline risk-reward profiles when measured using standard deviation as an absolute measure of risk, versus coefficient of variation as a relative measure of risk, the results indicate that the mean return (i.e. mean gross income) is a greater determinant of risk-efficiency than absolute risk. The results also indicate the need to balance between fleece weight and fibre diameter so as not to excessively increase the variability of returns when breeding objectives focus strongly on fibre diameter reduction in lieu of increasing or maintaining fleece weight.

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

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

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Tables & Figures

Table 1: Summary of production characteristics for 268 Merino bloodlines (derived from Martin *et 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

Table 2: Summary of historical wool and sheep meat price data from 28/6/2005 to 10/11/2011 (Sources: (AWEX various issues; MLA various issues)). Price statistics are in cents/kg carcass weight for merino weaners and mutton prices, and cents/kg clean for micron price guides.

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

a) b)

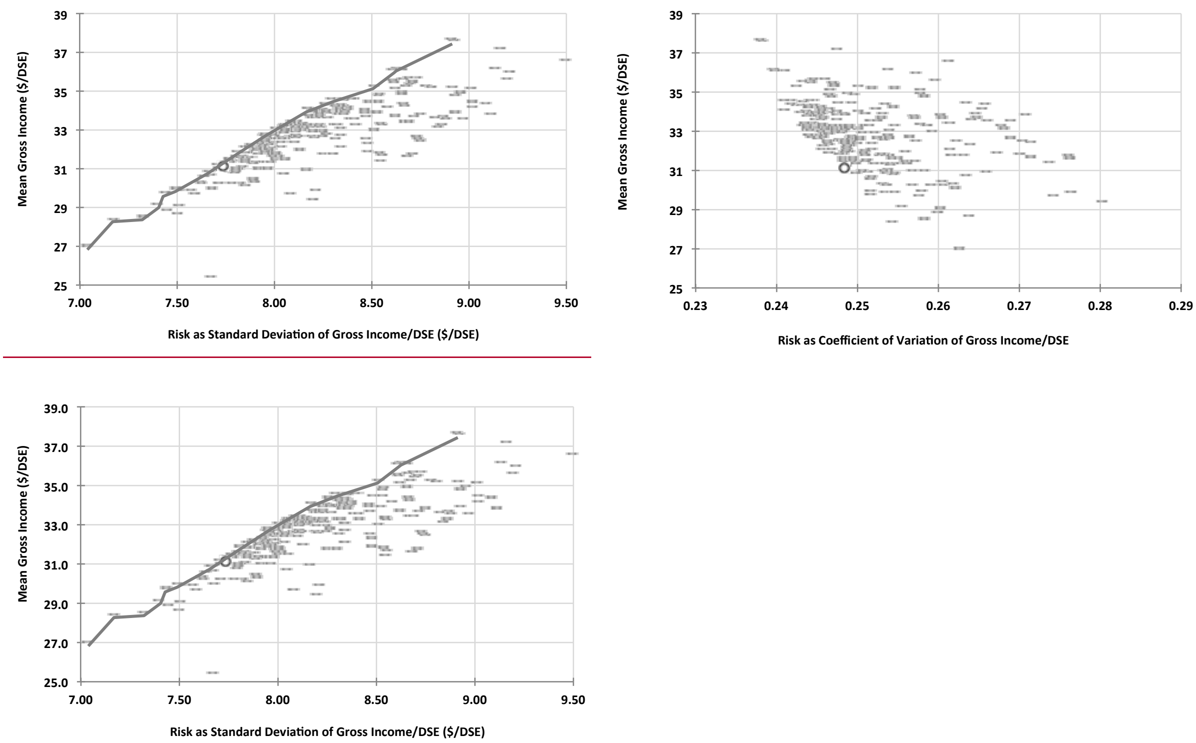

Figure 1: Risk-reward for Australia merino bloodlines, a) Absolute risk measured as Standard Deviation of Mean Gross Income, and risk-efficiency against Mean Gross Income per DSE; b) Relative Risk measured as coefficient of variation of Mean Gross Income against Mean Gross Income per DSE.

Table 3: Mean productive characteristics of absolute risk-efficient bloodlines in relation to the degree 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

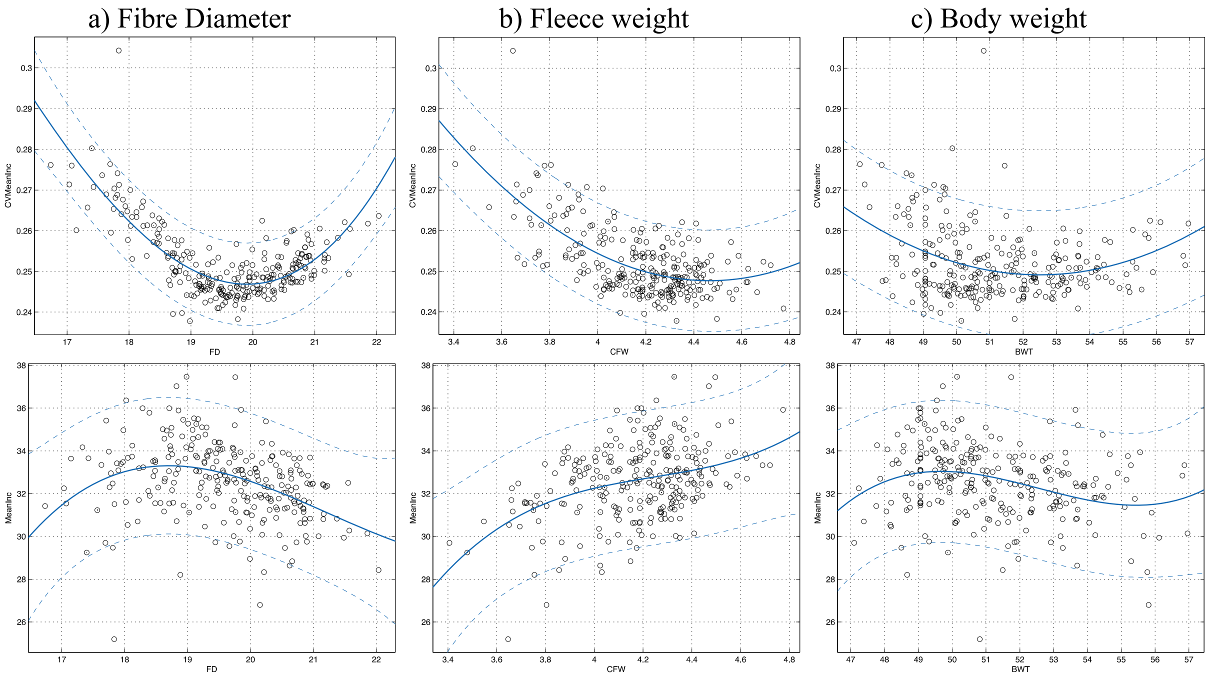

Figure 2: Relationships between bloodline a) Fibre Diameter, b) Fleece weight, and c) body weight; and gross income ($Gross Income/DSE) and risk (measured as standard deviation of Mean Gross Income/DSE) with fitted regressions and 95% confidence intervals shown (dotted line).