An analysis of the wool characteristics that determine wool price in South Africa

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Received 19 June 2023
Revised 10 August 2023
Accepted 20 September 2023

Abstract

Purpose – South Africa's wool industry plays an important role in the agricultural sector. The wool industry provides a valuable source of income for farmers who practice sustainable farming practices. However, wool farmers face numerous challenges, such as wool contamination, dirty wool and producing good-quality wool. Good-quality wool is determined by fibre diameter, clean yield, vegetable matter and staple length. This study aims to address these challenges.

Design/methodology/approach – A multiple regression analysis of price (R/kg) of White wool and Merino wool was applied to four variables fibre diameter: vegetable matter, clean yield and staple length. The analysis was based on the data for the 2009–2019 data from Cape Wools auctions.

Findings – Fibre diameter, clean yield and staple length, with exception of vegetable matter, made a statistically significant contribution to the determination of wool price after all other independent variables were controlled for ($p < 0.05$). A one-unit (micron) increase in fibre diameter resulted in a 0.404-unit decrease in wool price (R/kg). A one-unit (mm) increase in staple length resulted in a 0.022-unit increase in wool price (R/kg). There was no statistically significant association between vegetable matter and wool price. A one-unit increase in clean yield was associated with a 0.111-unit increase in wool price (R/kg).

Research limitations/implications – Since wool fleeces consist of the largest portion of wool shorn from sheep, it is important for wool farmers to focus on wool with low fibre diameter, high clean yield percentage, low percentage of vegetable matter content and good length of the wool.

Practical implications – Since wool fleeces consist of the largest portion of wool shorn from sheep, it is important for wool farmers to focus on wool with low fibre diameter, high clean yield percentage, low percentage of vegetable matter content and good length of the wool.

Social implications – In a developing country such as South Africa, this study is important for the following reason. It is understanding the wool characteristics that have the most significance influence on the determination of wool price for Merino wool and White wool might effectively help the wool farmers to adapt their production systems to improve the wool characteristics that determine wool price.

The authors are grateful to Cape Wools South Africa for the availability of the research data.

Research Journal of Textile and Apparel
Emerald Publishing Limited
1560-6074
DOI 10.1108/RJTA-06-2023-0061

Originality/value – This study identified a need for a study to be conducted on all wool classes.

Keywords Fibre diameter, Clean yield, Staple length, Vegetable matter, Wool price

Paper type Research paper

1. Introduction

In South Africa, the success of wool grading has given wool buyers access to wool of the required quality at fair pricing (Dlodlo *et al.*, 2009). Wool is broadly classified into White wool and Merino wool (Cape Wools, South Africa, 2002; Cape Wools, South Africa, 2010). Strict classing standards are adhered to ensure the good name of the South African clip internationally (Cape Wools, South Africa, 2002). These standards have been drawn up for the South African National Wool Growers Association by the South African Wool Board in cooperation with processors, buyers and brokers (Cape Wools, South Africa, 2002). This was done to satisfy the needs of all the key players involved. Wool classing is done to ensure that the maximum income is generated from the wool clip within the marketing and packing rules (Cape Wools, South Africa, 2002; Cape Wools, South Africa, 2010).

Moreover, wool buyers want uniformity in fibre diameter, high percentage of clean yield, good length of wool and a low amount of vegetable matter within classes, for the reason that the end result can be predicted with greater certainty. Unnecessary breaking up of the wool clip during wool classing increases testing, marketing and handling costs, which does not ensure a better wool price for the wool farmer (Cape Wools, South Africa, 2002). Wool contamination must be avoided, as it results in lower prices. Contamination of wool by suint can be a challenge for wool farmers. Suint is a mixture derived from the sweat of sheep (Shamey and Sawatwarakul, 2014). It contains amino acids, organic acids and potassium salts that can be detected. The presence of vegetable matter reduces the amount of clean wool in a lot, and its presence is a challenge for users because it has to be removed before wool can be spurn into yarn (Baxter and Wear, 2021). According to Botha and Hunter (2010), the various types of vegetable matter include clover burr, spiral burr, other soft burrs, grass seed, shive, twigs and hard heads. Therefore, a high percentage of vegetable matter may result in low prices. Wool must have certain length in order to make yarn from washed combed fleece (Atav *et al.*, 2020). There are significant price differences for wool longer than 50 mm and wool shorter than 50 mm, depending on the different end-uses of wool (Cape Wools, South Africa, 2002). In South Africa, there are no premiums for wool longer than 85 mm; wool length should be less than 85 mm (Venter, 2017). Fibre diameter or fineness can be determined by the number of crimps per 25 mm and the size of the crimp (Cape Wools, South Africa, 2002). The smaller the crimp, the finer the wool (Cape Wools, South Africa, 2002; Human, 2018).

2. Wool concepts

2.1 Wool types in classing standards

According to Cape Wools, South Africa (2002) and Cape Wools, South Africa (2010), the following wool classes are shorn from sheep: fleeces, backs, lox, lox 1, lox 2, bellies and pieces (BP). The wool fleece is separated into the following categories after shearing:

- Fleece (which comprises the vast bulk): The fleece usually comes off as one large piece of wool, which is thrown across the wool table for skirting. Fleece wool is the wool shorn which comes from the entire sheep (LeValley, 2004; Nolan, 2014). Additionally, fleece wool makes up 64% of all wool shorn from sheep (Cape Wools, South Africa, 2021). Fleece wool is the most valuable and is classed according to strength, length, quality and appearance (Farmer’s weekly, 2019). According to Metcalfe and Collins (1994) fleece wool is associated with higher prices than other lines of wool, like: lox, backs, BP;

- Bellies and Pieces (Skirtings): The bellies comprise short wool shorn from underneath the sheep’s stomach. This wool is kept separately from the fleece because it has a less value and is processed differently. Pieces are made up of wool, which contains coloured or sweaty edges from the fleece (Nolan, 2014). Bellies make up 9% of all wool shorn from sheep, while pieces make up 10% (Cape Wools, South Africa, 2021). According to Cape Wools, South Africa (2002) and Cape Wools, South Africa (2010), bellies and pieces (BP) have to be packed separately from the fleece wool;
- Lox wool: Containing urine-stained wool, top knots, brisket wool, double cuts, cheek wool, dung and sweaty wool shorn from adult sheep have to be marked and packed separately as follows:
  - Lox 1: Consists of long top knots, long sweaty locks, long matted brisket wool and cheek wool which is 40mm minimum in length; and
  - Lox 2: Consists of short top knots, shanking, double cuts, cheek wool and hard, sweaty pieces less than 40mm.

  Lox wool should not be mixed with the other wool to prevent wool contamination (Farmer’s weekly, 2019). Lox wool makes up 8% of all wool shorn from sheep (Geyer and Venter, 2015; Cape Wools, South Africa, 2021). When classing wool, urine-stained matted wool, brisket wool, top knots and dung wool are packed separately and marked under lox wool 1, lox wool; and:
- Backs: Backs are wool that comes from the back of sheep. In short wool of 50 mm and shorter, it is not crucial to remove the backs, provided they do not differ too much from the rest. If they differ significantly, two lines of backs are marked as BKS and BKS2. Inferior backs (BKS2) are made up of shorter, very dusty, badly weathered and less attractive backs. Wool backs make up 2% of all wool shorn from sheep (Cape Wools, South Africa, 2021). According to Farmers weekly (2019), when wool from the backs of an adult sheep is clean and good, they are not removed from fleece. Dusty backs, weathered wool or wool which contains vegetable matter has to be removed from the fleece and marked as BKS.

Globally, there are limited studies conducted on prices of Merino wool and White wool classes (backs, fleeces, lox, lox 1 and lox 2, bellies and pieces) when investigating wool characteristics that determine wool price. This is important because of large differences between the wool classes and the contribution to the wool price. The aforementioned wool classes have to be used to get a complete representation of wool characteristics that determine the wool price in South Africa for both Merino wool and White wool.

A similar study conducted by Nolan (2012) have attempted to include wool classes such as wool pieces, fleeces and bellies when evaluating premiums and discounts associated with micron groups (ultrafine, superfine and extrafine wool) with the use of a hedonic model. The other wool classes, such as lox, lox 1, lox 2 and backs, are important. Therefore, there is a need to include all wool classes, such as Merino and White wool classes, such as backs, fleeces, lox, lox 1, lox 2, fleeces, bellies and pieces, when investigating wool characteristics that determine wool price. The reason behind this is that there is a big difference between them in terms of their contribution to wool price.

“White wool” is defined as wool that is free of kemp and pigmented fibre, excluding crossbred and Merino wool (Cape Wools, South Africa, 2002; Geyer and Venter, 2015). As with Merino wool, White wool follows the same classing procedures. The Dormer sheep breed is referred to as the "White wool wonder" in South Africa. The name "Dormer" comes from Dorset and Merino. A white wool mutton breed known as the Dormer was created by mating German Merino ewes with Dorset Horn rams.

According to Cape Wools, South Africa (2010), "Merino wool" is defined as wool that is free of kemp and has a fibre diameter of no more than 27 microns, with characteristics of the Merino sheep (Cape wool, South Africa, 2010). The South African Merino, which comes from Spain, and the South African Mutton Merino, which is descended from German Mutton Merino, are two breeds of fine wool. The locally developed Merino sheep breeds can be classified into fine wool breeds (Afrino, Dohne and Latelle) and Coarse wool breeds (Dormer). The Dohne Merino sheep is a dual-purpose breed rather than wool-producing breed (Van der Merwe *et al.*, 2020). Merino wool is a high-grade wool used to produce high-quality garments and textiles preferred by markets and consumers (Allafi *et al.*, 2020). Additionally, Merino breeds were selected in harsh climatic environments and are not only able to tolerate conditions of limited water and food resources but also parasites and diseases that limit production when such breeds are used (Almeida, 2011).

3. Methodology

Cape Wools SA in Port Elizabeth, South Africa, hosts all the South African wool price data. Secondary data were used because it was logistically impossible to collect data from 59,000 wool-producing farmers. The data were used to determine:

- which wool characteristics had the most significant influence on White wool and Merino wool price classes; and
- price differences between different wool characteristics.

The data were collected from wool auction results from 2009 to 2019 and included the following:

- prices of all different wool classes for White wool and Merino wool;
- market indicators (auction price per kilogram for greasy wool of a certain type);
- quantity of wool traded; and
- selling season.

3.1 Phase 1: data

Cape Wools SA provided the data, which included data on all wool sold through the formal auction system for the specific period 2009 up to 2019. As such, the effect of the independent variables on the dependent variable was tested. In this study, the independent variables comprised fibre diameter, staple length, clean yield and vegetable matter in the Merino and White wool classes. The dependent variables were price of clean wool per kg for Merino and White wool classes.

3.2 Phase 2: research design

This study applied an experimental research design. The principle of experimental research design is that it generates a situation in which variables are tightly controlled and subjected to an ideal environment for testing (Jain, 2019). In this study, the independent variables were controlled to observe the effect of each independent variable on wool price separately. A dependent variable, the outcome variable, was defined as that being tested in a study (Jackson, 2012; Wilson as cited in Liamputtong, 2019; Stockemer, 2019) and was represented by "y" (Stockemer, 2019). The influence of the independent variables on the dependent variables was measured. The independent variables were hypothesised to influence the dependent variable [Jackson (2012); Wilson, as cited in Liamputtong (2019), Stockemer (2019)] and were represented by "x" (Stockemer, 2019). As such, the effect of the independent variables on the dependent variable was tested.

In this study, the independent variables comprised:

- fibre diameter, vegetable matter, staple length and clean yield on White wool and Merino wool classes all combined together.

The dependent variables were:

- price of clean wool per kg for White wool and Merino wool classes.

3.3 Phase 3: statistical analysis

Statistical analyses of experimental data were carried out with the Statistical Package for Social Sciences version 24.0 software to determine wool characteristics that had a significant influence on wool price and whether there were significant price differences between the wool characteristics. An analysis of variance (ANOVA) was performed to assess the contribution of each wool characteristic to the variation in wool price. The F statistic, along with a *p*-value or confidence interval, was used to determine significant differences among groups. A *p*-value of 0.05 or less for the probability of the F statistic was accepted as an indication that the model had statistically explanatory power and reached statistical significance if the *p*-value was less than 0.05.

3.4 Phase 4: multiple regression analysis

Multiple regression analyses were applied to the price (R/kg) of White wool and Merino wool on four variables (fibre diameter, vegetable matter, staple length and clean yield). Multiple regression is a method used to explore relationships between independent variables and one continuous dependent variable (Pallant, 2016). Multiple regression provides information about the model and the contribution of each variable that makes up the model. Additionally, it allows testing whether the added variables can contribute to the model's predictive ability in addition to the variables already included (Pallant, 2016). It can be applied to statistically control additional variables when exploring the model's predictive ability. The multiple regression approach was chosen as the best technique for analysing wool characteristics that have the most significant influence on price determination in South Africa because of its ability to investigate complex interrelationships among given variables (Pallant, 2016). According to Kothari (2004), multiple regression equations take the form (Equation (1)):

$$\ddot{y} = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \tag{1}$$

where, X_1, X_2, X_3 and X_4 are the four independent variables, Y represents the dependent variable, and a, b_1, b_2, b_3 and b_4 are constants.

3.5 Results and discussions

3.5.1 Descriptive statistics of variables. Table 1 illustrates the summary of the averages (mean) of the combination of the wool characteristics and the average price for Merino wool and White wool of the data for the past 10 years analysed. It was found that wool fleeces proved to have the highest average prices (R/kg), followed by wool pieces, wool backs, wool bellies, wool lox, wool lox 1 and wool lox 2 for both Merino wool and White wool. A possible explanation is

Wool characteristics	*N*	Minimum	Maximum	Mean
Fibre diameter, vegetable matter and clean yield				
Merino wool: fleeces				
Fibre diameter (micron μ)	159	16.90	25.10	20.90
Vegetable matter (%)	159	0.30	1.10	0.73
Clean yield (%)	159	65.60	74.00	68.41
Price (R/kg)	159	33.78	146.75	82.78
White wool: fleeces				
Fibre diameter (micron μ)	153	17.60	25.40	21.53
Vegetable matter (%)	153	0.70	2.20	1.25
Clean yield (%)	153	55.90	64.20	59.66
Price (R/kg)	153	21.64	128.89	61.18
Fibre diameter, vegetable matter and clean yield				
Merino wool: pieces				
Fibre diameter (micron μ)	149	16.90	25.20	20.81
Vegetable matter (%)	149	0.60	4.40	2.11
Clean yield (%)	149	52.40	72.60	64.67
Price (R/kg)	149	28.34	132.44	73.47
White wool: pieces				
Fibre diameter (micron μ)	146	17.00	28.40	21.38
Vegetable matter (%)	146	0.40	5.40	1.95
Clean yield (%)	146	45.70	68.50	56.95
Price (R/kg)	146	16.08	150.00	51.29
Fibre diameter, vegetable matter and clean yield				
Merino wool: backs				
Fibre diameter (micron μ)	137	16.80	25.30	20.58
Vegetable matter (%)	137	0.60	4.60	1.98
Clean yield (%)	137	51.50	73.50	61.65
Price (R/kg)	137	18.00	141.95	71.95
White wool: backs				
Fibre diameter (micron μ)	142	17.40	30.20	22.16
Vegetable matter (%)	142	0.50	8.70	2.34
Clean yield (%)	142	43.40	63.70	52.41
Price (R/kg)	142	12.00	93.23	45.67
Fibre diameter, vegetable matter and clean yield				
Merino wool: bellies				
Fibre diameter (micron μ)	143	16.40	27.10	20.30
Vegetable matter (%)	143	0.36	11.80	2.87
Clean yield (%)	143	28.61	68.50	53.31
Price (R/kg)	143	12.00	148.00	50.12
White wool: bellies				
Fibre diameter (micron μ)	148	16.90	28.20	21.69
Vegetable matter (%)	148	1.00	10.40	2.46
Clean yield (%)	148	46.40	62.50	52.83
Price (R/kg)	148	51.50	103.85	42.35
Fibre diameter, vegetable matter and clean yield				
Merino wool: lox				
Fibre diameter (micron μ)	107	1.10	24.80	19.25
Vegetable matter (%)	107	0.37	1.00	0.75
Clean yield (%)	107	30.21	64.50	44.03
Price (R/kg)	107	10.96	76.46	38.90

(*continued*)

Table 1. Comparative descriptive statistics for Merino wool and White wool separately

Wool characteristics	N	Minimum	Maximum	Mean
White wool: lox				
Wool characteristics				
Fibre diameter (micron μ)	146	17.20	31.00	26.68
Vegetable matter (%)	146	0.40	4.60	1.07
Clean yield (%)	146	45.90	68.50	60.07
Price (R/kg)	146	12.83	68.00	31.11
Merino wool: lox 1				
Fibre diameter (micron μ)	128	17.00	25.50	20.31
Vegetable matter (%)	128	1.10	2.80	1.95
Clean yield (%)	128	28.40	54.80	42.13
Price (R/kg)	128	10.00	69.70	34.21
White wool: lox 1				
Fibre diameter (micron μ)	137	17.00	28.10	21.83
Vegetable matter (%)	137	1.50	2.70	2.12
Clean yield (%)	137	34.10	55.80	43.54
Price (R/kg)	137	3.10	72.68	28.08
Fibre diameter, vegetable matter and clean yield				
Merino wool: lox 2				
Fibre diameter (micron μ)	121	17.00	24.40	20.11
Vegetable matter (%)	121	3.00	6.80	4.25
Clean yield (%)	121	30.70	50.90	40.52
Price (R/kg)	121	4.10	63.10	29.46
White wool: lox 2				
Fibre diameter (micron μ)	139	17.50	26.30	21.65
Vegetable matter (%)	139	2.00	10.90	4.18
Clean yield (%)	139	31.90	58.40	40.70
Price (R/kg)	139	12.10	53.17	20.58

Source: Authors' own work

Table 1.

that wool fleeces are the most valuable and are classed according to strength, length, quality and appearance (Farmer's weekly, 2019). Metcalfe and Collins (1994) reported that wool fleeces are associated with higher prices as compared to the other lines of wool such as the lox, backs, bellies and pieces. Wool pieces are part of fleeces and are also good wool, associated with better prices at the wool auction (Geyer, personal communication 28 October, 2021).

According to Cape wools, South Africa (2002), wool backs come from the backs of an adult sheep. Wool backs are also paid better prices at the wool auction as compared to wool bellies, wool lox, wool lox 1 and wool lox 2. Wool bellies come from the belly of sheep. Bellies are less desirable because of the uneven, shorter wool which comes from the other parts of sheep and lacks character of the body of fleece (Nolan, 2012). Therefore, wool bellies are paid better prices at the wool auction as compared to the lox wool (Metcalfe and Collins, 1994).

Metcalfe and Collins (1994) reported that lox wool has the lowest price value as compared to other classes of wool such as bellies, pieces, backs and fleeces. The reason for this explanation is that when classing wool, urine-stained matted wool, brisket wool, top knots and dung wool are packed separately and marked under lox wool 1 and lox wool 2. Lox 1 is associated with low prices because it consists of long matted brisket wool, long sweat locks and long top knots (Cape Wools, South Africa, 2002). Wool lox 2 is associated with the lowest prices. A possible explanation is that they comprise hard sweaty pieces, double cuts, cheek wool and shankings (Cape wools, South Africa, 2002). These findings are in line with the South African wool industry, which finds that wool fleeces have the highest average prices (R/kg), followed by wool pieces, wool backs, wool bellies, wool lox, wool lox 1 and wool lox 2 for Merino wool and White wool.

The results indicate that fleece wool has the highest average price, followed by pieces, backs, bellies and lox for both Merino wool and White wool. Since wool fleeces consist of the largest portion of wool shorn from sheep, it is important for wool farmers to focus on producing Merino wool and White wool with low fibre diameter, high clean yield percentage and good length of the wool.

3.6 Model results

The results of the multiple regression analysis of price (R/kg) of Merino wool and White wool on four variables (fibre diameter, vegetable matter, staple length and clean yield) on White wool and Merino wool, all combined for 2009–2019, are illustrated in Tables 2, 3 and 4.

The R square value indicates the degree of variance in the dependent variable explained by the model. Thus, how well the estimated prices (R/kg) match the actual prices and, hence, how well the model explains variation in price for Merino wool and White wool all combined? The adjusted R square was used to provide a better estimate of the true representative of the sample. In this case, including all the independent variables, explained 45% of the variance in the wool price (adjusted R square = 0.447), while the 55% is explained by some other influences in the wool market not analysed in this model (Table 2).

To evaluate the statistical significance of the regression model, the F value and the p value are presented in Table 3. As depicted in Table 3, the F value was 166.035 and the p value was < 0.001. Both F value and P value are significant at $\alpha = 0.05$ and at F critical value = 230.16, respectively, showing that fibre diameter, vegetable matter, clean yield and staple length of both wool types all combined had a significant influence on the determination of wool price.

Model	*R*	*R* square	Adjusted *R* square	Std. error of the estimate
1	0.670	0.449	0.447	1.481

Notes: Wool types = Merino wool and White wool, all combined; independent variables = fibre diameter, staple length, clean yield, vegetable matter; dependent variable = price (R/kg); where: R = (correlation between the predicted values and observed values of Y); R square = percentage of variation in response, explained by model
Source: Authors' own work

Table 2.
Model summary for Merino wool and White wool all, combined

Model		Sum of squares	Df	Mean square	*F* value	*p*-value
1	Regression	1,821.918	5	364.362	166.035*	< 0.001**
	Residual	2,231.926	1,017	1.195	–	–
	Total	4,053.844	1,022	–	–	–

Notes: Wool type = Merino wool and White wool all, combined; dependent variable = price (R/kg); independent variables = fibre diameter, vegetable matter, staple length and clean yield; where: Df = degrees of freedom, (the number of values that are free to vary); F = (the ratio of two mean squares that forms the basis of a hypothesis test); Sig = significance level.*F value significant at critical value = 230.16; **p-value significant at $\alpha = 0.05$
Source: Authors' own work

Table 3.
Anova table of Merino wool and White wool, all combined

The results in the Anova Table 3 illustrate the overall predictive power of the model, but they do not show which of the independent variables made a statistically significant unique contribution to the determination of wool price. Therefore, we need to interpret the coefficient in Table 4.

3.6.1 The effect of fibre diameter on the wool price for Merino wool and White wool, all combined. Fibre diameter/fineness made a statistically significant contribution to the determination of wool price after all other independent variables were controlled for ($p < 0.05$) (Table 4). A one-unit (micron) increase in fibre diameter resulted in a -0.404-unit R/kg decrease in wool price for Merino wool and White wool, all combined, after all other independent variables are taken into account. The negative impact of fibre diameter on wool price can be explained by a few different factors. Firstly, as fibre diameter increases, the wool becomes less flexible and coarser. This can make the wool to be difficult to process and less desirable to wool buyers, who prefer softer wool. Secondly, coarser wool is less durable and less resistant to tear and wear, which can affect its value in the market. Lastly, coarser wool absorbs more moisture and is dirty, which affects the marketability and quality of wool. Fibre diameter plays an important role in the determination of wool price for Merino wool. In this case, the fibre diameter for Merino wool and White wool, all combined, plays a significant role in determination of wool price. A possible explanation is that the variation in fibre diameter is not large between wool farmers due to breeding programs. Moreover, wool from wool farmers during wool classing is put under one category; therefore, the variation in fibre diameter is not large. The aforementioned factors may have contributed to the fact that fibre diameter played a significant role in the determination of wool price for Merino wool and White, all combined.

Similar results from several scholars were observed by several scholars, such as Erasmus and Delport (1987), Pepper *et al.* (2000), Gibbon and Nolan (2011), Nolan *et al.* (2013), Nolan (2014) and Scobie *et al.* (2015), who found that fibre diameter has the greatest influence on the Merino wool price. The sizes of wool fibres are described by the diameter of wool fibres (Das *et al.*, 2015). As expected, an increase in fibre diameter resulted in a decrease in wool price for Merino wool and White wool all combined, because wool buyers generally pay better prices for finer wool. Geyer and Van der Walt (2013), Masters and Ferguson (2019) and Zhao *et al.* (2019) reported similar results: finer wools are associated with higher prices on the market. Finer wools are associated with higher prices because it is used to make expensive fabrics (Cottle and Baxter, 2015).

Fine and strong wools are a reference to wool fibre diameter, which is one of the most significant and important parameters that determines how the fibre is used (Wang and Wang, 2004; She *et al.*, 2005; Pawson and Perkins, 2013; Ullah, 2019). The fineness of wool depends on fibre diameter (Allafi *et al.*, 2020). The fineness can be determined by the number of crimps per 25 mm and the size of the crimp (Cape Wools, South Africa, 2002). The smaller the crimp, the finer the wool (Cape Wools, South Africa, 2002). Human (2018) also explained that the lower the micron of fibre, the finer the wool. Wool fibres differ in terms of fibre diameter (Deng *et al.*, 2007). The diameter of the wool fibre can vary due to genetics, the breed of sheep and environmental conditions, among other factors. In South Africa, the average Merino clip is around 19.8 μ and ranges from as fine as 14 μ right up to 23 μ for Merino wool and up to 30 μ for crossbreed's sheep (Human, 2018). Nolan *et al.* (2013) found similar results: a decrease in fibre diameter by one micron was associated with an increase in wool price. Furthermore, these findings concur with the results of the Australian wool industry that micron premiums increase rapidly as fibre diameter decreases (Nolan, 2012; Nolan *et al.*, 2013; Nolan, 2014; Masters and Ferguson, 2019). This indicates that fibre diameter plays an important role in the determination of wool price for Merino wool and White wool. Wool producers may increase the economic returns of wool production through

Table 4. Coefficient table of Merino wool and White wool, all combined

Model	Unstandardised coefficients B	Unstandardised coefficients SE	Standardised coefficients Beta	T	Sig.	95.0% confidence interval for B Lower bound	95.0% confidence interval for B Upper bound	Correlations Zero-order	Correlations Partial	Correlations Part	Collinearity statistics Tolerance	Collinearity statistics VIF
(Constant)	7.941	0.590		13.549	0.000	6.783	9.099					
Staple length	0.022	0.002	0.262	9.733	0.000	0.018	0.026	0.359	0.292	0.226	0.745	1.343
Fibre diameter	−0.404	0.032	−0,379	−12.686	0.000	−0.467	−0,342	−0.197	−0.370	−0.295	0.606	1.650
Vegetable matter	0.083	0.047	0.046	1.746	0.081	−0.010	0.175	−0.219	0.055	0.041	0.784	1.276
Clean yield	0.111	0.006	0.523	17.315	0.000	0.098	0.123	0.543	0.477	0.403	0.593	1.686

Notes: Where: wool type = Merino wool and White wool, all combined; dependent variable = price (R/kg); β = (beta is the degree of change in the outcome variable for every 1 unit of change in the predictor variable); t = coefficient divided by the standard error; Sig = significance level. (sig=$p < 0.05$); VIF = variance inflation factors (determines level of multicollinearity)
Source: Authors' own work

selection and breeding of rams and ewes to produce finer wool; thus, finer wool is associated with better prices. Therefore, selection and breeding are important to improve the genetic potential of sheep for wool traits to meet the rising demand for finer wool for Merino wool and White wool.

3.6.2 The effect of vegetable matter on the wool price for Merino wool and White wool, all combined. There was no statistically significant association between vegetable matter and wool price after all other independent variables were controlled for ($p > 0.05$) for Merino wool and White wool, all combined (Table 4). In this case, the vegetable matter for Merino wool and White wool, all combined, did not play a significant role in the determination of wool price. It could be expected for vegetable matter to not play a significant role in the determination of wool price for all wool classes because vegetable matter is a form of wool contamination. An increase in vegetable matter is associated with a decrease in wool price (Gibbon and Nolan, 2011). Vegetable matter, therefore, does not influence wool price significantly in the South African context. Gibbon and Nolan (2011) found that an increase in vegetable matter resulted in a decrease in wool price in superfine and medium wool under Australian conditions. Contamination of wool by vegetable matter negatively influences prices in Australia (Pepper *et al.*, 2000; Nolan *et al.*, 2013). Increases in vegetable matter contamination increase the cost of processing for a given amount of vegetable matter (Jones *et al.*, 2004; Gibbon and Nolan., 2011).

There is an opportunity to improve the returns from wool by reducing wool contamination by vegetable matter (Ford and Cottle, 1993). One method of reducing contamination of wool by vegetable matter is to use sheep rugs and coats. Ford and Cottle (1993) reported that the use of coats may improve the returns for wool growers with sheep, which have heavy, coarser wool. Sheep which have heavy or coarser wool are more prone to contamination with vegetable matter. In Australia, rugs and sheep coats have been used in a variety of environments (Ford and Cottle, 1993). The interest in their use has increased due to price reductions being applied at wool auction to wools with high amount of vegetable matter. In South Africa, shorter shearing intervals produce shorter wool (Henderson, 2015). The advantage of shorter wool is that the fleece wool will consist of less vegetable matter.

Cape Wools, South Africa (2002) advised that neckfold wools contain excessive amounts of vegetable matter and have to be packed separately during wool classing. Wool from the back of sheep contains seeds as a type of vegetable matter and is classified under BKS3. Fleece wool usually has fewer seeds. Lox wool contains more seeds. It also contains urine, dung-stained matted wool, top knots and sweaty wool (Cape Wools, South Africa, 2002). Wool shorn from the jaw or cheek of sheep can contain seeds as a type of vegetable matter (Nolan, 2012). De Beer and Terblanche (2015) reported burr/weeds as the major source of vegetable matter under the South African conditions. The amount of vegetable matter that sheep can catch in their fleece depends on the type of the country in which they run and the season of the year (Baxter and Wear, 2021). These results indicate that vegetable matter does not play a significant role in the determination of wool price for all wool classes. The results of vegetable matter might help wool farmers adapt their production systems to improve the amount of vegetable matter in wool. Therefore, proper weed management on the veld and fields for intensive sheep farming systems is important to control the contamination of wool by vegetable matter. Weed management influences the level of vegetable matter in wool. A high presence of weeds will have an economic impact on the farm enterprise, resulting in low wool prices. Wool with a higher number of weeds (seeds) must go through a carbonising process that adds to the end product’s cost, resulting in a lower purchasing price. In addition, an increase in vegetable matter decreases wool quality, clean yield and performance (Chishti *et al.*, 2021). Wool quality plays an important role for wool textiles, especially for fabric comfort and manufacture of clothes (Li and Xue, 2023).

3.6.3 The effect of clean yield on the wool price for Merino wool and White wool, all combined. Clean yield influenced wool price significantly, with a one-unit increase in clean yield associated with a 0.111-unit increase in wool price (R/kg), after all other variables were controlled for ($p < 0.05$) for Merino wool and White wool, all combined (Table 4). Clean yield plays an important role in the determination of wool price for Merino wool. In this case, clean yield for Merino wool and White wool, all combined, plays a significant role in the determination of wool price. It was expected that an increase in clean yield would result in an increase in wool price for Merino wool and White wool, all combined, because wool buyers pay higher prices for clean wool. Thus, the cleaner the wool, the better the wool prices at the wool auction. Lupton *et al.* (1993) found similar results: clean yield was positively and significantly ($P < 0.01$) correlated with Merino wool price in the USA. Clean yield percentage can be calculated by evaluating the difference between clean fleece weight and greasy fleece weight (Ullah *et al.*, 2020). Additionally, clean yield can be determined by the colour, amount of the yolk and foreign matter in the wool. The colour of greasy wool varies from yellow to near white (Gelaye *et al.*, 2021). Yellow discolouration occurs as a result of chemical reactions that occur within the fleece under the influence of bacterial activity, temperature and moisture (Gelaye *et al.*, 2021). In a study conducted by Scales *et al.* (2000) in New Zealand, it was found that purebred Merino wool was less yellow as compared to other breeds. This indicates that Merino wool is less contaminated by vegetable matter as compared to other breeds. Clean yield determines the amount of the end product that can be obtained from greasy wool (Khan *et al.*, 2012; Chishti *et al.*, 2021). The pigmented fibres may cause problems during dying; therefore, non-pigmented fibres have more value (Khan *et al.*, 2012). Textile processers are interested in weight of clean wool that remains after soil, epidermal substances and grease are removed from wool (Scobie *et al.*, 2015). Clean yield also varies within sheep flock due to varying amounts of wax and contaminants such as vegetable matter and dirt (Cottle and Baxter, 2015). A similar study conducted in New Zealand found that clean scoured yield proved to be higher for ewes rearing singles as compared to those rearing twins at both shearing's (Morris *et al.*, 1994). The current results indicate that clean yield plays a significant role in the determination of wool price for White wool and Merino wool, all combined. Australian and New Zealand wool sheep farmers use covers or coats to improve the clean yield, something that more South African wool sheep farmers in intensive system should consider in order to improve their profitability.

3.6.4 The effect of staple length on the wool price for Merino wool and White wool, all combined. Staple length made a statistically significant contribution to the determination of wool price for Merino wool and White wool, all combined, after all other independent variables were controlled for ($p < 0.05$) (Table 4). A one-unit (mm) increase in staple length resulted in a 0.022-unit increase in wool price (R/kg) after all other independent variables are taken into account. In this case, staple length for Merino wool and White wool, all combined, plays a significant role in the determination of wool price. It could be expected that an increase in staple length resulted in an increase in wool price for Merino wool and White wool because wool buyers pay according to the increase of staple length. Scott (1990) and Pepper *et al.* (2000) found similar results: wool price increases if staple length increases across the entire micron range in Merino wool in Australia. As the staple length of wool increased, so did the price ratio (Pepper *et al.*, 2000). These results indicate that staple length plays a significant role in determining the wool price for Merino wool and White wool, all combined. In sheep farming systems, wool growth can be related to changing patterns of diet selection and feed intake, which affect season of shearing and sheep age (Allafi *et al.*, 2020). Wool growth depends on the supply of nutrients to the follicles, which exerts a considerable influence on the characteristics of wool and rate of wool production. Less wool is grown by young sheep per unit of feed intake, probably due to competition for nutrients between tissues and follicles (Allafi *et al.*, 2020). Shearing frequency also affects staple length of wool. To meet market requirements, wool farmers stick to 6 month shearing intervals while others stick to 12 month or 8 month intervals (Human, 2018). De Barbieri *et al.* (2018) reported that ewes shorn in mid-pregnancy produce stronger and lighter fleeces with shorter staple lengths, stronger fleeces and poorer colour as compared to those shorn post-partum. The difference in staple length of fleece wool when packed in the same class should be less than 25 mm for wool longer than 50 mm and 20 mm for wool shorter than 50 mm (Cape Wools, South Africa, 2002). Wool buyers prefer evenness in staple length. There are significant price differences for wool shorter than 50 mm and wool longer than 50 mm, depending on the different end-uses of wool (Cape Wools, South Africa, 2002). In South Africa, there is no premiums for wool longer than 85 mm, wool length should be less than 85 mm (Venter, 2017). Wool length determines its suitability for end use. Longer wool is preferred because it is easy to process and increases wool quality and production (Chisti *et al.*, 2021). The cross-section area of wool fibres along wool length has an impact on the mechanical properties of those fibres; thus, wool fibres are subjected to tensile strength during wool processing, and this may affect the wool fibre cross-section area (Deng *et al.*, 2007; Tandon, 2015). Longer wool results in stronger and smoother yarns, which are easier to handle during the spinning process. This can have a significant impact on the final quality of the textile and the products made from it. Hence, it is important for wool farmers to pay close attention to wool length and take the necessary steps to ensure their materials meet the required standards at the wool auction.

3.7 Conclusions and recommendations

The results indicate that wool fibre diameter, clean yield, vegetable matter and staple length play a significant role in the determination of the wool price for Merino wool and White wool. Since wool fleeces consist of the largest portion of wool shorn from sheep, it is important for wool farmers to focus on producing Merino wool and White wool with low fibre diameter, high clean yield percentage, low percentage of vegetable matter and good length of the wool.

Additionally, the study demonstrated that fibre diameter contributed most to the wool price, followed by clean yield, staple length and vegetable matter. The results of the study may assist wool producers in evaluating the economic returns of wool production and taking advantage of desirable wool characteristics. All future research must be acknowledged as an investment in the wool industry.

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