DEMAND FOR WOOL BY GRADE

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PREFACE

Product demand is often described as a relationship between the quantity purchased and the price. However, for many "products", such as wool, there are a very wide range of factors involved in defining what the product is.

The research presented in this Report is an attempt to analyse the relationships between the factors which comprise the wool product and the prices paid for wool. Varying end uses, differences in characteristic requirements and the effect of different combinations of characteristics are explored in an attempt to provide an analysis of the price/quantity relationships which exist for the range of wool types.

This Research Report provides an example of an econometric approach to wool demand analysis, setting a base upon which further models can be developed.

AC Zwart
Director

SUMMARY

This study reports a project undertaken by the AERU on behalf of the New Zealand Wool Board. The aims of the project were to examine the relationships between auction prices of different types of wool, to identify categories of wool and to investigate substitution effects amongst wools.

A modelling framework was developed which enabled these relationships to be analysed. Two modelling approaches were used within this framework. Cross-sectional hedonic models and time series aggregated models were specified and estimated. Hedonic models identify the relationships between wool characteristics and price, while aggregate models deal with the broader issue of wool supply mix and its effect on price. These two modelling approaches were implemented in such a way that they could be synthesised to build on the strengths of each.

The study also examined a number of possible categorisations for wool, based on parameters supplied by the New Zealand Wool Board or on cluster analysis. Three main categorisations were identified and incorporated in the modelling exercise.

The estimation results were generally satisfactory. The time series models all gave high R-squared statistics although in most cases had relatively few significant coefficients. The hedonic models gave acceptable results in keeping with prior expectations regarding the effects of wool characteristics on auction price.

Overlapping groups or categories of wool were found to give the best estimates for the time series models in particular. This contrasts with the more traditional approach of using distinct categories and suggests a useful avenue for further research.

By linking the time series models with the hedonic models a fairly detailed picture of the workings of the wool market can be built up, since this captures both aggregate supply and demand factors and wool quality factors. While there are some clear avenues for further research, this study makes some useful first steps towards a conceptualisation of wool markets.

CHAPTER 1

INTRODUCTION

In 1986-87, 61% of the New Zealand wool clip was sold by public auction. A feature of auction sales is the thousands of individual lots, each with unique characteristics defined by objective measurement, which comprise a sale. In view of the range of types of wool available, and the possible end uses to which wool may be put, price determination in wool auctions is a complex arbitrage process.

An important characteristic of much of New Zealand's shorn wool clip is that it is coarse in diameter. New Zealand is the largest coarse wool producer in the world. This coarseness means that the wool is better suited for end uses in products such as carpets, upholstery and hand-knitting yarns. About 60% of New Zealand wool is used in carpets as the end product, according to a 1982 study reported by the New Zealand Wool Board (NZWB) in its 1986-87 Statistical Handbook.

Fashion trends may influence demand for some wool attributes. For example, lighter coloured wools are necessary for the dyeing process if light coloured yarn is wanted. Hence a premium may be paid for such wool if the current fashion is for light colours. As a consequence those wools suitable for use in garments, generally the finer wools, may be subject to considerably more price fluctuation than other wools as clothing fashions change relatively quickly.

The different processing technologies, and different end uses, also give rise to demands for particular sets of wool characteristics. Owing to technical considerations only certain ranges of fibre diameter, vegetable matter content or length may be suitable. The two major processing methods for wool are the worsted and the woollen processes. Longer wools are more suitable for the worsted process, whereas short fibres are required for the woollen process. Both processes can be used to make a range of final products. It is demand for these products which ultimately determines demand for types of wools. Unfortunately because of the complex distribution channels and the activities of marketing intermediaries it is impossible to collect detailed information on the end use of New Zealand wool.

Wool prices are also influenced by the NZWB. It operates a "Strata Price Control Scheme" to pick up unwanted lots of wool and to ensure no sudden falls in prices from one sale day to the next. These support prices can be changed at any time. On a longer term basis, the Board sets a Market Intervention price at which it supports the market.

This price, which may be reviewed, is not disclosed. The size of the NZWB stocks can also be expected to influence the market.

Considering all the factors mentioned in the preceding discussion, it can be seen that changes in the supply mix of physical or technical wool characteristics, intervention purchasing by the NZWB and changing demand considerations give rise to a complex series of arbitrage and price determination processes. Such relationships may be difficult to analyse, but a range of approaches to modelling price relationships are possible.

This report presents the results of a research project undertaken by the AERU on behalf of the NZWB. The aims of the project were to examine the relationships between auction prices for different types of wool, identify categories of wool and investigate the extent of price linkages and substitution effects amongst wools. Due to the wide range of possible wool types, the various end uses to which wool can be put and the different characteristics which influence prices, this is a complex task. The following chapter discusses possible modelling frameworks within which to conduct such a study.

CHAPTER 2

MODELLING FRAMEWORK

In order to examine the impact of changes in wool availability on wool price, it is useful to consider a modelling framework. Models can be powerful tools for investigating such relationships and for quantifying various effects.

However, the wool market is a complex system to study. There are potentially an infinite number of products since each individual lot has a unique set of characteristic, and the value of each lot will be related to its specific characteristics. On the other hand, at a broader, more aggregate level, fluctuations in the overall supply of or demand for wool of a certain type (for instance fine wool) will also impact upon price. Therefore, a combination of two modelling approaches is discussed below. Each approach is capable of dealing with one facet of this problem.

2.1 Hedonic Models

One possible approach to modelling wool price determination is to identify the relationships between individual characteristics such as diameter, vegetable matter content, and length, and the market price. Such models are known as "hedonic" pricing models, and have commonly been applied to similar situations in the past. Hedonic models arose from the observation that prices of goods vary with quality as well as quantity of the goods. Different prices are paid for different levels of characteristics. Hedonic prices are defined as the implicit prices of the characteristics. One example of the hedonic pricing approach is discussed by Rosen (1974). Simmons (1980) and Bramma et al (1985) are two examples of hedonic pricing analyses of the Australian wool market. The NZWB itself already performs some analysis of this type.

This type of model is able to give an accurate picture of a cross section of the market at a particular point in time, and allows individual lots of wool to be valued in relation to some representative price. Such data can be used to derive implicit prices for each of the inherent product characteristics. This can provide information for producers who may wish to change the composition of their flock (Stanley-Boden) or to marketing authorities that may wish to set reference prices (Simmons).

However, the hedonic modelling approach gives no insights into how relative market prices are established, or how the implicit prices for characteristics respond to the availability of wool having those characteristics.

2.2 Aggregate Models

Instead of examining the objective characteristics or qualities of individual lots, it is possible to take a broader view of the auction price determination process. In this context a useful concept is that of a "category" of wool - a set of sale lots whose characteristics fall within certain specified ranges. For instance, a "fine wools" category could be defined as all wools with diameter of less than 30 microns.

Categories of wool have been developed and used in studies of the demand for wool in the past. Connolly and MacAulay (1985), for instance, divided the Australian wool clip into seven groups, based on fibre diameter and whether the wool was classified as combing or carding wool. In such cases, the wool clip is divided into mutually exclusive groups defined in terms of one or two parameters.

Conventional demand curves, with associated direct and cross-price relationships, can be estimated from time series of such data. This approach is often simplistic in its definition of wool categories, as particular end users of wool may purchase wools from several different categories. It is the arbitrage between categories which creates the apparent "substitution" measured in such models. This approach is based on the presumption that any particular lot of wool will fall into only one category. While this may be appropriate if the market is viewed from a producer's perspective, it may not be consistent with the wool user's perspective of the same market.

In practice, the boundaries between categories are less clearly defined, particularly in terms of end use. Any given lot may have more than one potential end use. Hence as an alternative, it may be more realistic to create categories which reflect the overlapping nature of user group requirements. Such categories are not necessarily mutually exclusive and are defined in terms of the characteristics desired by competing end users.

Wool suitable for each of these categories can be specified in terms of a range of characteristics and each lot in an auction can be assigned to a category. Where a lot (or number of lots) of wool is suitable for more than one end use, there is an intersection group between categories, and it is the competition between end users for such wool that provides arbitrage and price linkages between categories. If the intersections are only partial - for instance, only a small portion of wool suitable for worsted apparel is also suitable for woollen carpets - or occur between several categories, there will be only imperfect substitution between categories. Moreover, the substitution effects will be of different magnitudes for different categories because the relative importance of an intersection group to one category may be much less than the relative importance of the same intersection set to another category.

A further complication is introduced by the activities of NZWB. Purchases of wool by the NZWB can be viewed in one of two ways: either as competing with buyers of wool having certain characteristics, or acting to underpin price levels by buying unwanted or residual lots of wool. In either case, NZWB purchases would have to be taken into account in any analysis of demand and supply parameters.

In this aggregate view of the wool market it is the relationships between categories and the substitution effects involved which are important in understanding the impact of a changing wool supply mix, and purchases by a marketing authority, on wool prices. The characteristics of individual lots are only important in assigning wool to a general category. This contrasts with the hedonic model approach where characteristics are all-important in determining lot prices. The question of whether distinct or overlapping categories give a more accurate description of the arbitrage process can be examined by comparing results of the two approaches.

But, as Bramma et al note, "Estimates of wool demand and supply parameters derived from econometric models which do not account for the demand and supply of quality factors (characteristics) are likely to be biased". Therefore, it is also important that the model allows for the implicit prices of characteristics of each lot, while at the same time reflecting the broader issues of availabilities and demand for mixes of characteristics (categories). The theoretical models outlined in the following section seek to strike a synthesis of the hedonic and aggregate approaches.

Definitions of the categories used in this study are presented in Chapter 3, which also includes a discussion of how other categories might be defined.

2.3 Model Specifications

The following price dependent demand function can be used to describe the aggregate time series models discussed above:

$$P_{ct} = f\ (A_{1t}, A_{2t}, \ldots, A_{Nt}) \text{ for } c = 1, \ldots, N \tag{1}$$

where P_{ct} = price of wool in category c in time period t.

A_{ct} = availability of wool in category c = 1,...,N in period t.

Equation (1) reflects the general relationship between prices and availabilities over a period of time. Although the exact time period involved is not important to the discussion of a general model specification, monthly data was used in this study. For each time period (month), it is possible to define prices and availabilities for each category relative to the weighted average price and availability for all wool in that period. The weighted average price in time period t is P_{Tt}, where:

$$P_{Tt} = \left\{ \sum_{c=1}^{N} (P_{ct} * A_{ct}) \right\} / A_{Tt} ,$$

and A_{Tt} is the total amount of wool available in period t.

Thus $RP_{ct} = P_{ct}/P_{Tt}$, for c = 1,...,N

is the price of category c relative to the average price for all categories, in period t,

and $RA_{ct} = A_{ct}/A_{Tt}$, for c = 1,...,N

is the availability of wool in category c at time t relative to the total quantity of wool available in each period t.

Substituting these relative prices and availabilities into equation (1) gives:

$$RP_{ct} = f(RA_{1t}, RA_{2t}, \ldots, RA_{Nt}) \text{ for } c = 1, \ldots, N \text{ in period } t \qquad (2)$$

When expressed in this form, RP_{ct} and RA_{ct} can represent either the price and availability of wool in a set of N mutually exclusive categories, in which case the RA_{ct}'s sum to 1, or in overlapping categories, when the RA_{ct}'s may sum to more than 1 for each time period t. Furthermore, the use of relative prices and availabilities eliminates any need for discounting prices for the effect of inflation, exchange rate, and other common demand shifting factors.

A number of functional forms are possible for the demand relationships in (2). In this study, the relationships were assumed to be linear in logarithms and were estimated by econometric techniques. The assumption of log-linearity implies that elasticities may be taken directly from estimated coefficients. It would normally be expected that the diagonal elements of the matrix of estimated coefficients would be negative, a direct effect of the availability. Off-diagonal elements would be subject to more complex relationships which make it difficult to anticipate expected signs a priori.

More complexity can be introduced into the model by taking account of the activities of the NZWB. Effectively, this can be handled in one of two ways. If the NZWB is seen as competing with other buyers for wool, then the levels and prices of NZWB purchases have an impact on overall price levels. A suggested formulation is:

$$RP_{ct} = f(RA_{1t}, RA_{2t}, \ldots, RA_{Nt}, RW_{Ct}) \text{ for } c = 1,\ldots,N \tag{3}$$

where RP_{ct} and RA_{ct} are as before, and RW_{ct} = NZWB purchases of category c wool in period t, relative to the total amount of wool available in time t.

A second approach is to assume that the Board has no influence on other buyers, but simply purchases the residual lots that no one else wants. In this case it may be more correct to completely remove the NZWB purchases from the model, so that:

$$RP^*_{ct} = f(RA^*_{1t}, RA^*_{2t}, \ldots, RA^*_{Nt}) \text{ for } c=1,\ldots,N \tag{4}$$

where RP^*_{ct} = price of category c wool in time period t relative to all wool purchased in that period, excluding NZWB purchases, and

RA^*_{ct} = availability of all wool in category c in period t, excluding NZWB purchases in that period.

A difficulty with all these model formats is that the category prices modelled are the aggregate prices for specific user groups. However, any individual lot of wool could appear in more than one category, in the case of overlapping categories. Also, as previously noted, the aggregated category approach does not account for the full effects of implicit characteristic prices. A second set of relationships reflecting these factors can also be developed.

Therefore, a hedonic pricing model of the following form could be estimated using cross-sectional data of the technical characteristics of each auction sale lot:

$$P_l = f(c_{1l}, c_{2l}, \ldots, c_{ml}) \tag{5}$$

where P_l is the price of lot l, and $c_{1l},\ldots,c_{ml}$ are characteristics of the wool in lot l. As with the aggregate models already considered, the lot price P_l could be expressed relative to the overall average price. More importantly, as the cross-sectional data can be allocated to wool categories, it is possible to compare the relationships between price and characteristics between different categories. This means that the price could be expressed relative to the average price of wool in the particular category concerned:

$$P_{cl} = f(c_{1l}, c_{2l}, \ldots, c_{ml}) \qquad (6)$$

where P_{cl} = price of lot l in category c relative to the average price of category c for the period in which the sale occurs (i.e. $P_{cl} = P_l/P_{ct}$ if lot l is sold in period t, where P_{ct} is as previously defined). This provides a linkage to the aggregate time series models through the divisor P_{ct}, the average price of category c wools in time period t, since this is effectively the dependent variable of the time series models. However, the lot price P_{cl} could alternatively be expressed relative to the overall weighted average price for the period in which the sale occurs, P_{Tt}, as calculated for the aggregate models discussed above (i.e. $P_{cl} = P_l/P_{Tt}$). In this case the link to the aggregate models would not be possible since P_{Tt} is exogenous to the models.

As a final step, the hedonic models can be linked to the aggregate models through category availabilities by including the aggregate availabilities directly in the specification:

$$P_{cl} = f(A_{ct}, c_{1l}, \ldots, c_{ml}) \qquad (7)$$

where A_{ct} is the availability of category c wool in the time period t in which lot l is sold. This specification identifies the linkage that can exist between the availability of wool in a category and the impact that availability can have on the valuations of the individual characteristics.

Again the hedonic models have been presented in a general functional form. In order to estimate the above relationships a log-linear functional form was assumed.

The following chapter discusses in more detail the data organisation required in order to estimate the models specified above. Three alternative categories of wool are presented and discussed. Chapter 4 presents the estimation results of some of the equation specifications. Some additional estimation results are presented in the Appendix.

CHAPTER 3

DATA ORGANISATION

The data sample used in the study consists of 6761 observations of wool lots sold by auction at New Zealand wool sales for the period July 1 1982 to June 30 1987. The sample includes wool purchased by both wool exporters and the NZWB.

The sample was constructed by drawing sequentially every 100th lot from the NZWB's data base of all auction wool sales in New Zealand. One feature of this method of sampling is that it imposes a non-random ordering on the sample data, since the raw data itself is ordered on the basis of sale date and location. Associated with each lot in the sample are a number of variables. These variables represent the quality characteristics of the wool in the lot (length, diameter, colour and so on, as objectively measured and recorded by the NZWB or derived using their CONVERT computer program), plus other sundry information (such as date of sale and sale location).

In the original sample data, greasy prices and weights were recorded. Using the yield which was supplied for each lot, prices and volumes were converted to a clean equivalent basis. It was these clean equivalents which were used in the modelling exercise results reported in Chapter 4.

A casual comparison of the actual number of lots sold in each year with the sample indicates that, at an aggregate level, the sample is reasonably representative. That is, the sample data are in line with the national trends in wool auction sales over the period.

Because the data is used on both a cross-sectional and time-series basis and since different groupings or categories of wool are also used, different methods of data management are applied. These approaches are outlined in the following sections. Discussed below are three different categorisations of wool, namely overlapping and mutually exclusive groups, based on NZWB advice, and clusters. These will be referred to as groups, sets and clusters, respectively in the remainder of this report.

3.1 Overlapping Wool Usage Categories (Groups)

Based on parameters provided by the NZWB the data was grouped into six broad usage-defined groups as displayed in Table 1 below. These groups divide the available wool into general processing options, which overlap with other potential uses in many instances. Thus, these groups do not represent the actual processes for which each category of wool is finally used, but rather the potential use of a particular volume of wool possessing certain characteristics. The ability of a wool type to be in several groups is important since it reflects the actual demand for an individual type for a range of end uses.

Table 1
Usage-Group Specification Parameters

Usage Group:	A	B	C	D	E
Length (barbe-mm)	50-150	50-150	<90	<100	50-150
Diameter	<30	28-44	<34	28-44	28-44
Colour (Y-Z)	any	any	any	any	any
Vegetable Matter (%)	<2	<2	<0.3	<0.5	<0.2
Percentage of Total Wool Availability	12.7	82.2	18.2	65.2	28.7

A = Worsted system - fine apparel (woven and knitted)
B = Worsted system - coarse (hand knitted, apparel, interior textiles).
C = Woollen system - fine apparel (knitted, woven, handknitted yarn)
D = Woollen system - coarse (blankets,interior textiles, carpets).
E = Semi-worsted - (handknitting, interior textiles).

Fibre diameter measures the fineness of the wool (microns); length represents the processing length of the wool after carding (mm) - as opposed to the simple staple length; colour here is used to describe the yellowness of the fibre (Y-Z); vegetable matter expresses the physical contamination of the wool itself (%). Another factor considered here which is not used in determining the processing options displayed above, but of potential importance in determining prices, is the percentage of medullated or hollow fibres.

The data supplied by the NZWB contains a range of other characteristics for each lot, including brightness, bulk and yield, which may play a part in determining prices. Also factors such as time of sale and location have been found to be important in previous studies such as that by Simmons (1980).

In addition to the 5 usage-groups, a residual category (group X) exists for all wool not suitable (based on the above criteria) for use in any of the major processes. This mutually exclusive group consists of 6.1 percent of the available clip in the data sample. Although it does not appear in any particular grouping explicitly, it is quite likely that this wool may be used in situations when the marginal prices relative to the marginal costs of any required additional processing are sufficiently favourable. It was generally found that wool was excluded from other groups on the basis of length and that the wool in group X was short wool.

3.2 Mutually Exclusive Categories (Sets)

For this analysis the same raw data and the same user-groups previously identified are used. Data are split into a number of sets containing only intersection or mutually exclusive elements. For example, a set may contain the wool eligible for use in fine to medium worsted processing (A) only, while the next contains wool that is eligible for fine to medium worsted and woollen processing (A and C) only, and so on. Of course a number of sets are empty or contain very few elements such as that for wool only suitable for both fine to medium worsted processing and medium to coarse worsted processing (A and B).

In addition group E forms a complete subset of B. Thus wherever E, occurs, B must also occur. That is, semi-worsted wool processing is a simple component of worsted processing. This can be seen by considering the definitions of the groups B and E previously presented in Table 1.

The mutually exclusive sets are formed for the entire sample, as well as over individual years. A total of 18 sets (including the residual user group X) are constructed for each period, but as Table 2 below displays, 91 percent of the wool is accounted for in the 10 largest sets. Seven of these sets form the basis of the subsequent analysis.

3.3 Categories Defined by Cluster Analysis (Clusters)

The overlapping and mutually exclusive categories previously discussed were based on broad usage-defined groupings from the parameters supplied by the NZWB. A third grouping or categorisation was made based on similarities between wool auction lots inherent in the characteristics of the wool itself. Cluster analysis was used in order to identify the separate groupings. Cluster analysis is a statistical technique which groups observations (in this case, wool auction lots) together on the basis of a measure of closeness or similarity in terms of selected criteria.

Table 2
Mutually Exclusive Sets as a Percentage of
Usage-Groups over 5 year Sample

Usage Group: (%)	A (12.7)	B (82.2)	C (18.2)	D (65.2)	E (28.7)	X (6.1)	
Percentage only in Usage Set:							Percentage of Total:
A	24.2						3.1
B		17.6					14.5
D				4.6			3.0
BD		37.1		46.8			30.5
BDE		18.4		23.2	52.6		15.1
BCDE		7.1	31.9	8.9	20.2		5.8
BE		7.2			20.6		5.9
BCD		4.7	21.4	6.0			3.9
AC	24.4		17.0				3.1
X						100.0	6.1
Other	51.2	7.9	27.0	10.5	6.6	0.0	9.0
Total	100.0	100.0	100.0	100.0	100.0	100.01	100.0

The selection criteria were the same as used previously to identify the usage-groups, namely vegetable matter content, fibre diameter and length.

A range of clustering techniques are available and several were applied to the data. References such as Everitt (1980) and the SAS Institute's Statistics Manual give a description of many clustering techniques and applications.

It was found in general that all those techniques applied to the wool sample data gave similar final clusters of wool lots. Two sets of distinguishing characteristics or variables were used, the first being the three characteristics upon which the usage based groups were defined, namely vegetable matter content, fibre diameter and length. A second clustering based on these three parameters plus a fourth, relative price level, was also made.

The statistical computer package used provides a number of statistics from which it is possible to estimate the most appropriate number of clusters for a given cluster analysis. On the basis of these statistics most of the clustering methods identified four or five key clusters for each set of characteristics. The final clusters themselves also appeared to be quite similar for most of the methods.

Ward's minimum variance method was the clustering technique selected for the results reported in Table 3. This is one of the most commonly used clustering methods. Ward's method is biased towards producing clusters of roughly equal size, although this was not found to be a problem in this analysis. In Ward's method the distance between two clusters is measured as the ANOVA sum of squares between the clusters, summed over all the variables.

Four clusters were found for the first set of three characteristic variables and five clusters for the second set of characteristics when price was included as a variable. Each lot was allocated to one of these four (or five) clusters, so the clusters are mutually exclusive. Strictly speaking, no interpretation of the clusters in terms of end-usage is possible - they are simply groupings of wool with similar characteristics.

Table 3 shows some of the key statistics associated with the characteristic variables determining each set of clusters. The four clusters based on length, diameter and vegetable matter content have some identifiable differences in terms of the means and ranges of these characteristics. Although the boundaries, in terms of characteristic ranges, are not as clear cut as with the previous categories, it is possible to make some broad statements regarding the type of wool in each cluster.

Cluster 1 has high vegetable matter content and a relatively low (compared to the other clusters) mean diameter, but a high variance in diameter. It is also the smallest cluster, by far. Cluster 3, while also mainly shorter wool, has lower average vegetable matter than Cluster 2, and has the finest mean diameter of the four clusters. The final cluster, cluster 4, has the longest, coarsest wool, with generally low vegetable matter content. It is interesting to compare these categorisations, based purely on similarities between characteristics, with the categories based on end usage: there are some clear parallels in terms of distinctions between long coarse wool, short fine wool and so on.

Table 3 Cluster Means

Clusters based on length, diameter and vegetable matter content:

		MEAN			**STD. DEVIATION**			**MINIMUM**			**MAXIMUM**		
Cluster	Number of lots	Length	Veg.	Diam.	Length	Veg.	Diam.	Length	Veg.	Diam.	Length	Veg.	Diam.
1	620	62.78	1.46	28.98	21.39	0.58	4.80	8.6	0.60	18.56	122.0	5.5	41.5
2	2732	66.13	0.43	35.40	11.12	0.25	2.82	23.50	0.10	29.91	86.8	1.6	43.5
3	1157	56.55	0.35	26.71	15.42	0.16	3.53	14.4	0.1	14.5	93.1	0.1	34.0
4	2252	93.93	0.27	35.98	10.69	0.09	3.53	65.0	0.1	27.5	128.0	0.7	44.8
Overall	6761	73.44	0.46	33.52	19.78	0.41	4.99	8.6	0.1	14.5	128.0	5.5	44.8

Table 3 (cont.)

Clusters based on length, diameter and vegetable matter and relative price*

		MEAN				**STD. DEVIATION**				**MINIMUM**				**MAXIMUM**			
Cluster	Number of lots	Length	Veg.	Diam.	Price	Length	Veg.	Diam.	Price	Length	Veg.	Diam.	Price	Length	Veg.	Diam.	Price
1	702	63.54	1.44	30.71	1.33	19.43	0.54	5.27	0.28	8.6	0.7	17.5	0.541	122.0	5.5	42.0	2.40
2	650	53.11	0.41	25.14	1.84	13.14	0.25	3.83	0.47	14.4	0.1	14.5	1.18	83.6	2.0	33.1	3.91
3	1076	54.48	0.47	33.38	1.08	12.59	0.20	3.34	0.16	20.0	0.1	21.0	0.49	97.3	1.0	41.5	1.41
4	2673	88.95	0.28	33.47	1.40	14.44	0.11	3.44	0.11	53.8	0.1	23.0	1.10	128.0	1.2	44.5	2.07
5	1660	72.90	0.34	38.15	1.30	10.23	0.14	2.28	0.08	35.0	0.1	33.3	1.02	92.3	0.9	44.8	1.71
Overall	6761	73.44	0.46	33.52	1.36	19.78	0.41	4.99	0.28	8.6	0.1	14.5	0.49	128.0	5.5	44.8	3.91

* **Note:** relative price, so price = 1 means price equal to market average

The five alternative clusters based on price and the other three characteristics appear to be perhaps less clearly defined. Clusters 1 and 2 contain less than 1000 lots. Cluster 1 consists of wool with much higher average vegetable matter content than the other clusters, but in other respects is not very different from the overall averages. Cluster 2 contains shorter, finer wool, with a high average price. This contrasts with cluster 3, which although it also contains shorter average length wool, has a coarser diameter and much lower average price: in fact cluster 3 has the lowest average relative price of the five clusters. Clusters 4 and 5 both contain wool with greater mean length than the other clusters, with cluster 4 being the largest cluster grouping. Cluster five seems distinguished also by having the highest mean fibre diameter, and contains more coarse wool - the minimum diameter for wool in cluster 5 being 33.3 microns.

In general it seems that including price as a variable in the cluster analysis does not improve the results. Indeed, the distinction between and interpretation of clusters appears less clear than with the previous clustering.

3.4 Aggregation of Data

The original data supplied by the NZWB consisted of observations in date order. However, the sampling process used meant several lots from a single sale could be in the data set, so that as it stood the data was suitable for cross-sectional rather than time series analysis.

Time series data was required for estimation of the aggregate models. It was decided to aggregate data to give a monthly time series. Since five years data were available, this gave 60 monthly observations. Thus, a monthly series of sale volumes and prices was derived by simply summing the wool sold for each month (in the sample), and calculating a monthly weighted average price in the manner described in the discussion of the modelling framework in Chapter 2,

$$Pt = \frac{\sum (P \times A)}{\sum A} \quad \text{for each month}$$

where P = lot price,
A = lot weight.

As mentioned in the discussion of the theoretical model, a similar aggregation can be made for each category, and then volumes and prices relative to the overall monthly volumes and prices calculated for each category.

3.5 Potential Data Problems

Regular seasonal fluctuations in wool demand and supply are well documented, and indeed have been the subject of a number of studies (e.g. Dickson (1987). This seasonality inherent in the data is a potential problem when it comes to estimating the aggregate relationships between price and availability using the time series data. Two commonly used methods to overcome the problem are dummy variables and deseasonalisation by regression, although a host of deseasonalising and smoothing procedures are available. The dummy variable approach simply consists of including a dummy variable for each month in the estimated equation, a variable 1 in the month concerned and zero elsewhere. In the regression approach, the dependent variable (price in this study) is regressed against a set of monthly dummy variables, and then the residuals from this regression used in the estimation procedure.

Johnston (1984) discusses in some detail these and other methods for overcoming seasonality. The work of Lovell (1963) indicates that the choice of deseasonalising method has little or no effect on OLS regression results. The dummy variable approach was chosen in this study, for simplicity and ease of interpretation. Moreover, the inclusion of a set of seasonal dummy variables in the time series models allows for seasonality in both wool prices and availabilities.

Another potential difficulty arises, again with the aggregated data, because of the overlaps (in the case of the "groups"), or similarities (in the case of "sets" and "clusters") between the different categories. Collinearity, which is a common problem with time series models, can be expected from the way many of the variables are defined. However analysis of correlations between variables showed that collinearity was not a major problem; this seemed to be due to the practice of using relative variables (relative prices and volumes) in place of actual levels.

A practical data problem with estimating the time series models was lack of observations for certain categories. In particular, all wool in the group "E" was found to occur only in the period November to January each year. Thus, although group "E" contained a significant amount of the overall wool clip, it could not be used in the time series analysis since there were insufficient monthly observations. This restriction did not apply to the cross-sectional (hedonic) models, however.

A final potential problem is that the composition of the wool categories may change over time, so that the relative prices and availabilities calculated would not be consistent over time. In other words, there may be a non-seasonal movement in the average prices and availabilities of some categories which means that the relative prices and availabilities calculated from the averages are biased. Effectively this means that the wool categories are wrongly identified. This is likely to be more serious for the hedonic models than for the time series models. Regular seasonal fluctuations do not pose a problem for the time series models since the dummy variables cater for this. The danger that exists is that it may be possible for the chosen categories to be separated into smaller groups with widely differing properties.

For the purposes of the analysis it was assumed that this was not the case. However, the outcomes at the three categorisations used was compared. The categorisations based on end-usage reflect the range of uses to which wool can be put, and are based on information supplied by the NZWB. These categories, although rather broad in some cases, cannot be made any smaller on the basis of end usage alone. Moreover, as the cluster analysis identified four or five key clusters it appears that five wool categories is not inappropriate. Indeed, if more categories were used for the time series analysis the case of group "E" would likely be repeated, with insufficient observations available.

A further important aspect of the time series aggregate analysis is that overlaps between the user group categories do exist, and it is this competitive aspect which may determine wool auction prices. In this case, identifying further categories may only serve to weaken the analysis.

CHAPTER 4

RESULTS

Two modelling approaches, and the models that evolved from them, were discussed and presented in Chapter 2. The equations specified in that chapter were formulated as log-linear relationships and estimated using ordinary least squares (OLS). Clean equivalent prices and volumes were used throughout. Estimation results of both the aggregate time series and the cross-sectional hedonic models are summarised in this chapter. The alternative methods of categorising the data are also examined and compared in the light of the estimation results.

4.1 Time Series Analysis of Aggregate Models

The preceding chapter on data has described how the raw wool auction data can be treated as overlapping end-usage determined groups, as mutually exclusive sets based on these groups, or as separate clusters based on the inherent characteristics of the wool itself. Each of these groupings or categorisations may be used as the basis of a time series analysis of auction prices.

As was discussed in the previous chapter, it is possible to develop data on the availability of wool in the individual categories identified by allocating each individual lot in a sale to the appropriate category or categories. By aggregating data on individual lots, it is possible to derive a monthly time series of prices and availabilities in each of the categories (whether usage groups, sets or clusters).

The results of the OLS regression procedures for each of the categorisations are reported in Tables 4 to 6. It should be noted that seasonal dummy variables are included in each equation to account for the seasonality inherent in the data. A time trend variable is also included in order to capture any differences in price trends over time between categories and account for the effects of any omitted exogenous demand shifters. Further, for the groups, the lack of an adequate time series of monthly observations on group E (wools suitable for the semi-worsted processing system) meant that group could not be included in the analysis. Similarly, the mutually exclusive sets which intersect E could not be used: instead, the largest sets not intersecting E were chosen.

Table 4
Time Series Models for Overlapping Groups

GROUP:	A	B	C	D	X
CONSTANT	0.122	0.012	-0.160	0.028	-0.143
	(1.61)	(0.50)	(-1.87)	(1.12)	(-0.88)
TREND	-0.002	0.0003	0.0002	-0.0002	0.0005
	(-3.48)	(1.07)	(0.29)	(-0.83)	(-0.34)
RAVA	-0.035	0.001	-0.009	-0.006	-0.076
	(-2.18)	(0.27)	(-0.51)	(-1.13)	(-2.2)
RAVB	0.060	0.004	-0.465	-0.00003	0.098
	(0.38)	(0.08)	(-2.57)	(-0.00)	(0.29)
RAVC	0.002	0.0004	-0.071	0.0002	0.018
	(0.07)	(0.05)	(-2.92)	(0.03)	(0.35)
RAVD	-0.030	-0.011	0.028	-0.022	0.283
	(-0.42)	(-0.48)	(0.34)	(-0.90)	(1.81)
RAVX	-0.005	0.003	0.009	0.011	0.003
	(-0.50)	(0.81)	(0.79)	(2.95)	(0.10)
RWBA	0.003	-	-	-	-
	(0.59)	-	-	-	-
RWBB	-	0.001	-	-	-
	-	(0.56)	-	-	-
RWBC	-	-	0.015	-	-
	-	-	(2.64)	-	-
RWBD	-	-	-	0.001	-
	-	-		(0.48)	-
RWBX	-	-	-	-	0.004
	-	-	-	-	(0.31)
D1	-0.350	0.013	0.088	-0.008	-0.439
	(-4.56)	(0.51)	(1.02)	(-0.31)	(-2.65)
D2	-0.007	0.001	-0.007	-0.035	0.115
	(-0.15)	(0.09)	(-0.13)	(-2.25)	(1.11)
D3	0.034	-0.030	0.038	-0.056	0.240
	(0.68)	(-1.84)	(0.68)	(-3.35)	(2.20)

(continued)

Table 4 (cont.)

GROUP:	A	B	C	D	X
D4	0.084 (1.55)	-0.065 (-3.67)	0.083 (1.36)	-0.090 (-4.91)	0.274 (2.32)
D5	0.092 (1.85)	-0.067 (-4.13)	0.138 (2.44)	-0.069 (-4.17)	0.248 (2.24)
D6	0.092 (2.04)	-0.036 (-2.48)	0.109 (2.12)	-0.040 (-2.61)	0.187 (1.90)
D7	-0.010 (-0.23)	-0.018 (-1.27)	0.091 (1.79)	-0.017 (-1.12)	0.110 (1.14)
D8	-0.032 (-0.69)	-0.008 (-0.50)	0.077 (1.48)	-0.013 (-0.87)	0.082 (0.81)
D9	-0.003 (-0.08)	-0.010 (-0.71)	0.016 (0.32)	-0.012 (-0.85)	0.102 (1.08)
D10	-0.045 (-1.14)	-0.005 (-0.38)	-0.007 (-0.15)	-0.002 (-0.18)	0.113 (1.33)
D11	-0.067 (-1.61)	0.004 (0.26)	0.010 (0.21)	-0.006 (-0.44)	-0.041 (-0.45)
R-SQUARED	0.75	0.73	0.63	0.82	0.51
ADJ R-SQU	0.62	0.60	0.45	0.74	0.27
DURBIN -WATSON	1.67	2.17	1.59	1.41	1.79

(t-statistics in parentheses)

Table 5
Time Series Models for Mutually Exclusive Sets

SET:	A	B	BCD	BD	X
CONSTANT	0.512	-0.090	-0.044	0.057	0.016
	(2.18)	(-0.91)	(-0.40)	(1.11)	(0.06)
TREND	-0.003	0.004	-0.0003	0.0002	-0.003
	(-1.92)	(6.53)	(-0.54)	(0.73)	(-1.67)
RAVA	0.041	0.013	-0.017	0.008	-0.003
	(1.58)	(1.14)	(-1.37)	(1.38)	(-0.10)
RAVB	0.063	0.177	-0.033	-0.010	-0.021
	(0.95)	(0.63)	(-1.06)	(-0.67)	(-0.25)
RAVBCD	0.017	-0.008	-0.011	-0.014	0.008
	(0.45)	(-0.53)	(-0.61)	(-1.70)	(0.18)
RAVBD	-0.018	-0.008	0.008	0.015	0.109
	(-0.34)	(-0.40)	(0.33)	(1.34)	(1.96)
RAVX	0.004	0.009	0.025	0.025	-0.005
	(0.14)	(0.74)	(1.84)	(3.92)	(-0.13)
RWBA	-0.001	-	-	-	-
	(-0.09)	-	-	-	-
RWBB	-	0.007	-	-	-
	-	(1.34)	-	-	-
RWBBD	-	-	-	0.009	-
	-	-	-	(3.03)	-
RWBX	-	-	-	-	0.012
	-	-	-	-	(0.66)
D2	0.016	0.061	0.025	-0.018	-0.002
	(0.11)	(1.12)	(0.41)	(-0.61)	(0.01)
D3	0.002	0.007	0.043	-0.063	0.103
	(0.01)	(0.13)	(0.66)	(-2.09)	(0.66)
D4	-0.034	-0.010	-0.003	-0.069	0.102
	(-0.24)	(-0.17)	(-0.05)	(-2.34)	(0.70)
D5	0.149	-0.047	-0.034	-0.058	0.243
	(1.01)	(-0.84)	(-0.52)	(-1.91)	(1.60)

(continued)

Table 5 (cont.)

SET:	A	B	BCD	BD	X
D6	0.193 (1.38)	-0.056 (-1.02)	-0.028 (-0.45)	-0.045 (-1.54)	0.229 (1.56)
D7	0.175 (1.13)	-0.0003 (-0.01)	-0.024 (-0.37)	-0.011 (-0.35)	0.173 (1.12)
D8	-0.067 (-0.38)	0.078 (1.12)	-0.060 (-0.78)	0.067 (1.80)	0.110 (0.60)
D9	-0.011 (-0.09)	0.029 (0.61)	0.008 (0.14)	-0.009 (-0.35)	0.094 (0.73)
D10	0.068 (0.55)	0.036 (0.76)	0.016 (0.30)	0.004 (0.16)	0.130 (1.04)
D11	0.048 (0.35)	0.036 (0.70)	-0.011 (-0.61)	0.001 (0.05)	-0.028 (-0.19)
R-SQUARED	0.55	0.78	0.42	0.83	0.42
ADJ R-SQU	0.28	0.64	0.09	0.73	0.07
DURBIN -WATSON	1.81	1.70	1.63	1.52	1.70

(t-statistics in parentheses)

Table 6
Time Series Models for Clusters

CLUSTER:	1	2	3	4
CONSTANT	0.036	0.022	-0.031	0.031
	(0.17)	(0.42)	(-0.24)	(-0.52)
TREND	-0.0001	0.001	-0.0003	-0.00005
	(-0.08)	(2.35)	(-0.45)	(-0.17)
RAV1	-0.027	0.011	-0.009	-0.011
	(-0.99)	(1.65)	(-0.54)	(-1.50)
RAV2	0.075	0.062	0.090	0.010
	(0.88)	(3.15)	(1.77)	(0.44)
RAV3	0.014	-0.0002	-0.04	0.002
	(0.44)	(-0.02)	(-2.10)	(-0.24)
RAV4	0.029	0.0002	-0.023	0.002
	(0.43)	(0.01)	(-0.60)	(0.13)
RWB1	-0.004	-	-	-
	(-0.38)	-	-	-
RWB2	-	-0.0002	-	-
	-	(-0.10)	-	-
RWB3	-	-	0.006	-
	-	-	(1.03)	-
RWB4	-	-	-	-0.0002
	-	-	-	(-0.06)
D1	-0.058	-0.001	-0.249	0.037
	(-0.73)	(-0.06)	(-4.95)	(1.73)
D2	0.067	-0.060	0.017	0.050
	(1.00)	(-3.7)	(0.41)	(2.82)
D3	0.087	-0.101	0.183	0.003
	(1.21)	(-5.90)	(4.02)	(0.15)
D4	0.136	-0.099	0.290	-0.039
	(1.80)	(-5.69)	(6.28)	(-2.00)
D5	0.117	-0.063	0.292	-0.068
	(1.67)	(-3.76)	(6.49)	(-3.58)
D6	0.167	-0.044	0.175	-0.044
	(2.54)	(-2.76)	(4.18)	(-2.54)

(continued)

Table 6 (cont.)

CLUSTER:	1	2	3	4
D7	0.068 (0.97)	-0.014 (-0.85)	0.092 (2.03)	-0.031 (-1.69)
D8	-0.013 (-0.19)	0.009 (0.51)	0.044 (0.98)	-0.018 (-0.96)
D9	0.011 (0.16)	-0.007 (-0.41)	0.036 (0.84)	-0.015 (-0.85)
D10	0.026 (0.41)	-0.005 (-0.36)	0.035 (0.86)	0.003 (0.18)
D11	-0.072 (-1.11)	-0.022 (-1.40)	0.050 (1.20)	0.019 (1.05)
R-SQUARED	0.42	0.87	0.81	0.69
ADJ R-SQU	0.18	0.82	0.72	0.56
DURBIN-WATSON	2.09	2.13	1.66	1.48

(t-statistics in parentheses)

The following variable abbreviations are used in the tables:

Constant - the constant or intercept term
Trend - the time trend variable (1 in month 1, 2 in month 2, and so on)
RAVi - availability of category i type wool relative to the total monthly availability of all wools
RWBi - NZWB purchases relative to the total monthly availability of all wools
Di - seasonal dummy variables, 1 in month i, 0 otherwise

In each equation, the dependent variable is the relative clean equivalent price of wool. The alternative equation specifications discussed in Chapter 2, with NZWB purchases subtracted from available wool, were also estimated but not found to be significantly different from the results presented here.

The results presented for the overlapping usage based categories, in Table 4, are reasonably satisfactory. Most of the coefficients on the main "diagonal" of own price against availability, have the anticipated negative signs. The exception to this is the coefficient of relative availability of group B wools in the B price equation. This may be understandable, since as was shown in Table 1 group B makes up over 80% of the sampled data. Group B may not be sufficiently distinct from the other groups to reveal the expected response and in any case can be expected to be less price sensitive to variations in availability. Groups C and A show the greatest price response to own availability, with statistically significant coefficients of -0.071 and -0.035 on the main diagonal. This suggests that prices for finer wools are more sensitive to changes in availability than those for coarser wools in groups B and D.

Overall the R-squared statistics for the "group" models are all greater than 0.5, and only one, that for the group X wools, is less than 0.65. The Durbin-Watson test statistics do not show autocorrelation to be a major problem. However, relatively few of the coefficients estimated are statistically significant. Only one of the off-diagonal elements measuring substitution and cross-price effects of the different wool types has a statistically significant coefficient: namely the effect of group X availability on group D prices.

Some of the estimated trend coefficients are of possible interest. In particular, the negative coefficients on A and D wools indicates that prices for these wools have fallen, relative to the market average, over the period of the analysis (1982-1987). Group A is fine worsted wool, suitable for fine apparel, while D is coarse woollen wool used in carpets, blankets and interior textiles.

The results reported in Table 5 for the mutually exclusive sets make an interesting comparison. Here, while again the overall R-squared and Durbin-Watson statistics appear satisfactory, there are again very few statistically significant coefficients. Of some concern is the fact that only two of the signs on the estimated "diagonal" elements are negative, and these coefficients are not significantly statistically different from zero. The adjusted R-squared statistics are also low for some of the "sets".

In Table 6 the results for the clusters are presented. These equations also have good explanatory power in terms of R-squared statistics. However as with the sets models there are few statistically significant coefficients and the signs of the main diagonal elements do not accord with expectations, with two coefficients having positive signs. The cluster results seem to be better than those for the sets, in the sense that higher R-squared statistics were obtained and the signs on the diagonal coefficients are little different.

It is interesting also to examine the estimated coefficients on the variables measuring NZWB purchases. For the groups, a number of these have statistically significant coefficients, while for the sets and clusters most are not significantly different from zero. It appears that in general the NZWB's purchasing activities act to increase prices since the estimated coefficients are generally positive. This is what would be expected since that is their stated aim. However, for group B wools the coefficient was negative, though small, which suggests that the effects of NZWB purchasing are not consistent across all wool types.

Overall the time series of aggregate models provide some useful insights into how the availability of wool having certain characteristics may have an impact upon prices of other wools. However, there also seems to be room for some improvement in terms of specification of the relationship, or in the definition of the categories of wool to be used. Comparison of the different categorisations used - groups, sets and clusters - shows the results obtained to be similar in terms of the test statistics such as R-squared and t-statistics. However the groups give results more in accord with the a priori expectations of negative signs on the "diagonal" elements of the matrix of estimated coefficients. These results tend to suggest that it is the overlapping groups which better capture the price arbitrage which takes place between different wool categories.

There is scope for further work in development of a time series model, particularly in view of the low statistical significance attached to most of the coefficients. For instance, a full demand and supply type model, using some form of overlapping category as a basis, might be developed. Moreover, in this study no demand shifting factors have been identified which might differ between categories. This of course would be subject to the availability of suitable data. As it stands, the model developed here and its results do give an indication of some of the processes involved in price determination. The hedonic models also developed, and their results which are reported in the next section, complement the time series model and add to its explanatory power.

4.2 Hedonic Models on Cross-Sectional Data

Hedonic models may be used to describe a cross-section of the wool market over a period of time so as to derive implicit prices for certain characteristics of the wool. Of course they do not in themselves explain the influence of the availability of specific combinations of characteristics. They may, however, serve to quantify relationships which are familiar to those involved in wool marketing, for instance that a premium is paid for wool with low vegetable matter content. In conjunction with the time series models, the hedonic functions make it possible to focus on the factors which will determine the prices of individual lots within the previously defined categories. This considerably enhances the usefulness of the hedonic models as it incorporates the impact of supplies of similar types of wool on the price of an individual lot.

The basic form of the model is to regress the relative auction price of a series of lots against the characteristics - diameter, length, vegetable matter content and so on - of the wool in the lots. This can be carried out for each of the wool groupings previously considered. The models were estimated for each category and also for all observations for the full period (1982-1987) for which data was available. Although prices are in clean equivalent terms, yield is still included in the models (and found to be significant) since yield will have some bearing on processing costs. This was also found to be the case in the Australian study by Simmons. The results are summarised in Tables 7 to 10. The following variables are used in the tables.

CONSTANT = constant or intercept term in regression equation.
VEG = vegetable matter content.
LENGTH = wool length.
DIAM = wool diameter.
BULK = bulk of wool.
BRI = brightness.
MED = medullation.
YELL = yellowness.
YIELD = yield.

The hedonic models for each of the overlapping usage groups were also estimated on a year by year basis. The results are not presented here, but are given in the Appendix. Some of the alternative specifications mentioned in Chapter 2 were also estimated but did not give results significantly different from those reported.

Table 7
Hedonic Model for All Observations

CONSTANT	1.609 (13.73)
VEG	-0.031 (-4.70)
LENGTH	0.002 (15.32)
YELL	-0.044 (-21.77)
MED	-0.005 (-7.06)
DIAM	-0.023 (-29.42)
YIELD	0.542 (12.93)
BULK	0.024 (16.42)
BRI	-0.006 (-4.51)
R-squared	0.48
DW	1.66

(t-statistics in parentheses)

Table 8
Hedonic Models for Overlapping Usage Group Categories

	A	B	C	D	E
CONSTANT	-0.088 (-0.10)	-0.247 (-1.52)	-1.120 (-1.86)	-1.790 (-7.89)	-2.381 (-5.24)
VEG	-0.020 (-3.26)	-0.003 (-1.00)	-0.029 (-2.69)	-0.010 (-2.04)	0.002 (0.25)
LENGTH	0.123 (4.98)	0.181 (25.55)	0.120 (9.22)	0.151 (21.75)	0.135 (14.80)
YELL	-0.034 (-2.47)	-0.092 (-21.06)	-0.033 (-3.30)	-0.074 (-14.14)	-0.032 (-4.49)
MED	-0.016 (-2.47)	-0.012 (-4.12)	-0.020 (-3.03)	-0.014 (-4.32)	-0.005 (-1.41)
DIAM	-1.068 (-21.27)	-0.208 (-13.03)	-0.843 (-23.76)	-0.200 (-11.61)	-0.137 (-5.42)
YIELD	0.016 (0.20)	0.206 (12.39)	0.120 (2.63)	0.188 (10.02)	-0.090 (-3.19)
BULK	0.082 (1.23)	-0.008 (-0.40)	0.361 (7.70)	0.074 (3.35)	-0.040 (-1.09)
BRI	0.753 (3.87)	0.173 (6.15)	0.667 (5.20)	0.503 (11.24)	0.663 (7.21)
R**2	0.60	0.42	0.69	0.42	0.25

(t-statistics in parentheses)

Table 9
Hedonic Models For Sets

SET:	A	B	BCD	BD	X
CONSTANT	-2.534	1.830	-3.143	-1.962	1.308
	(-1.24)	(4.54)	(-3.24)	(-6.21)	(1.78)
VEG	-0.023	0.018	-	0.038	-0.067
	(-1.35)	(2.00)	-	(2.92)	(-4.47)
LENGTH	0.030	0.172	0.092	0.213	0.249
	(0.45)	(7.82)	(2.97)	(15.21)	(6.55)
YELL	0.021	-0.138	-0.036	-0.089	-0.027
	(0.70)	(-10.62)	(-2.12)	(-11.13)	(-1.04)
MED	-0.121	-0.007	0.005	-0.012	-0.014
	(-3.56)	(-0.78)	(0.56)	(-2.00)	(-0.67)
DIAM	-1.107	-0.268	-0.219	-0.096	-0.845
	(-8.93)	(-4.70)	(-1.63)	(-2.67)	(-10.97)
YIELD	0.383	0.366	0.057	0.161	0.752
	(3.36)	(8.51)	(0.89)	(6.19)	(9.77)
BULK	0.652	-0.211	0.113	0.014	0.521
	(3.23)	(-3.46)	(2.02)	(0.45)	(4.17)
BRI	1.166	-0.087	0.850	0.449	-0.112
	(2.78)	(-1.98)	(5.15)	(8.16)	(-0.91)
R**2	0.52	0.54	0.38	0.40	0.56
D-W	1.32	1.45	1.35	1.57	1.60

(t-statistics in parentheses)

Table 10
Hedonic Models for Clusters

CLUSTER:	1	2	3	4
CONSTANT	-1.115 (-1.79)	-0.398 (-2.18)	-1.791 (-2.33)	-2.665 (-6.49)
VEG	-0.023 (-1.07)	0.015 (3.13)	-0.044 (-3.65)	-0.001 (-0.26)
LENGTH	0.138 (5.46)	0.268 (21.32)	0.031 (1.71)	0.136 (10.02)
YELL	-0.051 (-2.79)	-0.140 (-19.63)	-0.040 (-2.97)	-0.021 (-2.92)
MED	-0.016 (-0.86)	-0.015 (-3.67)	-0.029 (-2.52)	-0.001 (-0.25)
DIAM	-0.020 (-7.25)	-0.006 (-6.97)	-0.037 (-19.57)	-0.001 (-1.45)
YIELD	0.472 (6.59)	0.259 (11.37)	0.465 (8.28)	-0.024 (-0.92)
BULK	0.490 (4.06)	-0.015 (-0.51)	0.066 (10.34)	0.032 (1.16)
BRI	0.035 (0.32)	0.020 (0.59)	0.260 (1.45)	0.565 (6.23)
R**2	0.41	0.52	0.63	0.17
D-W	1.50	1.50	1.35	1.22
OBSERVATIONS	620	2732	1157	2252

(t-statistics in parentheses)

In general, the hedonic models for all groups confirm the influence of characteristics on price which are well known to those in the wool industry. For instance, the coefficient on diameter is invariably negative, indicating that relative prices are higher for low diameter, or fine wools. The signs on the estimated coefficients were as expected a priori in almost all cases. The coefficients thus serve to quantify the implicit prices for each of the characteristics in the models.

Perhaps the most interesting outcome is a comparison of coefficients between groups. For example, the coefficients on vegetable matter content for group A and C wools (in Table 8) are -0.020 and -0.029 respectively, while for B wool the coefficient is -0.003. Vegetable matter content appears, in this case, to have a greater impact on prices of fine wools than coarser wools. It is also interesting to compare the statistical significance as measured by the t-statistics across different categories.

Some characteristics are highly significant in some categories, but not so significant in others. For instance, length has a t-statistic of 25.55 for group B (in Table 8), the most significant t-score for this wool group. Yet for group A wools, length has a t-statistic of only 4.98, and it is diameter with a t-statistic of -21.27 which appears to be the "most" significant factor in terms of price. This comparison implies that diameter is the major determinant of fine wool prices, while for coarser wools length is more important; for the coarse wools in groups B and D diameter is relatively unimportant in determining price.

The summary statistics - R-squared and Durbin-Watson appear to vary between groups, in some cases quite significantly. It is interesting to note that these statistics also varied across years, for the overlapping groups (as reported in Appendix A), and yet the actual coefficients estimated were in most cases relatively stable. Some coefficients were unstable across time, however. This problem of temporal instability is not unexpected when performing a cross-sectional analysis such as this across data from a five-year period. Some of the relationships involved are likely to have undergone modifications over time, and hence although nearly all the estimated coefficients have very statistically significant test statistics, the overall R-squareds are not in general high when compared to those achieved in a year by year analysis.

None of the possible categorisations - groups, sets or clusters - appears to give clearly better results overall for the hedonic models in terms of R-squared statistics. This may be because it is certain key characteristics such as diameter and length, used to define the categories, which have the major influence on price. For each categorisation it was certainly true that the coefficients on length and diameter were the most statistically significant.

However, as has already been noted, the coefficients do vary across the different categories within each categorisation. Thus the hedonic models are able to identify different sets of implicit prices for each of the categories. This is useful information since it means, for instance, that rather than applying a fixed implicit price for, say, diameter to all wools, a buyer at auction is able to assign an appropriate implicit price for diameter in a particular lot based on the type of wool in the lot.

CHAPTER 5

CONCLUSIONS

The aims of the study were to examine the relationships between auction prices for different types of wool, to identify categories of wool and to investigate the extent of price linkages and substitution effects. In order to do this, a range of categorisations for wool and two types of models were developed. Given the innovative nature of some of the model work, particularly the aggregated time series models, some difficulties were inevitable. Nonetheless, some useful results have been obtained. The implications of these results are discussed briefly below. Also discussed below are the uses of both the time series and hedonic models and the applicability of the modelling framework presented in previous chapters to price determination.

5.1 Implications of Results

Three different categorisations were used in the modelling exercise: overlapping groups, mutually exclusive sets, and clusters. The overlapping groups represented an innovative concept in models of this type. More work may be needed on the setting of boundaries to the categories however, since for example over 80% of wool in the sample falls within group B. However, the groups were based on end use and finer divisions consistent with end-usage may prove difficult to obtain.

In view of this difficulty, cluster analysis held promise for determining alternative categories. By selecting categories on the basis of inherent similarities between wools, some gains in terms of quality of estimates might have been expected. Some interesting results were obtained, but only four or five categories were identified. These clusters suffered from the problem that they were difficult to interpret or to categorise in terms of end use. The clusters did not significantly outperform the other categorisations in model estimation. Further analysis using different variables as a basis for forming clusters may yield more useful categories - the clusters found in this study did not fulfill their promise.

As a whole, the time series or aggregate models gave quite good explanation of wool prices, in terms of statistical measures such as R-squared. Interactions between the categories were seen to be more effectively captured by having overlapping groups. This contrasts with the more traditional approach of using distinct categories which do not overlap. The overlapping groups also gave individual coefficients which were more in keeping with a priori expectations. However, in view of the low statistical significance of many of the coefficients in these models, it may be that some alternatives need to be considered. One possibility is to develop a full supply and demand model for New Zealand wool, based on the overlapping wool groups used in this study and to identify any other variables which may have an impact on the relationships involved. Certainly, the next natural step would be to include exogenous demand shifting factors which may impact on each of the categories.

The hedonic models also gave satisfactory results which accorded well with a priori expectations. In particular, the signs on individual coefficients were all as expected. The three different categorisations gave similar statistical test results.

Of the three categorisations considered, the results presented in Chapter 4 indicate that the overlapping groups, based on end use, best capture wool price formation.

5.2 Use of Models

The models developed allow a number of questions relating to wool price determination to be examined. Substitution between wool types can be examined by the time series models. If more wool of one type becomes available, the price response of the market to this increased availability can be determined by the model. This response will occur not just in the wool type concerned, but also in other types with similar characteristics.

Table 11 documents the impact elasticities for such supply changes based on the estimates reported in the previous chapter. Using these elasticities, it is possible to calculate how relative prices for each group will change in response to changes in relative availabilities. For instance, if the relative availability of group A wools increases then the relative prices of A and C wools (the finer wools) will drop, according to the impact elasticities in Table 11.

Table 11
Impact Elasticities

% Change in price in response to shock in relative availability

	A	B	C	D
5% shock to A	-0.17	0.01	-0.03	-0.03
5% shock to B	0.30	0.02	-2.30	0.00
5% shock to C	0.01	0.02	-0.35	0.00
5% shock to D	-0.15	-0.06	0.14	-0.11

The price effects are all small in absolute terms, with all but one of the elasticities estimated being less than 1% for a 5% shock in availability. The diagonal elements of Table 11 would be expected to be negative, since the normal response to an increase of availability is anticipated to be a decline in price. The response of wool group B appears perverse in this respect, but is probably due to the extent of overlap between group B and the other groups - as mentioned earlier over 80% of the wool in the sample is in group B.

The substitution effects between group B and D wools (the coarser wool groups) and between groups A and C (the finer wool groups) are emphasised by examining the price changes in these wools in response to increases in the respective relative availabilities. A 5% increase in the relative availability of group B gives rise to no immediate change in the relative price of group D, but the corresponding response of group B's price to an increase in group D availability is a 0.06% fall. Similar effects can be found for other wools.

The fact that relative prices are not especially sensitive to changes in relative availabilities, as evidenced by the small magnitudes of the elasticities reported in Table 11, is itself a valuable piece of information for those concerned with wool marketing.

The major shortcoming of the time series models is that, as discussed in Chapter 2, while they are able to estimate a representative relative price for each group in each month, no information is given on the values of individual lots. This is where the value of the hedonic modelling approach can be seen. In essence, the time series models give an overview of the wool market at an aggregate level while the hedonic models can be applied at the level of individual auction lots.

The hedonic models are able to quantify the relationships between wool characteristics and auction price which are already well known within the wool industry. By separating wool into categories, and estimating on this basis, additional insights into which characteristics are especially important in terms of setting the price of particular types of wool were gained. This is of interest to a buyer at auction who can make use of implicit prices for characteristics to estimate an expected price for a given lot.

Using the overlapping groups, more than one price may be obtained for each lot, since the lot may be categorised in more than one group. These different prices may contain valuable information, since each represents the valuation which a particular end-user places upon the lot. For instance, the "group A" hedonic price of a lot represents the value attached to the lot if it is used to make fine apparel by the worsted system. The final sale price of the lot will be determined by arbitrage between the different end-users: this process will impact on the prices of other lots in affected overlapping groups.

Although the exact details of the arbitrage process are beyond the scope of the models presented here, it is possible to at least estimate ranges within which prices can be expected to fall. Some extension of the models in order to include the process of resolution of conflicting demands for end-usage may be possible.

By linking the time series models with the hedonic models it is possible to incorporate both broad changes in relative availabilities at an aggregate level and the implicit prices of individual lot characteristics into wool prices. This exercise enables a fairly detailed picture of the workings of the wool market and price determination process to be built up since it captures both aggregate supply and demand factors and wool quality factors.

The models presented have thus succeeded in shedding light on the wool price determination process. While there are some obvious avenues for further improvement of both the time series and hedonic models, the study has made some useful first steps towards a new conceptualisation of wool markets.

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APPENDIX

Hedonic Models for Overlapping Groups on Year by Year Basis

The hedonic models for the overlapping groups were also estimated on a year by year basis. These results are presented below. The test statistics, particularly in terms of R-squared, are in many cases higher for individual years than for the full period, 1982-87. This suggests that for some characteristics in some groups implicit prices have changed over time. Those factors which are considered to be the major quality characteristics sought by buyers - particularly diameter and length - show far more stability of coefficients across the time period than others - for instance medullation.

Group A:

	1982-83	1983-84	1984-85	1985-86	1986-87	1982-87
CONSTANT	-5.963 (-1.57)	-1.106 (-0.45)	3.449 (0.47)	0.268 (0.19)	-0.498 (-0.39)	-0.088 (-0.10)
VEG	-0.013 (-0.56)	0.005 (0.36)	-0.036 (-1.28)	0.003 (0.36)	-0.009 (-0.80)	-0.020 (-3.26)
LENGTH	0.150 (2.03)	0.162 (3.67)	-0.007 (-0.07)	0.194 (4.61)	0.069 (1.46)	0.123 (4.98)
YELL	-0.029 (-0.57)	-0.045 (-1.36)	-0.109 (-0.72)	-0.092 (-3.61)	-0.014 (-0.750	-0.034 (-2.47)
MED	-0.018 (-0.51)	0.096 (4.17)	-0.001 (-0.02)	0.023 (1.28)	0.015 (0.82)	0.016 (1.59)
DIAM	-1.14 (-7.29)	-1.312 (-11.44)	-1.020 (-4.97)	-1.074 (-11.85)	-1.030 (-13.74)	-1.068 (-21.27)
YIELD	-0.304 (-1.37)	-0.178 (-1.12)	-0.362 (-1.05)	0.052 (0.40)	-0.047 (-0.38)	0.016 (0.20)
BULK	0.288 (1.35)	0.374 (2.62)	0.092 (0.28)	-0.242 (-2.06)	-0.474 (-4.16)	0.082 (1.23)
BRI	2.103 (2.46)	0.941 (1.74)	0.089 (0.05)	0.854 (2.55)	1.318 (4.76)	0.753 (3.87)
R**2	0.59	0.79	0.49	0.69	0.71	0.60
D-W	1.20	1.43	1.63	1.33	1.50	1.35

(t-statistics in parentheses)

Group B:

	1982-83	1983-84	1984-85	1985-86	1986-87	1982-87
CONSTANT	-2.767	0.256	2.724	-1.694	-2.563	-0.247
	(-2.94)	(0.25)	(7.80)	(-6.18)	(-13.39)	(-1.52)
VEG	0.008	-0.014	0.022	-0.023	-0.026	-0.003
	(1.08)	(-1.97)	(3.21)	(-5.66)	(-6.28)	(-1.00)
LENGTH	0.425	0.311	0.117	0.159	0.148	0.181
	(21.35)	(15.35)	(6.83)	(16.57)	(16.97)	(25.55)
YELL	-0.112	-0.105	-0.157	-0.086	-0.024	-0.092
	(-8.82)	(-7.61)	(-13.11)	(-11.27)	(-4.35)	(-21.06)
MED	-0.026	0.008	0.004	-0.025	-0.016	-0.012
	(-3.47)	(1.05)	(0.65)	(-5.60)	(-4.15)	(-4.12)
DIAM	-0.309	-0.439	-0.451	-0.050	-0.128	-0.208
	(-6.01)	(-8.76)	(-12.07)	(-2.37)	(-5.79)	(-13.03)
YIELD	0.170	0.147	-0.138	0.147	0.370	0.206
	(3.10)	(2.87)	(-2.56)	(4.02)	(11.30)	(12.39)
BULK	0.147	-0.032	-0.202	0.012	0.013	-0.008
	(2.87)	(-0.62)	(-3.80)	(0.38)	(0.49)	(-0.40)
BRI	0.469	0.086	-0.090	0.348	0.572	0.173
	(2.64)	(0.44)	(-2.01)	(6.53)	(17.43)	(6.15)
R**2	0.55	0.49	0.39	0.62	0.72	0.42
D-W	1.81	1.60	1.48	1.31	1.60	

(t-statistics in parentheses)

Group C:

	1982-83	1983-84	1984-85	1985-86	1986-8	1982-87
CONSTANT	-1.545	0.523	10.333	2.619	0.175	-1.120
	(-0.67)	(0.32)	(3.03)	(1.96)	(0.16)	(-1.86)
VEG	-0.022	-0.006	-0.088	-0.082	0.029	-0.029
	(-0.95)	(-0.39)	(-3.13)	(-2.48)	(0.95)	(-2.69)
LENGTH	0.213	0.210	0.068	0.110	0.054	0.120
	(5.92)	(8.39)	(2.30)	(4.91)	(1.63)	(9.22)
YELL	-0.040	-0.044	-0.144	-0.130	-0.031	-0.033
	(-1.20)	(-1.88)	(-2.36)	(-4.98)	(-1.66)	(-3.30)
MED	0.030	0.030	0.063	-0.030	-0.006	-0.020
	(1.80)	(2.40)	(3.01)	(-2.21)	(-0.44)	(-3.03)
DIAM	-0.805	-1.108	-1.098	-0.704	-0.688	-0.843
	(-7.88)	(-15.88)	(-10.72)	(-9.51)	(-10.48)	(-23.76)
YIELD	-0.479	-0.154	-0.256	0.249	0.275	0.120
	(-3.41)	(-1.31)	(-1.65)	(1.80)	(2.28)	(2.63)
BULK	0.352	0.295	0.138	0.152	-0.020	0.361
	(2.65)	(3.46)	(0.88)	(1.50)	(-0.23)	(7.70)
BRI	0.694	0.436	-1.674	-0.236	0.521	0.667
	(1.45)	(1.20)	(-2.17)	(-0.82)	(2.15)	(5.20)
R**2	0.64	0.79	0.39	0.70	0.68	0.69
D-W	1.42	1.50	1.48	1.56	1.51	

(t-statistics in parentheses)

Group D:

	1982-83	1983-84	1984-85	1985-86	1986-87	1982-87
CONSTANT	-2.368 (-2.47)	-2.064 (-2.00)	-0.416 (-0.39)	-3.189 (-6.21)	-2.401 (-9.06)	-1.790 (-7.89)
VEG	-0.023 (-2.14)	-0.026 (-2.67)	-0.008 (-0.60)	-0.077 (-7.83)	-0.062 (-6.84)	-0.010 (-2.04)
LENGTH	0.375 (21.91)	0.247 (15.33)	0.048 (3.23)	0.147 (13.24)	0.154 (12.79)	0.151 (21.75)
YELL	-0.095 (-7.16)	-0.074 (-5.33)	-0.072 (-3.48)	-0.077 (-5.88)	-0.034 (-4.37)	-0.074 (-14.14)
MED	-0.014 (-1.82)	0.015 (1.97)	-0.002 (-0.31)	-0.033 (-6.04)	-0.027 (-5.29)	-0.014 (-4.32)
DIAM	-0.293 (-6.07)	-0.358 (-7.80)	-0.440 (-8.75)	-0.056 (-2.18)	-0.166 (-5.89)	-0.200 (-11.61)
YIELD	0.022 (0.37)	0.083 (1.55)	-0.180 (-2.66)	0.161 (3.46)	0.283 (6.76)	0.188 (10.02)
BULK	0.197 (3.78)	0.116 (2.49)	0.060 (0.92)	0.119 (3.01)	0.062 (1.81)	0.074 (3.35)
BRI	0.380 (1.99)	0.525 (2.52)	0.509 (2.36)	0.640 (5.64)	0.547 (11.14)	0.503 (11.24)
R**2	0.53	0.46	0.36	0.65	0.65	0.42
D-W	1.79	1.72	1.75	1.34	1.39	

(t-statistics in parentheses)

Group E:

	1982-83	1983-84	1984-85	1985-86	1986-87	1982-87
CONSTANT	3.222 (3.13)	2.471 (2.02)	5.957 (1.72)	-2.493 (-3.04)	-6.204 (-9.02)	-2.381 (-5.24)
VEG	-0.036 (-3.10)	-0.064 (-4.71)	-0.006 (-0.19)	- -	- -	0.002 (0.25)
LENGTH	0.237 (12.91)	0.177 (9.00)	-0.001 (-0.02)	0.143 (10.85)	0.080 (6.45)	0.135 (14.80)
YELL	-0.045 (-3.38)	-0.038 (-2.62)	-0.024 (-0.46)	-0.032 (-1.77)	0.040 (2.95)	-0.032 (-4.49)
MED	0.005 (0.60)	0.032 (3.77)	0.041 (2.80)	-0.005 (-0.75)	-0.005 (-0.93)	-0.005 (-1.41)
DIAM	-0.210 (-3.74)	-0.330 (-6.04)	-0.661 (-5.41)	-0.069 (-1.94)	-0.099 (-2.58)	-0.137 (-5.42)
YIELD	-0.386 (-6.32)	-0.457 (-6.99)	-0.664 (-5.13)	0.116 (1.90)	0.160 (2.73)	-0.090 (-3.19)
BULK	0.171 (2.37)	-0.056 (-0.81)	-0.321 (-1.72)	-0.076 (-1.33)	-0.006 (-0.13)	-0.040 (-1.09)
BRI	-0.850 (-4.13)	-0.343 (-1.36)	-0.459 (-0.62)	0.627 (3.43)	1.537 (9.93)	0.663 (7.21)
R**2	0.45	0.40	0.44	0.57	0.60	0.25
D-W	1.60	1.20	1.94	1.32	1.38	

(t-statistics in parentheses)

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