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Investigating the price of the New Zealand wool clip using modelling approaches

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Abstract: The price of the New Zealand wool clip has steadily decreased over the years and the incumbent practitioners are looking for ways to increase the price. The price of the wool is determined by the marketing approaches that are adopted. An auction system is one of the wool marketing approaches and a total of 45% of the New Zealand wool clip is traded via auction (WIN, 2007).This auction is *the English open out-cry public auction* which has been running for the last 150 years in New Zealand. The key players of the auction (buyers, brokers and growers) as well as the New Zealand government are trying to understand the reasons behind the steady decrease in the price of the New Zealand wool clip. Further, the incumbent practitioners are questioning the auction system and looking for alternative ways of wool marketing. In this study, an attempt is made to model auction data. The data is available from the only auction centre in the South Island of New Zealand in Christchurch. Analytical approaches are used in developing the models from the data. Before fitting the data into the models, the database is thoroughly cleaned and a necessary and sufficient set of the parameters is produced by developing the approximation equations. The probability distributions of the parameters in the data base are observed. Best fitted distributions for all physical parameters are observed in terms of three measures namely mean square error, the chi-square and Kolmogorov-Smirnov (K-S) goodness-of-fit hypothesis tests. The cleaned database is used in the models. The models are developed to predict the price of the different types of wool. The price from the auction centre and the predicted price are compared. The models based on linear regression analysis, multiple regression analysis and principal component analysis are developed. The developed regression models are tested for the goodness-of-fit against **coefficient of determination**, $\boldsymbol{R}^2$, which describes the proportion of variability in the data set accounted for by the model. The model from the principal component analysis is used for the possible dimensionality reduction in the data set. The developed models and the physical parameters of wool are discussed. The role of physical parameters that account for the price of wool in the auction system is investigated.

It is hoped that the analysis of auction database and the developed models will help the practitioners of the New Zealand wool industry in better understanding the role of physical parameters of wool and the price formation of it.

Keywords: *Open out-cry English auction, New Zealand wool clip, Physical parameters, regression analysis, principal component analysis*

1. INTRODUCTION

The New Zealand Wool Industry (NZWI) is of significant value to the New Zealand economy, contributing more than a billion New Zealand dollars a year (Mallard, 2006). This iconic industry is at a cross-road due to the steady decrease of the unit price of the New Zealand wool clip over the years. The unit price of New Zealand wool depends on various factors. It mainly depends on the physical properties of the wool clip such as diameter, colour, length, vegetable matter, bulk, and medulla. These physical properties vary due to the weather and various farming practices adopted by the growers. Variation in the physical properties leads to more than 3000 different types of wool in the market. This indicates that New Zealand wool is a complex fibre; therefore, it is difficult to practitioners to estimate its price.

The price of the wool also depends on the marketing approaches from farm gate to the end user. Primarily, the New Zealand wool clip is marketed via three different methods (i) auction, (ii) direct supply from growers and (iii) buying from private merchants. The auction system is the principal wool marketing approach and a total of 45% of the New Zealand wool clip is traded via auction (WIN, 2007). This auction is based on the English open out-cry public auction which has been operating for the last 150 years in New Zealand.

The key players in the auction system (buyers, brokers and growers), as well as the New Zealand government, are trying to understand the reasons behind the strong decrease in the price of New Zealand wool. Further, the incumbent practitioners are questioning the auction system and focus on alternative methods such as direct supply of wool from the growers. The argument for alternative approach is backed by the previous proposals. Proposals recommended that direct linkages between growers and the market may correct the market disconnection inherent in the long-established auction system. In this scenario, all the players face a challenge in understanding the wool price dynamics and are in a dilemma about the marketing approach. In the past, studies have been carried out to understand the price behaviour of the New Zealand wool clip (e.g. Angel et al., 1990; Carnaby et al., 1988; Maddever, 1989; Stanley-Boden, 1985; Stanley-Boden et al., 1986). Apart from studies on the price of wool as a commodity, previous studies also attempted to address relative price issues by taking into consideration wool properties. However, the price dynamics issue still remains poorly understood.

To better understand the price dynamics issues and for the betterment of New Zealand wool industry, various attempts have been made to develop other strategies. Despite these reports, recommendations and initiatives, the New Zealand wool industry has undergone further significant decline and is, once again, at the cross-road. Among the many issues raised by the previous proposals (submitted for industry reforms), a change in the wool selling system is a hardy perennial. There has been and is now no consensus on the optimal wool selling system for the New Zealand wool clip. Recently, in 2007, yet another initiative was taken to form the Wool Industry Network (WIN). It is claimed that the WIN's role is to revitalise New Zealand's $1-billion wool industry with a market-led approach to maintain and grow wool's profitability for the benefit of all sub-sectors from farm to retail. In this context, there is a need for a study that can provide insight into the price dynamics issues of New Zealand wool.

In this study, our emphasis is on the buyers / exporters who export wool. As stated earlier, auction is still a major wool trading avenue and the buyers / exporters are participating / bidding in auction; therefore, our analysis focuses on the database available from a local wool auction centre. The database contains the outcome of bidding value -the price- of wool after competition between the bidders in the auction. As wool is diverse and complex in nature, the bidders in the wool auction follow the traditional ways of the bidding system. The live nature of the New Zealand wool auction shows that though the bidding procedure is traditional, the bidders are getting real time feedback via their offices on some major factors, like currency fluctuations, as the auction is in progress.

In this setting, **the price formation dynamics and the analytical approaches (modelling approaches)** for the database considered for this study are the main areas where the rest of this paper focuses. Hence, this paper is organized as follows: an overview of price formation dynamics that include pathways of New Zealand wool marketing, physical properties of New Zealand wool, and buyers' pricing perspectives. The other section covers the database from Christchurch auction centre followed by the test of data with different analytical models. We conclude the paper with some discussions on price dynamics analysis and its usefulness to the stakeholders of the New Zealand wool industry.

2. AN OVERVIEW OF PRICE FORMATION DYNAMICS

2.1. Pathways of New Zealand wool marketing

In the marketing of any agricultural products, they need to travel a path from their origin to reach to the end user. In the case of wool, generally, the pipeline of wool supplying the industry consists of the following stages (Canesis, 2006):

- sheep growing
- wool harvesting
- sampling and storage in a wool broker's store
- pre-sale testing of individual lots
- sale to an exporter at auction / or by private treaty from a wool merchant
- wool blending & scouring
- post sale testing of amalgamated lines ready for export
- shipping to mill (NZ or overseas)
- spinning into yarns
- weaving, knitting or tufting into products.

Various players are involved in performing the above tasks. Generally, growers, brokers, private merchants, auction centres and exporters / buyers are the key players of the wool pathways. The wool buyers act on behalf of the processing / exporting sector. Buyers buy the wool mostly at auction; however, they try to find the wool at the lowest price so that they can increase their profits irrespective of the trading system. The brokers / auction centre / exporters route plays a key role in price formation since it is a public process with open flow of price information. We can say that the basis for price formation is the physical properties of wool irrespective of the pathway.

2.2. Physical properties of wool

Wool has a number of physical properties, also called quality factors, that determine its commercial value as a textile fibre, the ease with which it can be processed into yarn and the products into which it can be converted (Angel et al., 1990; Wood, 2003; Canesis 2006). These properties vary for wools obtained from different parts of the body of a sheep, individual sheep in the same flock, strains of sheep within a breed, ages of sheep within a breed, breeds, environments (i.e. climate, terrain, pasture etc.), farming properties, shearing regimes (timing, frequency, preparation procedures), geographic regions and seasons of the year.

The physical properties which are considered as the major determinants of price formation of the wool are colour, diameter, vegetable matter, length, bulk, and medulla.

Among the physical properties of wool, colour can be described in three parameters, namely; X, Y, and Z. These trios of measurements are referred to as the tristimulus values, a common term used in colour science. From the wool trade perspective, two derivative parameters are significant (Y and Y-Z), where, Y is brightness and Y-Z is used to characterize yellowness. In general, the whiter (brighter) the wool, the better price it will demand and the more yellow the wool, the less will be the price in the market. On the other hand, fibre diameter is possibly the most important property of wool since it determines its suitability for certain end-uses. The finer the wool (micron), the higher the price in the market and vice versa. For example; merino (finer wool) gets better prices in the market than strong wools (coarser wool). The other quality factor is vegetable matter (VM) in wool which is indicative of contamination of the wool. It consists of burrs, grass seeds, thistles, hard heads, straw, chaff and twigs that stick to the fleece when the sheep is grazing (Teasdale, 1995). While VM's contribution for price is based on degree of contamination, the length largely determines the processing system by which the wool will be manufactured, and the properties of the resulting yarn. Like fibre diameter's importance in fine wools, the length is of equal importance in coarser wools from the pricing perspective. The other quality factor, bulk, is related to its crimp characteristics and is a measure of its ability to fill space and have a springy handle (Canesis, 2006). Bulk is closely associated with wool lustre (or shine); generally, the higher the lustre, the lower the bulk of the wool. Lustrous wools are undesirable in most types of machine-made carpets, but are acceptable in hand-made rugs. On the other hand, wool fibres having hollow cells which are not composed of solid keratin are said to be medullated wool (Wood, 2003). Medullation is generally unwanted from a processing point of view.

The physical properties are the basic foundation in the price formation process for all players.

2.3. Buyers' / exporters' pricing perspective

The pricing perspective of many buyers depends on the physical properties of wool. These physical properties are taken into account by the bidders or buyers in any of the wool trading systems (auction or direct supply). The relative price is governed by the physical properties.

Relative price of the wool = f (physical properties of wool clip).

In the case of auction bidding, the buyers / bidders' decision making can be conceptualized in a two stage model (Figure 1). First stage is prior to auction and the second stage is during and after auction.

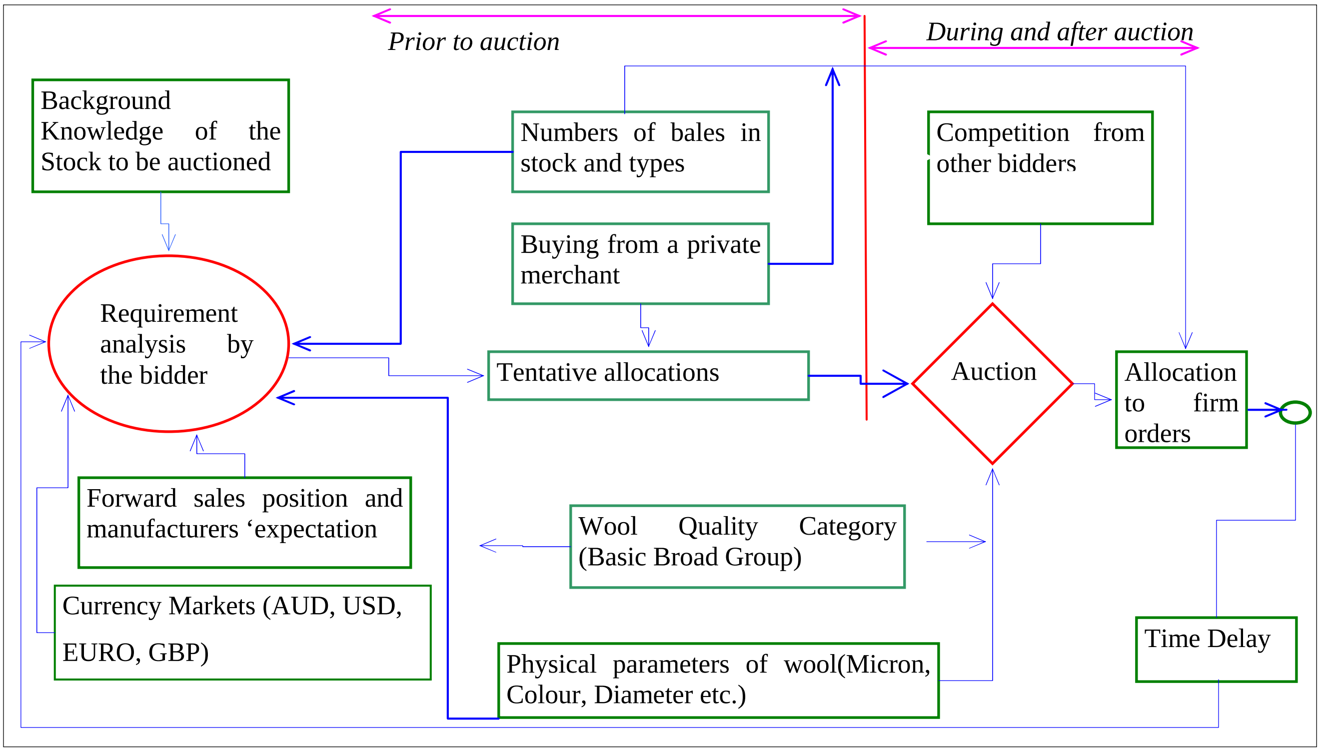

Figure 1. An overall model showing the decision making behaviours of a bidder in the New Zealand wool auction environment.

Prior to auction, the bidders are given the opportunity to inspect a sample of the wool lots going to be auctioned along with catalogues. In the catalogues, information such as wool quality factors is provided. Prior observation helps to achieve the requirement analysis for the bidder. Three major factors play a role in both (prior to auction and during and after auction) situations: 'physical parameters of wool', 'wool quality category' and 'number of bales in stock and types'. Among the factors presented in the model above, some are common (physical parameters, wool quality category) to all the bidders and some are independent (stock held, forward sales position, available wool types in specific auction, currency factor, seasonality of supply) to the bidders and not known to each other. These independent factors play a vital role in price formation during the auction environment where competition is going live and the bidder chooses whether to be active at the start price. This competition ends up with the price for each wool type under sale in the auction.

3. THE CHRISTCHURCH AUCTION CENTRE AND THE DATABASE

3.1. The Christchurch auction centre

The auction centre in Christchurch is in Canterbury region of South Island of New Zealand. This centre is dealing with 40% of total wool trading in New Zealand. Further, Canterbury is New Zealand's largest and most diverse wool production region (WIN, 2007). Many of the country's most significant wool enterprises are based in Canterbury. There are 7.5 million sheep (20 per cent of the national flock) in the Canterbury region (WIN, 2007). The commercial base of the New Zealand wool industry is in Canterbury.

It is highly likely that the models developed from the analysis of the data from the Christchurch auction centre would represent the trend of marketing for the whole New Zealand wool clip. The data contains the attributes like physical parameters of the wool: [(diameter, colour (Y, Y-Z), length, yield)], market indicators (auction price per kg for greasy wool of certain type), quantity of wool traded at the auction, auction date, broker and warehouse, and wool types[1].

3.2. Data cleaning and preparation

The database is carefully examined and cleaned prior to the testing with quantitative models. The cleaning process includes omitting data having either no auction prices or zero auction prices. The zero auction prices indicate that those lots were not sold at that auction date. The data are reclassified using a filtering technique. The reclassification generates groups of the wool types into classes. The wool types are defined in combination with categories (eg; Bellies, down fleece etc.) and descriptors (cotts, lustre etc). A general standard has been set up in the wool industry for types of wool. For the grouped wool types, more physical properties of wool, such as Bulk and Medulla, are predicted from the subjective wool type code by developing the approximation equations (Carnaby, 2007). This calculation provides the full set of necessary and sufficient conditions to define the wool space. The probability distribution of each parameter in the full set of data is observed. The best fitted distribution is observed by using the Simulation software - ARENA[2]. These distributions for all physical parameters are tested in terms of three measures namely mean square error, the chi-square and Kolmogorov-Smirnov (K-S) goodness-of-fit hypothesis tests. Thus a neat database is prepared for testing with various analytical models.

4. MODEL BASED ON ANALYTICAL APPROACHES

4.1. Models on regression analysis

Models are developed performing the analysis based on simple and multiple linear regression once the database is cleaned and has full set of necessary and sufficient conditions of the data to define the wool space (Carnaby et al., 1985). These regression models give the R-Squared (R^2) value of the model describing the goodness of fit. Further, regression coefficients, and scatter plots are observed and the effect of parameters on predicted clean price is analysed. As the regression analysis assumes normal distribution of data, the normal distribution curves for six parameters are observed. Further, the major contributing parameters in predicting the price of the wool among the physical parameters are observed in this analysis. Models are developed for the prediction of auction price against the 6 parameters namely; colour (Y, Y–Z), VM, length, diameter, bulk, and the medulla.

Table 1. Summary of simple linear regression models for the clean price against physical properties of wool

Physical properties	Regression Fit Y = bo + b1X	R-Squared value
Colour Y	Y = 7.710 - 0.06503 * ColY	58.1%
Col (Y-Z)	Y = 4.891 - 0.3224 * ColY-Z	25%
VM	Y =3.736 + 0.9020 * VM	9%
Length	Y = 4.608 - 0.05237* Length	7%
Medulla	Y = 5.045 - 0.1425* Medulla	24.3%
Bulk	Y = - 3.275 + 0.3288* Bulk	56.4%
Diameter	Y = 11.07 - 0.2104 * Diameter	63%

The simple linear regression model follows the form $\mathbf{Y = b_o + b_1X}$, where **Y** is the response (in this case predicted clean price); **X** is the predictor (measurement – in this case value of physical parameters of wool); $\mathbf{b_o}$ is the intercept; and $\mathbf{b_1}$ is the coefficient. A summary of the simple linear regression models for the clean price against physical properties of wool is presented in Table 1. This shows that the simple regression model developed by using diameter (micron) produces a high R^2 value (63%).

Table 2. Summary of simple linear regression models for the clean price against diameter

Physical properties	Regression Fit $Y = b_o + b_1X$	R-Squared value
Diameter (<30 micron)	Y = 16.7 - 0.444 Diameter (< 30 Mic)	69.2%
Diameter (>= 30 micron)	Y = 4.81 - 0.0392 Diameter (>=30 Mic)	5.9%

[1] Various types of wool coded with symbols that represent in order category, colour, length and descriptors

[2] Simulation software which is popular for system modelling based on the simulation language SIMAN

However, this value is not good enough in assessing the model. To better understand the contribution of diameter in predicting the auction price, an attempt is made in partitioning the data into two groups based on the diameter. First group contains the data having less than 30 micron diameter and the second group is greater than or equal to 30 micron diameter. These two groups are visualised separately for the linear regression models along with scatter plot. The results from these two models (presented in Table 2 and Figure 2) show that lesser the diameter the higher the price of the wool in the auction. The R^2 value for < 30 micron group is 69.2% while it is 5.9% for the >= 30 micron group.

In addition to simple linear regression model described above, to better understand the combined effect of all the physical parameters, a multiple linear regression model is developed. The regression equation developed for this model provides the clean auction price per kg (CAucPkg),

CAucPkg = 8.59 + 0.0352 Y - 0.0628 (Y-Z) - 0.153 VM + 0.342 L - 0.217 D +0.0662M - 0.0551B

From this analysis it is observed that the model developed from multiple linear regression produced a fairly good R^2 value (84.4%). However, considering the comparatively low value of the wool types having following categories and descriptors, they are excluded for further analysis: categories: G, H, J, O, T, V, W, X, Y (19~2.51% of total) and descriptors: F, I, J, K, L, V, Y, Z (127~ 16.82% of total). An analysis is made after the exclusion of these types of wool. Simple linear regression models as well as multiple linear regression models are developed. Partitioning of database is made as before. Among the developed models, a model based on multiple regressions produced R^2 value of **92.7%** for a model < 30 micron (before 69.2%). This result signifies that wool types having low quality which have low value and price are playing a major role for the R^2 value and hence the goodness of the model.

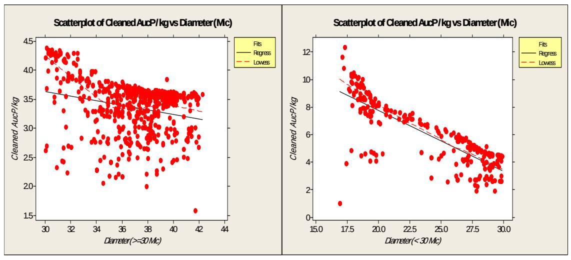

Figure 2. Scatter plots developed from simple linear regression model for diameter (>= 30 micron) and diameter (< 30 micron) from left to right.

Further exploration is made by observing the principal component analysis and possible dimensionality reduction.

4.2. Model based on Principal Component Analysis and dimensionality reduction

Principal Component Analysis (PCA) gives the idea of clustering the data into particular clusters. To do so, wool types are discritised based on six parameters; colour (Y, Y-Z), VM, length, diameter, medulla and bulk. The result from PCA is presented in Table 3. The first principal component has variance (Eigen value) 3.6848 and accounts for 0.526 which is 52.6% of the total variance (Table 3). The coefficients listed under PC_1 show how to calculate the principal component scores:

Table 3. Eigen analysis of the correlation matrix

Eigen value	3.6848	0.9978	0.9316	0.6765	0.5890	0.0974	0.0229
Proportion	0.526	0.143	0.133	0.097	0.084	0.014	0.003
Cumulative	0.526	0.669	0.802	0.899	0.983	0.997	1.000
Variable	**PC_1**	**PC_2**	**PC_3**	**PC_4**	**PC_5**	**PC_6**	**PC_7**
ColY	0.389	0.237	-0.169	-0.186	0.738	-0.401	-0.157
Col (Y-Z)	0.219	-0.231	0.843	-0.391	-0.051	-0.172	-0.053
VM	-0.278	0.341	0.500	0.668	0.331	0.014	0.016
Length	0.219	0.818	0.049	-0.116	-0.490	-0.163	-0.024
Diameter	0.511	-0.027	0.023	0.160	0.052	0.169	0.825
Medulla	0.402	-0.322	-0.073	0.558	-0.314	-0.511	-0.241
Bulk	-0.503	-0.034	-0.053	-0.125	-0.047	-0.702	0.482

PC_1 = 0.389 ColY+ 0.219 Col(Y-Z) - 0.278 VM + 0.219 Length + 0.511 Diameter (Mic) + 0.402 Medulla – 0.503 Bulk

The second principal component has variance (eigenvalue) 0.9978 and accounts for 14.3% of the total variance. As the interpretation of the principal components is subjective, it is difficult to say which principal component is representing an overall population size. However, from Table 3, the first five principal components together represent 98.3% (52.6% + 14.3% + 13.3% + 9.7% + 8.4%) of the total variability. Thus, most of the data structure can be captured in five underlying dimensions. The remaining two principal components account for a very small proportion (1.7%) of the variability.

5. DISCUSSIONS AND CONCLUSIONS

As Canterbury is the most vibrant region of the New Zealand wool industry, a sample database is chosen from the auction centre in Christchurch. Like previous studies, the developed model showed an agreement that fibre diameter has a significant role in the price formation of the New Zealand wool. However, other physical parameters also have roles. The results in the beginning are not so encouraging; however, once low value wool types which has negligible price in the market are discarded from the database, an improved R^2 value model is achieved. Further, the principal component analysis showed that first five components are important for the data set under study.

Despite the fact that many previous studies attempted to analyse the wool appraisal data from the auction centre, the price formation process from the bidder's perspective has not been studied to support the decision –making. The novelty of the work lies in the price formation process from a bidder's perspective. As the auction data are the result of the competition between many bidders, we aim to formulate the price formation process from the bidders perspective that would generate the auction price and hence the data. With the developed models in particular, buyers / bidders can test their data set for the possible fluctuation in the price of any particular wool type.

We are aware that the price dynamics issue is governed by global supply and demand, inter and intra fibre competition and whether wool is considered as a commodity or a niche product while marketing. None of these factors is considered in this investigation. We hope that these simple models would give insight into the price dynamics issues to the stakeholders of the New Zealand wool industry.

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