*Australian Journal of Agricultural Economics*, Vol. 34, No. 1 (April 1990), pp. 67–79

# PRODUCT CHARACTERISTICS AND ARBITRAGE IN THE AUSTRALIAN AND NEW ZEALAND WOOL MARKETS*

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**The physical characteristics of wool are important determinants of its spinning properties, yarn quality and end use. The degree to which wools from different countries of origin may be substituted has important implications for the domestic marketing policies of Australia and New Zealand. The hypothesis examined in this paper is that the differences in wool prices can be explained by differences in the physical characteristics of the wool and that objective measures of these characteristics allow for effective arbitrage between these markets. The alternative hypothesis is that premiums or discounts exist owing to country of origin. A hedonic price analysis was conducted on wool prices in Australia and New Zealand using a balanced sample of sale lot data from the 1986–87 selling season. In the year examined, there was no evidence of any price premiums associated with country of origin.**

The physical characteristics of wool largely determine its spinning properties, the quality of yarn produced and its final use. The physical characteristics of wool vary with sheep breeds, production practices and climate. Wool-exporting countries may exploit a comparative advantage in the production of different wool types. Given that substitution possibilities between different wool types are limited in the production of textiles, the degree of direct price competition between export suppliers may, for the most part, be determined by the existing or potential overlap in the profile of product characteristics. This paper examines the question of whether measured differences in wool characteristics explain price differentials and allow effective arbitrage between exporting countries.

The degree to which wools from different countries of origin may be substituted in the production of textiles has important implications for the domestic marketing policies of Australia and New Zealand. Australia and New Zealand are the world's largest exporters of apparel and non-apparel wool, respectively. They both operate buffer stock schemes and engage in promotional activities which to some extent may benefit foreign suppliers.

Wool in Australia and New Zealand is sold under a sample description which includes both objective and subjective measurement. The principal measurements are related to fibre diameter, length, strength, clean yield, vegetable fault and colour. The hypothesis under consideration here is that wools with identical sample measurements are regarded by buyers as perfect substitutes and that these measurements

* Research on this project was supported by a grant from the Wool Research and Development Fund.

allow for effective arbitrage between these markets. The alternative hypothesis is that premiums or discounts exist owing to country of origin. Such premiums could exist if sale lot descriptions are viewed to be incomplete or a country is favoured in terms of reputation for quality. In addition, different selling methods, handling facilities or transport may offer a cost advantage. To evaluate this hypothesis, a hedonic price analysis of wool prices in Australia and New Zealand was conducted using a balanced sample of lot sale data from the 1986–87 selling season.

## *Background*

Several studies have examined the effect of differences in raw wool characteristics most important in processing (Walls 1974; Turpie 1985; Rottenbury, Andrews and Brown 1983). These technical studies identified the four most important characteristics as fibre diameter, length, strength and vegetable matter.

Fibre diameter has been shown to be the major factor influencing the processing and end-use performance of wool and wool textiles. The diameter of fibre will be a major determinant of the end use of the wool. Generally, wools used to produce carpets and other furnishings are of a higher mean fibre density than wools used in apparel goods. Fibre diameter also has a significant effect on end-use properties such as drape in fabrics and resilience in carpets.

Fibre length may improve the spinning performance of wool and to a lesser extent the properties of wool yarn. As with diameter, fibre length will influence the end use of the wool. The length of the fibre is one of the major determinants of the particular method used in processing, that is, the worsted system (semi-worsted in carpet manufacture) or the woollen system. Generally, longer wools are used in the worsted system where the fibres become relatively parallel in the yarn while the woollen system is more suited to shorter fibres where the fibres are more tangled. Yarns from the worsted system are used in the production of woven fabrics which are used to make items such as suits, while yarns from the woollen system are used in the production of knitted goods such as jumpers. Fibre length also affects the quality of the final good. For example, longer fibres may improve fabric abrasion resistance and the strength of knitted fabrics (Turpie 1985; Walls 1974). While fibre length and fibre diameter are important individual characteristics of the wool, they are not independent. Fibre length tends to decrease as wools become finer. Therefore, the interaction of these characteristics is also important.

Fibre strength is of greatest importance in the early stages of the processing system where weaknesses will result in increased fibre breakages during carding and, in the worsted system, during combing. In the worsted system, breakages may lead to a reduction in the mean fibre length of the wool and an increase in noil (short fibres removed during combing), depending on the position of the break in the fibre.

Vegetable matter content and type is also most important in the early processing stage. While the level of vegetable matter generally affects the yield of the wool rather than quality, some types of vegetable matter may lead to wool and/or machinery damage and may thereby affect spinning performance and the quality of the processed wool.

There are other raw wool characteristics which will influence the processing performance of the wool and the properties of the end product. The importance of these characteristics will vary between end uses. For example, it is not desirable to have a high grease content in carpet wools following scouring as this may lead to accelerated soiling characteristics once the carpet is in service (Calver, Franklin-Backhouse, Jackson and Robinson 1988).

These technical findings are consistent with the results of a number of hedonic analyses which have been conducted on wool prices in Australia (Skinner 1965; Simmons 1980; Davidson and Bond 1984; Bramma, Curran and Gilmore 1985). In summary, the results of these studies indicate that fibre diameter and yield were the most important attributes affecting wool prices. Significant relationships are also found for measures related to length, strength, vegetable fault and colour. The relationships between graded attributes of wool and wool prices were, in some cases, non-linear. Furthermore, these relationships have changed over time, as factors affecting the supply and demand for quality characteristics in wool have changed.

Premiums and discounts for different wool characteristics will vary with shifts in demand for the final product. For example, fashion trends away from woollen knitwear towards cotton may partly explain the gradual widening of price differentials between fine and coarse wools in recent years (Beare and Harris 1988). Similarly, developments such as lightweight wool fabrics are likely to increase the demand for fine wools and, hence, attract a premium for this characteristic (Beare and Harris 1988). Price premiums and discounts for individual wool characteristics will also vary over time as supplies of different wool types change.

*Supply*

The micron profiles of Australia and New Zealand differ significantly (see Figure 1). Australia is the largest producer of fine wools with typically around 75 per cent of wool 23 micron and finer. New Zealand is the largest producer of coarse wool with around 75·6 per cent of wool typically 33 micron and coarser.

The climate and topography in New Zealand and the relatively small area of the average farm have favoured the intensive production of prime lambs. Prime lamb production suits the short period of high pasture availability in New Zealand. Returns to farmers are generally greatest where prime lambs are finished during periods of abundant feed before being sold to decrease stocking rates during periods of lower feed availability. Nearly 75 per cent of sheep in New Zealand are Romney Marsh and Romney Marsh cross-breeds which are well suited to prime lamb production and are relatively disease resistant in high rainfall conditions.

In Australia, conditions favour more extensive agricultural industries and the majority of sheep are farmed primarily for their wool. Over three-quarters of the Australian flock are purebred merino.

The different breed compositions of Australia and New Zealand flocks also determine the mean fibre length of each country's wool clip. The majority of sheep in New Zealand are long-wool breeds producing wools of around 200 mm in length if shorn annually. However, the

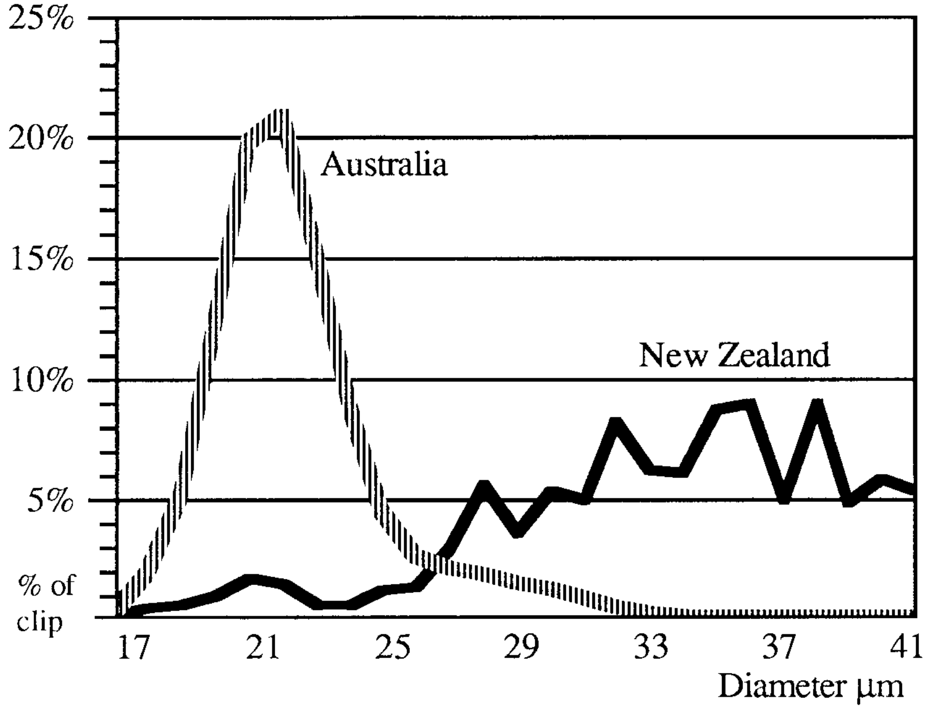


FIGURE 1—Fibre Diameter Profiles of Wool Production 1986–87.

practice of second shearing in New Zealand reduces the length of the clip. In Australia, the finer wool breeds which dominate the flock have annual fibre lengths ranging between approximately 70 and 100 mm. Average vegetable matter content also differs between Australia and New Zealand. The drier Australian climate results in a higher level of vegetable matter in Australian wools compared to those in New Zealand.

The different clip profiles between Australia and New Zealand mean that each country's wool is channelled into the production of different types of end-use items. As a result of the dominance of coarse wools in the New Zealand clip, carpets, blankets and other non-apparel wool items represent an estimated 74 per cent of end uses of New Zealand wool. In Australia, the dominance of fine wools predisposes most of the clip to the production of apparel items.

*Hedonic price models*

The hypothesis that a good is valued for its quality or utility-bearing (hedonic) characteristics has been well advanced in economics. Characteristic demand models were derived within a utility maximisation framework by Theil (1951/52) and Houthakker (1951/52). A consumer's utility was assumed to be a function of both quantity and quality characteristics. Within these analyses the prices of product characteristics are explicitly assumed within the budget constraint.

Lancaster (1971) reformulated the characteristic demand problem by assuming that consumers select a combination of products to achieve an optimal set of characteristics. Here, the budget constraint contains only product prices. Characteristic prices are then derived from first-order conditions:

$$P_i = \sum_j (\partial x_j / \partial q_i)(\partial E / \partial x_j) \tag{1}$$

where $P_i$ is the price of the $i$-th product, $x_j$ is the $j$-th product characteristic, $q_i$ is the quantity of the $i$-th product and $E$ is total expenditure.

The first term is the marginal yield of the $j$-th characteristic from the $i$-th product. The second term is simply the marginal value of the $j$-th characteristic, which can be interpreted as an implicit price.

Ladd and Zober (1977) considered that the physical attributes of a product may not correspond directly to utility-bearing characteristics of goods, as they are perceived by consumers. The problem is similar to that considered by Ladd and Martin (1976) in extending characteristic demand to the derived demand for factor attributes. It is necessary to assume that a functional relationship, consistent with the requirements of a production function, exists between physical input attributes and final product characteristics. Given that marginal rates of transformation can, in principle, be derived from a production process, the implicit price equation may be rewritten.

$$P_i = \sum_j [(\partial E / \partial x_j)(\partial x_j / \partial y_j)]\, \partial y_j / \partial q_i \tag{2}$$

$$= \sum_j [(\partial E / \partial x_j)(\partial x_j / \partial y_j)]\, y_j \tag{3}$$

where $y_j$ is the $j$-th measured attribute of the input (the yield of the attribute per unit quantity). The term enclosed in square brackets is the implicit or hedonic price of the measured attribute.

The marginal value of the $j$-th characteristic, as well as the marginal rate of transformation, may be dependent upon the level of other complementary or substitution relationships. For example, vegetable fault may be more heavily discounted in fine as opposed to coarse wools, as its removal may result in a greater degree of breakage. Thus, the hedonic price relationships may be non-linear in the measured attributes.

## *Analysis*

Weekly data on wool lots sold in Australia and New Zealand for the 1986–87 season were obtained from the Australian Wool Corporation (1987) and the New Zealand Wool Board (1987). The available Australian data consisted of all wool sale lots that were objectively measured for fibre diameter, fibre length, fibre strength, yield and vegetable fault. Fibre length and strength are additional measurements and were available for approximately 5 per cent of total Australian wool sales. The New Zealand data available for the analysis were a sample of sales, consisting of every 100th sale lot over the year. The data provided by the New Zealand Wool Board had measurements for fibre diameter, length, yield, vegetable fault and colour. Both data sets contained price, sale date and lot size information. In 1986–87, prices for almost all categories of Australian and New Zealand wool were above their respective floor prices. The price premiums for fine wools, in particular, were atypical of previous years. Hence, the price differences between similar wools from each country were not influenced by intervention in either country.

In matching the two data sets, only measurements on fibre diameter, fibre length, yield and vegetable fault were retained. The yields were used to convert prices to a clean equivalent basis while weekly exchange rates were used to convert New Zealand prices to Australian dollars.

The fibre diameter composition of the Australian and New Zealand samples differed greatly and the composition of sales varied between sale weeks. Consequently, a balanced sample was constructed taking into account both sale week and fibre diameter. That is, observations from the Australian and New Zealand samples were matched by sale week and micron class.

Fibre diameter classes were defined over 1 micron intervals from 18·5 microns to 30·5 microns. The micron range in the sample was restricted due to limited observations outside of this range. Only auction lots of Australian wools with 'additional measurements' were included in the sample, limiting the number of observations over 30·5 microns, while there were very few observations in the New Zealand data finer than 18·5 microns. For each fibre diameter class, all the observations for the data set containing the minimum number of observations were selected. An equal number of observations were then taken from the remaining data set using a stratified random sampling procedure. Descriptive statistics for the sample are presented in Table 1.

Within the micron ranges selected from the sample data used in the analysis, the mean fibre length is greater in the Australian wools than in those of New Zealand. This is likely to be the result of the presence of second shears and the micron range limiting the number of the longer wools from the sample. The Australian wools in the sample averaged 96 mm while New Zealand wools averaged 65 mm. The average level of vegetable matter in the sample data for Australian wool is approximately 1·4 per cent compared with only around 0·6 per cent in New Zealand.

In the combined data set, clean equivalent prices were normalised by subtracting weekly means. This eliminated the purely temporal variance component of the data. Prices were then regressed against fibre diameter, length, vegetable fault and a binary (country of origin) variable. A quadratic response surface was chosen as a general functional form for the regression. The binary variable was included as a constant term and also as an interactive term with fibre diameter.

TABLE 1

*Descriptive Statistics for the Sample Data*

| | | Mean | | Standard deviation | |
|---|---|---|---|---|---|
| Variable | Unit | Australia | New Zealand | Australia | New Zealand |
| Diameter | $\mu$m | 24·2 | 24·1 | 3·8 | 3·3 |
| Vegetable matter | % | 1·4 | 0·6 | 2·2 | 0·5 |
| Length | mm | 95·4 | 64·8 | 15·5 | 16·1 |

Interactive terms for the remaining variables were not included as the sample was not balanced with respect to these effects.

There are two potential sources of bias in the estimated price relationships which may, in turn, affect conclusions regarding price differentials between Australian and New Zealand wool. The first may result from the omission of a relevant variable, such as strength, which is on average greater in one of the two samples. This could lead to a sample selection bias as only additionally measured Australian wools were included in the sample. If wools suspected of being tender are not subjected to additional measurement the average strength in the Australian sample may be greater than in a random sample of New Zealand wool, resulting in a false price premium.

The second potential source of bias is in the choice of a smooth functional form. The suitability of wool for different end uses (fibre diameter), different spinning systems (fibre length) and different methods of top preparation (vegetable fault) may create discrete thresholds for different characteristics. Consequently, discontinuities may exist in the price relationships for these characteristics. There is a large difference between the mean fibre lengths of the Australian and New Zealand samples. A bias in the length premiums could again lead to false price premiums by country of origin. However, a quadratic function may still yield a good approximation of average length premiums within the various spinning systems.

The regression results are presented in Table 2. Model 1 is the complete quadratic regression with first- and second-order terms for all the included variables. The results suggest that the relationship between price and vegetable matter content was linear over the sample range. Two of the three second-order terms for vegetable matter were deleted to yield Model 2 (a joint $F$-test led to the acceptance of the null hypothesis of no country of origin effect at the 10 per cent level).

A joint $F$-test of the intercept and slope effects of country of origin was made. The results fail to reject the null hypothesis of no effect (there is a 99 per cent chance that the sample would be observed given the null is true). There are a number of factors influencing the power of the test. First, the sample is reasonably large with 264 observations and the confidence level at which the null hypothesis would be rejected is low. Second, there remains a reasonable degree of collinearity between the explanatory variables, as indicated by the variance inflation factors, which would tend to reduce the power of the test. However, variance inflation factors are roughly of the same order for all the variables and significant effects were estimated for fibre diameter, length and vegetable fault. Thus, it is reasonable to conclude that there is no evidence of country of origin effects on Australian and New Zealand wool prices.

The country of origin dummy variables were dropped, yielding the preferred form of the hedonic price model (Model 3). Diagnostic plots were generated from Model 3 to verify the results. Residual plots against time and fibre diameter are presented in Figures 2 and 3 respectively. There is no apparent systematic variation in the Australian and New Zealand residuals over the season. The variance of the residuals does appear to decline with increasing fibre diameter.

While the estimated premiums and discounts for micron, length and vegetable matter are not the primary concern of this study, they are still

TABLE 2

*Regression Results*

| | Model 1 | | | Model 2 | | | Model 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Coefficient | *t*-statistic | Variance inflation factor | Coefficient | *t*-statistic | Variance inflation factor | Coefficient | *t*-statistic | Variance inflation factor |
| Diameter | −2·84 | 13·70 | 394·22 | −2·87 | 13·98 | 387·34 | −2·85 | 14·06 | 381·24 |
| Veg. matter | −0·95 | 2·91 | 253·38 | −0·90 | 4·24 | 106·34 | −0·80 | 4·30 | 90·20 |
| DNZ[a] | −0·78 | 0·82 | 188·43 | −0·62 | 0·66 | 182·55 | | | |
| Length | 0·09 | 3·37 | 258·16 | 0·10 | 3·98 | 228·59 | 0·11 | 7·46 | 84·42 |
| Diameter × DNZ | 0·03 | 0·74 | 185·85 | 0·02 | 0·61 | 179·95 | | | |
| Diameter$^2$ | 0·05 | 11·36 | 441·15 | 0·05 | 11·70 | 431·48 | 0·05 | 12·32 | 403·05 |
| Diameter × Length | −0·001 | 0·70 | 343·89 | −0·001 | 0·95 | 332·83 | −0·001 | 2·46 | 121·94 |
| Length$^2$ | −0·0004 | 4·57 | 59·52 | −0·0004 | 4·84 | 56·39 | −0·0004 | 4·92 | 53·71 |
| Veg. × Diameter | 0·02 | 1·43 | 239·40 | 0·03 | 3·57 | 104·13 | 0·03 | 3·57 | 89·50 |
| Veg. matter$^2$ | 0·01 | 1·33 | 16·03 | | | | | | |
| Veg. × Length | 0·003 | 1·08 | 128·02 | | | | | | |
| $R^2$ | 0·81 | | | 0·81 | | | 0·81 | | |
| $F$* | | | | 1·05 | 0·36 | | 0·27 | 0·99 | |

[a] DNZ is the dummy variable for country of origin.

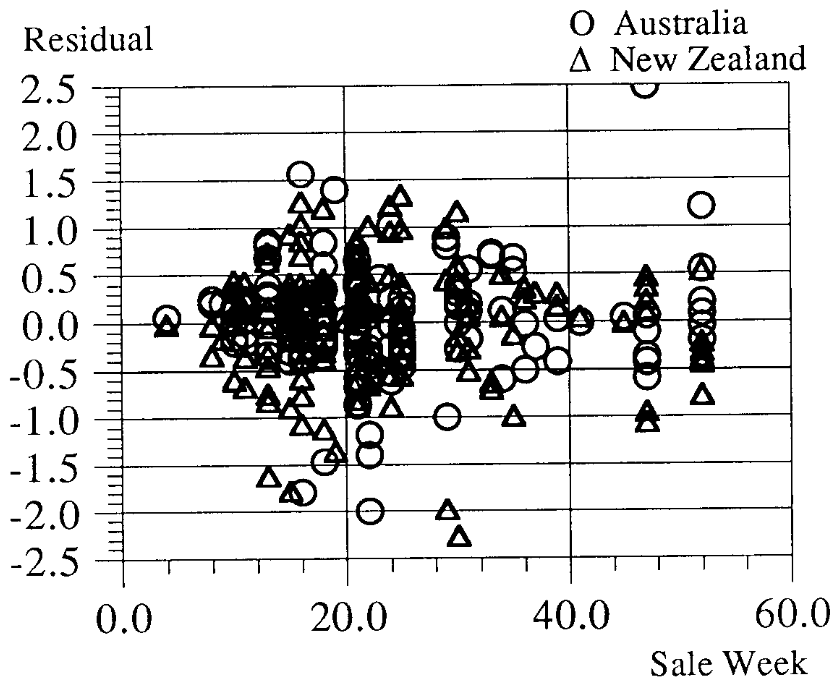


FIGURE 2—Residual Plot Against Sale Week.

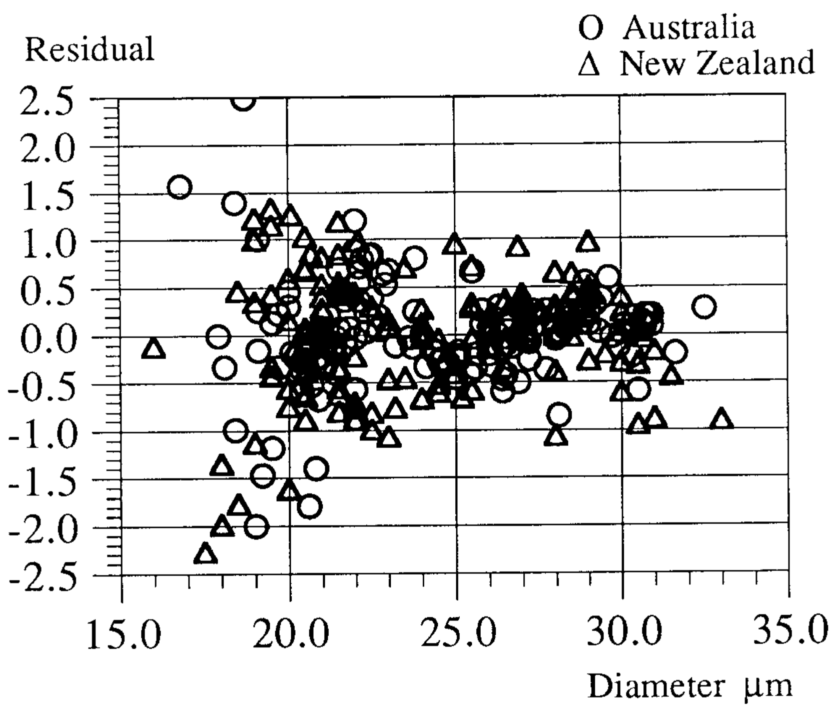


FIGURE 3—Residual Plot Against Fibre Diameter.

of interest as a final check on model specification and data and sample reliability may be verified by examining these results. Contours of the response surface for the 1986–87 season are shown in Figures 4 to 6. It should be noted that some areas of the response surfaces lie outside the bounds of the sample, for example, long fine wools and short coarse wools in Figure 4. Generally, there are substantial premiums for finer wools. Price premiums for finer wools increase as fibre diameter declines. However, there is a critical point in the estimated response surface at around 28·5 microns, above which prices begin to increase with increased fibre diameter. Presumably this represents a point of overlap between wools put to different end uses. While the number of sample observations above 28 microns in diameter was too small to draw any strong inferences, the result suggests that the relationships governing premiums for fibre diameter change for non-apparel uses such as carpets.

Price premiums for fibre length and discounts for vegetable fault increase as fibre diameter decreases. Fine wools spun on the worsted system generally produce a high quality fabric with a soft smooth texture and longer, combing-type wools are desired for processing on the worsted system. As mean fibre length tends to decrease with decreasing fibre diameter, an increased premium for length in finer wools would be expected. However, the strength of raw wool declines with decreasing fibre diameter and, therefore, removal of vegetable matter is more likely to damage finer wools. This results in a discount rate which is non-linear with respect to fibre diameter.

Price premiums for greater fibre length increase at a decreasing rate. This suggests that, in agreement with other studies, spinning characteristics of longer wools improve at a declining rate (Turpie 1985).

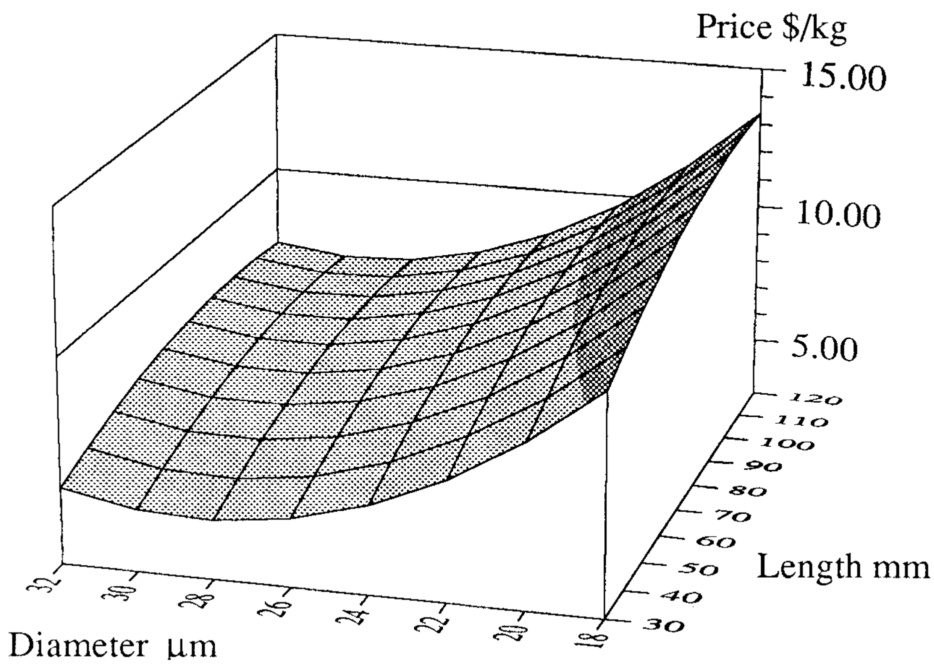


FIGURE 4—Response Surface Between Fibre Diameter and Length.

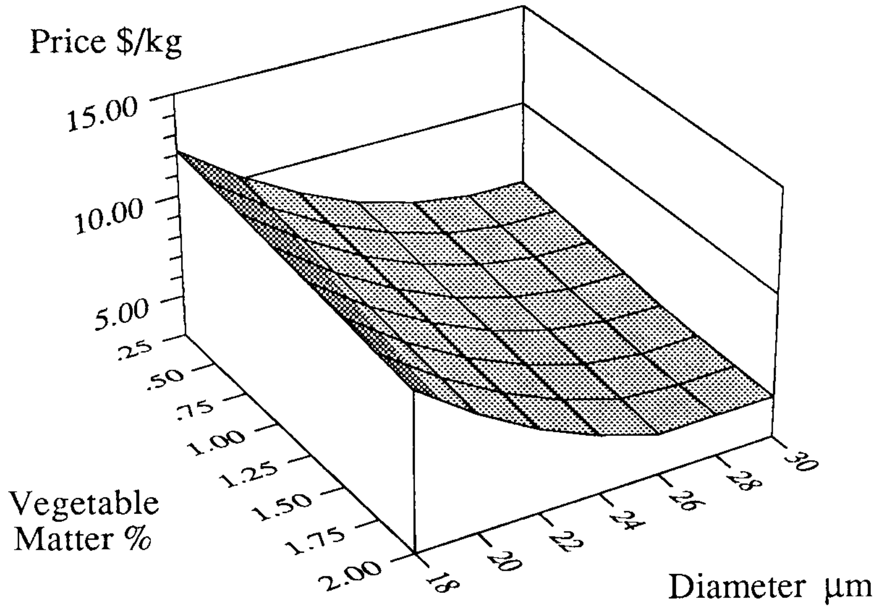


FIGURE 5—Response Surface Between Fibre Diameter and Vegetable Matter.

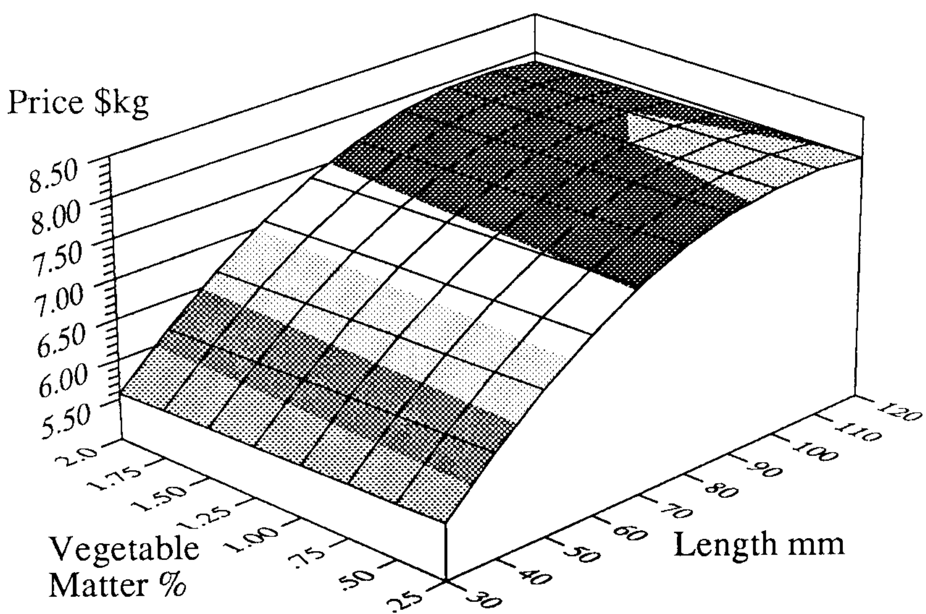


FIGURE 6—Response Surface Between Fibre Length and Vegetable Matter.

However, as noted, there may be a specification problem with a continuous premium for fibre length, as length largely determines the system on which the wool is spun. Fibre length is likely to have a different effect on spinning in the worsted and woollen systems.

The discount rate on vegetable fault is linear. However, as mentioned earlier, most of the sale lot observations contained only light vegetable fault; thus, more severe discounts may apply to heavily faulted wools. While the interactive effects between vegetable matter and length were not significant, this may again apply only over a limited range of vegetable fault. In longer wools, spun on the worsted system, a greater degree of vegetable matter can be removed through combing while shorter wools with a high degree of vegetable fault may require carbonising. Again, changes in processing systems may introduce discontinuities into discounts for vegetable fault.

While the premiums and discounts estimated in this analysis differ from those of other studies, the general response is consistent. Differences in the sizes of the estimates may be attributable to changes in the supply of and demand for the wool.

## *Conclusions*

The results of this analysis indicate that the sale of wool by physical description yields efficient price formation in the Australian and New Zealand wool markets. In the year examined, differences in wool prices in both New Zealand and Australia could be explained by differences in the physical attributes of wool which affect its spinning characteristics and suitability for different end uses. This does not imply that different wool types produced in the different locations are of similar quality, only that price differences can be explained by the different characteristics of the wool. Existing grading standards allow for effective arbitrage between geographically distinct markets.

There is no evidence of any price premiums associated with country of origin. Price differentials between Australian and New Zealand wool can be adequately explained by differences in fibre diameter, fibre length and vegetable fault. Transport and other handling costs do not appear to be significant between the two countries studied here. However, price differentials may exist between other competing wool exporters as a result of these types of costs. The degree of competition between export suppliers may depend on two sets of factors. The first are the characteristic profiles of production and product transformation possibilities in different countries. The second are the substitution possibilities which exist between these characteristics in textile production and final demand.

The substitution possibilities between wools of different fibre diameter and length may be quite limited. Wools of different fibre diameter are generally used in the production of yarns for different end uses. Long and short fibres are generally spun on different systems which yield yarns with distinctly different qualities. Historical observation of the fibre diameter profile in Australia suggests that the adjustment to relative prices is also limited. Geographical location and climate determine strong comparative advantages in the production of different wool types, leading to relatively inflexible product transformation possibilities. Consequently, the potential for change in price competition between wool-exporting countries may be low.

In both countries, the industries operate price stabilisation schemes which may also stabilise prices received for wool by other suppliers. Stockholding associated with these schemes may replace stockholding by foreign suppliers. Australia and New Zealand promote wool with expenditures targeted at different textile end uses. The leakage of benefits to other suppliers from these policies will be determined by the extent to which other suppliers can produce wools which are close substitutes for Australian and New Zealand wools.

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