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AN ECONOMIC EVALUATION OF ADDITIONAL MEASUREMENT IN WOOL PROCESSING

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The introduction of sale by sample and objective measurement in 1973 has resulted in a high level of acceptance and reliance on objective measurement in wool marketing. In January 1985, additional pre-sale measurements of staple length and strength became available and there may now be scope for further commercial gains from increased raw wool specification. Potential benefits from additional measurement for wool processors include increased predictability in top production, improved efficiency in wool purchasing and higher productivity within wool combing firms[1]. An established pre-sale demand for additional measurement could also lead to improved pricing efficiency leading to more informed production and marketing decisions. However, an important issue in wool marketing concerns the uncertainty surrounding the likely magnitude of benefits to processors from adopting additional measurement in relation to the costs of obtaining the information. The magnitude of benefits to processors from additional measurements and their distribution to growers via auction prices will in turn influence the diffusion process for the innovation.

In this note some empirical results are reported concerning one potential source of benefits from additional measurement for wool processors, namely increased predictability of the mean and variance of top length (hauteur). In the next section, some background information is provided about raw wool specification leading to the introduction of pre-sale additional measurement. Analytical concepts underlying a model to estimate benefits accruing to processors from increased predictability are then discussed. Basic risk analysis techniques are applied to the sample data to consider the impact additional measurement may have on uncertain processing outcomes. Finally, the results are discussed and some conclusions are drawn in relation to the benefits and costs of additional measurement.

Recent Developments in Raw Wool Specification

Prior to the introduction of objective measurement, wool processors experienced considerable technical and economic uncertainty in meeting their clients' (spinners') top specifications at minimum costs.

[1] Tops are produced by scouring and combing greasy wool. When finished, a top is a continuous strand of untwisted fibres from which the shorter fibres or noils have been removed by combing. The most important top characteristic is fibre diameter which presently accounts for about 80 per cent of the variation in the price of top. The remainder is accounted for by hauteur and fibre length distribution, not allowing for possible discounts for faults such as dark fibres (Bell 1983).

Subsequently, there has been an improvement in the understanding of the relationship between the core-test information (fibre diameter, yield and vegetable matter) and processed wool characteristics. Using core-test data, processors can predict with confidence the main top valuing characteristics of fibre diameter and the clean yield. Currently, there is virtually complete adoption of pre-sale core-testing, and wool sold with objective measurement normally attracts a price premium in comparison with untested wool (BAE 1979).

Recent developments in technical research have led to the pre-sale availability of the additional raw wool measurements of staple length and staple strength. It has long been established that there is a high correlation between greasy wool diameter and top diameter (David and Andrews 1984). However, the use of core-test measurement and visual appraisal techniques to predict top results still left a large amount of unexplained variation in top length (hauteur). At the same time, it was recognised that staple length and strength could explain a large part of the variation in hauteur (for example, Andrews and Rottenbury 1975; Downes 1975; Hunter 1980). To the extent that hauteur is a significant value determining attribute of top, there was an incentive to develop objective raw wool measures to predict hauteur.

The technical feasibility and logistics of offering pre-sale additional measurement were evaluated with a series of pilot trials in 1980 (known as the sale by additional measurement trials). Following the trials and initial research on the economic consequences of additional measurement by Spinks and Richardson (1980), it was decided to undertake extensive trials to monitor mill consignments for which post-sale measurements of length, strength and colour were available. Subsequently, the trials evaluating additional measurement (TEAM) have provided technical information on combing parcels of wool (up to 300 farm bales) for a range of mills in the major wool processing countries. This has enabled analysis of data to determine the best subset of raw wool characteristics to predict selected top characteristics. Using ordinary least squares regression techniques, it was found that raw wool length and strength, together with diameter and vegetable matter, were significant explanators of hauteur (Australian Wool Corporation 1985). The TEAM research also indicated that these equations could be used by mills to predict top length with greater confidence prior to processing (Australian Wool Corporation 1985).

From the trials it is now evident that additional measurement will assist more accurate technical prediction of top characteristics. However, the project was primarily technical in nature and, therefore, economic issues related to improved prediction were not specifically addressed. Following fibre diameter, hauteur is regarded as the most important top characteristic, although it accounts for a significantly smaller proportion of overall top value. Thus, given that current staple length and strength testing charges are higher than core-test charges, the marginal benefits from increased hauteur predictability must be weighed against the additional testing charges incurred. Thus, the objective of this analysis is to estimate the impact of increased hauteur predictability on the level and variability of processors' revenue. Conclusions may then be drawn concerning the likely demand for additional measurement in relation to current testing costs.

The benefits and costs of additional measurement to individual firms within the combing sector will vary depending on the type of operation. Some mills, typically topmaking firms, deliver top against specific orders and attempt to minimise costs by purchasing greasy wool which just meets the spinners' technical specifications. Other integrated mills produce standard tops and their commercial decisions relate more to blending sale lots of wool, either at the time of purchase or within the mill, to ensure costs are minimised. For commission combers, productivity is the key to benefits from additional measurement since it may be possible to reduce tolerances in machine settings. For integrated mills, predictability, blending and productivity could all play an important role in the level of profitability. While this study is restricted to analysing the improved prediction of hauteur from additional measurement, it is recognised that benefits related to blending and productivity could interact to influence future demand for increased specification.

Method of Analysis

If additional measurement reduces the variance of expected top results, there will be impacts on the level and variability of processors' revenue. Specifically, with additional measurement it is less likely that processors will 'underproduce' hauteur, and thus less likely that the finished top will be discounted by buyers. Similarly, there will be less 'overproduced' hauteur for which the opportunity costs to processors is the revenue forgone by delivering a higher value product against the quoted price, or processing another consignment to correct specification while bearing the risk of re-selling the previously completed top. In other words, processors are likely to achieve the specified hauteur more frequently by using additional measurement.

To estimate the likely benefits of additional measurement in hauteur prediction, a model was developed to assess the benefits of improved predictability to processors resulting from additional measurement using commercial trial data. The purpose of the model is to develop estimates of technical and price differences for a range of tops with and without measurement. The model comprised three stages:

(a) estimation of the extent to which additional measurement for raw wool reduces the variability in top results for hauteur;
(b) determination of price functions for the main value determining top characteristics, that is, top length and diameter; and
(c) estimation of the price effects of reduced hauteur variability.

A precursor to (a) was to determine the difference between hauteur values with and without additional measurement. Mills participating in the TEAM project processed consignments into top using existing core-test results and visual appraisal procedures. Information on the additional measurements was not available to processors prior to processing. The hauteur of top produced in this manner is taken to be the actual hauteur as denoted by H. Hauteur values obtainable *with* measurement were derived by using the 'best fit' regression equations for each mill in the trials. These equations for hauteur are based on the actual top results as a function of a subset of raw wool characteristics. While there were minor differences between mills, fibre diameter, staple length, strength and vegetable matter produced the 'best fit' equation for hauteur and the coefficients for the global equation are reported in Australian Wool Corporation (1984). The hauteur values calculated with these equations ($\hat{H}$) were used as proxies for the hauteur processors would expect to obtain if additional measurement were available. While this procedure is not ideal, the cost of undertaking subsequent experiments based on a new sample and the long lead time involved meant that an alternative approach was impractical.

As part of the trials, processors were also asked to provide their subjective expectation of the hauteur value before processing the consignment. This value, H^*, is the topmakers' subjective appraisal of the top the greasy wool would produce not knowing the additional measurements. Thus, the three values of hauteur that are relevant to the analysis are: H, the actual hauteur achieved by processing a consignment; $\hat{H}$, the value of hauteur that is derived from the predictive equation using diameter, vegetable matter, length and strength; and H^*, the expected value of hauteur, as estimated by processors using the core-test data together with other standard subjectively appraised information.

Using these hauteur values, the following identities can be defined which represent the error in hauteur estimates with and without additional measurement: $(H-H^*)_{ij}$, the topmakers' 'appraisal' error without additional measurement; and $(H-\hat{H})_{ij}$, the residual error that is not due to diameter, length, strength or vegetable matter, for mill i and consignment j.

Based on the assumption that additional measurement benefits processors if predicted results are closer to actual results for hauteur than subjectively assessed values, $|H-H^*|>|H-\hat{H}|$ implies additional measurement allows improved prediction of hauteur. Conversely, $|H-H^*|<|H-\hat{H}|$ implies that subjective appraisal together with existing core-test measurements provide a better prediction method.

The absolute values of the errors form the basis of the analysis since there are costs associated with being both 'over' or 'under' the specified hauteur value. Calculations and comparisons were undertaken for all mill consignments and averages obtained over individual consignments for each mill and over all mills.

The next step in the analysis, part (b) above, was to estimate the price relationships for hauteur and top diameter. Bell (1983) developed the percentage premium/discount relationships for hauteur and diameter graphed in Figure 1. This graph is representative of average price relationships for European topmakers and was derived by estimating percentage premium/discounts applicable to par values for standard tops during 1984. For example, a standard top of 22.5 micrometers is usually 65mm length and would have a value of approximately 680c/kg. If the top produced was 5mm longer than standard, it would attract a 1 per cent premium, increasing the price to 687c/kg. In Figure 1, the premium/discount percentages and par values for tops of 18.5, 20.5, 22.5 25.5 and 27.5 micrometers are detailed and linear interpolation was used to extend premiums/discounts applicable to the range of tops in the sample. Based on these price estimates, the hauteur variability aspect of the model was extended to determine the associated price in part (c) of the analysis.

Let P_{jH}, $P_{j\hat{H}}$ and P_{jH^*} equal the price of top with hauteur H, $\hat{H}$ and H^*,

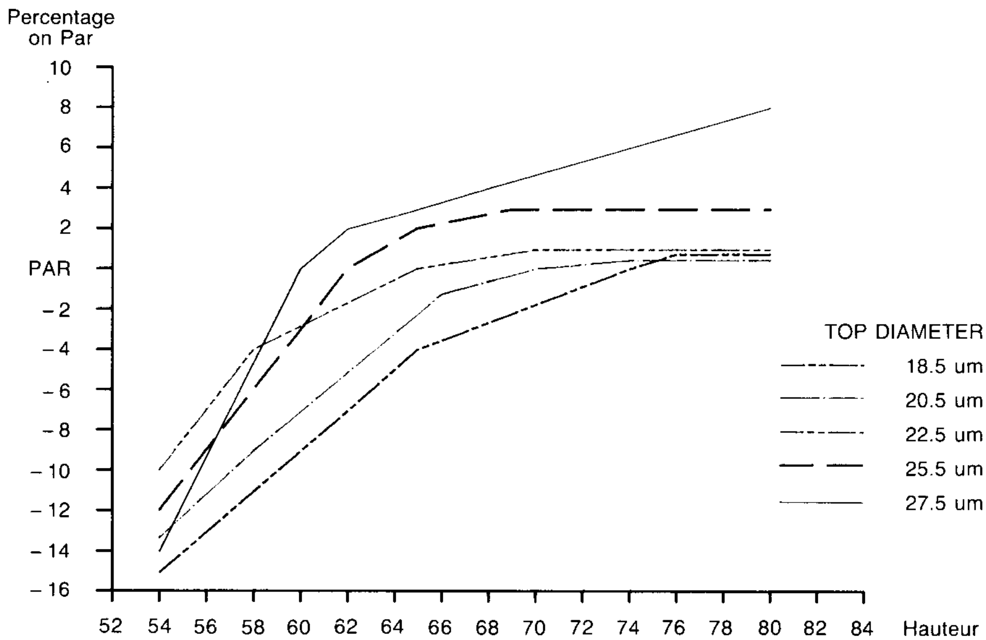

FIGURE 1—Price Premiums/Discounts for Tops.

respectively, for consignment j. The price effect of the subjective processing system (P^*_j) for consignment j can be estimated as:

$$(1) \quad P^*_j = P_{jH} - P_{jH^*}$$

and the price effect for the processing system with additional measurement ($\hat{P}_j$) for consignment j can be estimated as:

$$(2) \quad \hat{P}_j = P_{jH} - P_{j\hat{H}}$$

The difference between both price effects is $PE_j = P^*_j - \hat{P}_j$ and represents the change in the value of top (in cents per kilogram) that arises from using two different methods of predicting the hauteur of a top. The technical identities were then used to assess whether PE_j is a benefit that results from predicting with additional measurement or a cost. If $|H-H^*|>|H-\hat{H}|$, then PE_j will have a positive sign and is a benefit of additional measurement. However, if $|H-H^*|<|H-\hat{H}|$, then PE_j will have a negative sign and represents a cost of additional measurement.

The final step under part (c) of the analysis was to estimate the average revenue (price $\times$ quantity) effect for individual consignments and mills, and on average overall consignments and mills.

The average revenue effect (RE_i) for mill i can be calculated as:

$$(3) \quad RE_i = \frac{1}{m} \sum_{j=1}^{m} \frac{T_j}{100} PE_j$$

where T_j is the quantity of top and PE_j is the dollar amount per consignment that mill i could gain (if it is positive) or lose (if it is negative) when using additional measurement. For technical and price effects with and without measurement, the means and variances were estimated to evaluate the significance of changes to the average level of error.

Stochastic decision analysis

Commercial decisions regarding the use of additional measurement will probably be based on a combination of both the changes to the hauteur error distribution and processors' attitude to risk. The impact of risk could, therefore, be an important decision variable to the extent that processors face uncertain top outcomes.

In the case of hauteur errors, rational decision makers would prefer lower and fewer errors in attempting to achieve the desired hauteur.

In the absence of previous research on processors' risk preferences, a range of risk coefficients was tested so that some casual observations could be made as to whether the results are sensitive to risk assumptions. The main methods that were used in this assessment of risky decision strategies in wool processing were mean–variance (E–V) and stochastic dominance analysis, as outlined in Anderson, Dillon and Hardaker (1977). A detailed coverage of their application in this study is provided in Spinks and Lehmer (1985).

Results and Discussion

The results of the analytical approaches outlined in the previous section are detailed and discussed below.

Technical variability of hauteur

The technical and economic effects of additional measurement for individual mills were highly variable. However, on average, additional measurement seems to have improved the technical specification of raw materials for processors in the sample. The results of the absolute error distributions with and without measurement are detailed in Table 1. The interpretation of the statistics in Table 1 is discussed in terms of the averages over all mills; however, similar interpretations can be made for each mill separately.

The main result is the comparison of the two errors of prediction. The average $|H-H^*|$ is 3.69mm compared with $|H-\hat{H}|$ which is 1.90mm. Thus, on average, predictions of hauteur using additional measurements will, in absolute terms, lead to an average error in estimating hauteur of 2mm in comparison to 4mm without measurement. The corresponding standard deviations of $|H-H^*|$ and $|H-\hat{H}|$ are 4.46mm and 2.48mm, respectively. This means additional measurement has resulted in a smaller spread of the errors around their mean than subjective appraisal. If the errors are normally distributed, about 95 per cent of the errors of subjective appraisal would fall within the range -7mm to $+10$mm, while the corresponding range for additional measurement is -5mm to $+5$mm.

Price and revenue effects

On average, additional measurement increased gross revenue by \$760

TABLE 1

Error Distribution Parameters of Hauteur Prediction

Mill	Moment	$\|H-H^*\|$	$\|H-\hat{H}\|$	Number of consignments
		mm	mm	
A	Mean	6.10	1.99	19
	Standard deviation	3.20	1.50	
B	Mean	4.50	2.40	26
	Standard deviation	3.40	1.99	
C	Mean	2.80	1.40	21
	Standard deviation	2.30	1.40	
D	Mean	3.29	1.90	17
	Standard deviation	2.37	1.50	
E	Mean	1.60	1.70	20
	Standard deviation	1.20	0.40	
Total	Mean	3.69	1.90	104
	Standard deviation	3.01	1.58	

per consignment (Table 2). For mill E, additional measurement did not result in increased technical predictability and therefore its use would 'cost' the mill around $24 per consignment. The benefits were also highly variable between and within mills, as indicated by the large standard deviation of $1836 per consignment. Taking into account the quantity of wool processed per consignment, the average benefit is around 6c/kg clean with a range from 0c/kg to 13c/kg (Table 3).

Impact of risk

The results of the technical risk analysis indicate that additional measurement leads to improved stochastic efficiency in hauteur prediction for four of the five mills, irrespective of the assumed risk attitude. This means that these processors would always prefer using measurement since there is a higher probability of achieving expected top results more frequently and with greater accuracy. However, for mill E similar conclusions cannot be drawn. It is shown that subjective

TABLE 2

Price Effects of Additional Measurement

Mill	Moment	P^*	$\hat{P}$	PE	RE
		c/kg	c/kg	c/kg	$/consignment
A	Mean	22.70	6.40	17.20	1256.70
	Standard deviation	20.10	7.10	15.30	931.60
B	Mean	22.50	9.50	14.07	1156.00
	Standard deviation	35.50	17.10	26.67	147.40
C	Mean	17.42	8.22	13.06	836.89
	Standard deviation	19.26	9.78	16.10	2288.98
D	Mean	17.03	11.52	10.11	448.31
	Standard deviation	13.10	15.02	9.65	862.43
E	Mean	8.43	8.42	8.10	−24.34
	Standard deviation	13.60	10.80	13.65	2419.05
Total	Mean	17.86	8.82	12.61	760.49
	Standard deviation	23.20	12.65	17.98	1836.10

prediction dominates prediction with measurement in the second degree stochastic dominance sense (Spinks and Lehmer 1985).

Turning next to the price effects, for mills A and C, prediction of hauteur with additional measurement dominates subjective apraisal. For mill B, E–V analysis is inconclusive given that the decision strategy depends on the risk coefficient and, if the manager of mill B were a strong risk preferrer, additional measurement may not be the desirable strategy. For mills D and E, the outcome of the E–V analysis is dependent on the technique used for analysis under risk preference assumptions. However, for the range of risk averse assumptions, it is evident that the use of additional measurement will lead to improved hauteur prediction for mills D and E. For all mills combined, risk analysis shows clearly that additional measurement would improve stochastic efficiency in hauteur prediction. The cumulative density functions for technical and price effects are provided in Figures 2 and 3.

Conclusions

In this study the *ex post* benefits to processors from additional measurement through increased predictability of top outcomes have been estimated using commercial trial data. The analytical procedure comprised an evaluation of expected and actual wool top outcomes for hauteur for consignments processed with and without measurement for five European wool processors for which data were available. Due to the commercially sensitive nature of firm-level processing results, there were significant limitations to the collection of data and the analysis that could be undertaken. Nevertheless, the research provides some insight into an innovation affecting decision making at the intermediate demand stage for wool, particularly during an early stage in the adoption process.

Several factors must be appreciated when interpreting the results. First, price relationships in this analysis represent average premiums and discounts applying to hauteur ranges for European top in 1984. In practice, the effects for individual mills may be higher or lower depending on the spinner client, type of operation and top destination. In the longer term, individual mills could develop their own price equations and base commercial decisions on this information. Price

TABLE 3

Benefits (Costs) of Additional Measurement

Mill	Average top consignment	Benefit (cost)
	kg	c/kg of top
A	9 494	13.2
B	11 991	9.6
C	14 315	5.9
D	8 575	5.2
E	16 826	0.0
Total	12 343	6.2

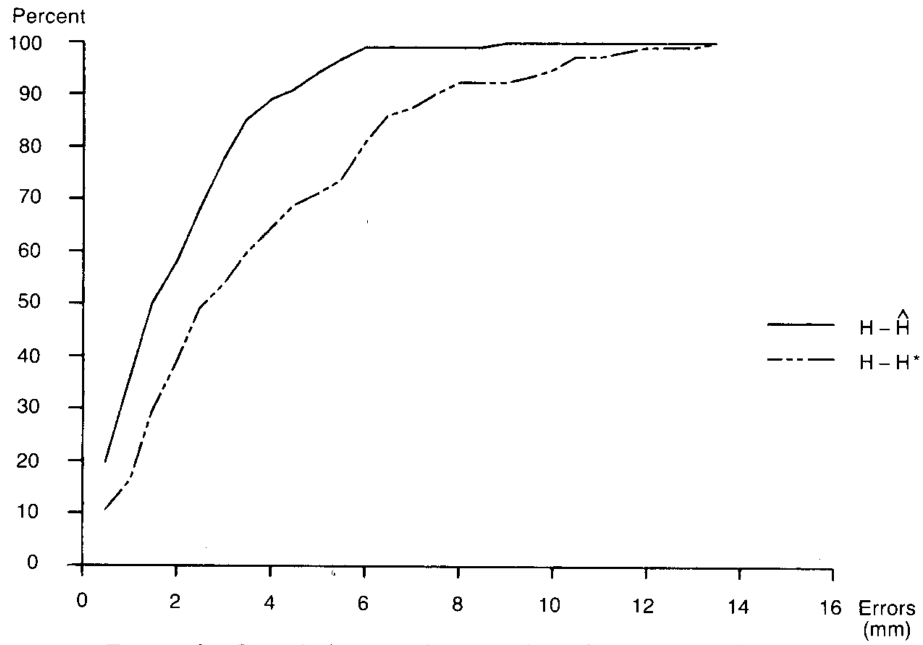

FIGURE 2—Cumulative Density Function of Errors (all mills).

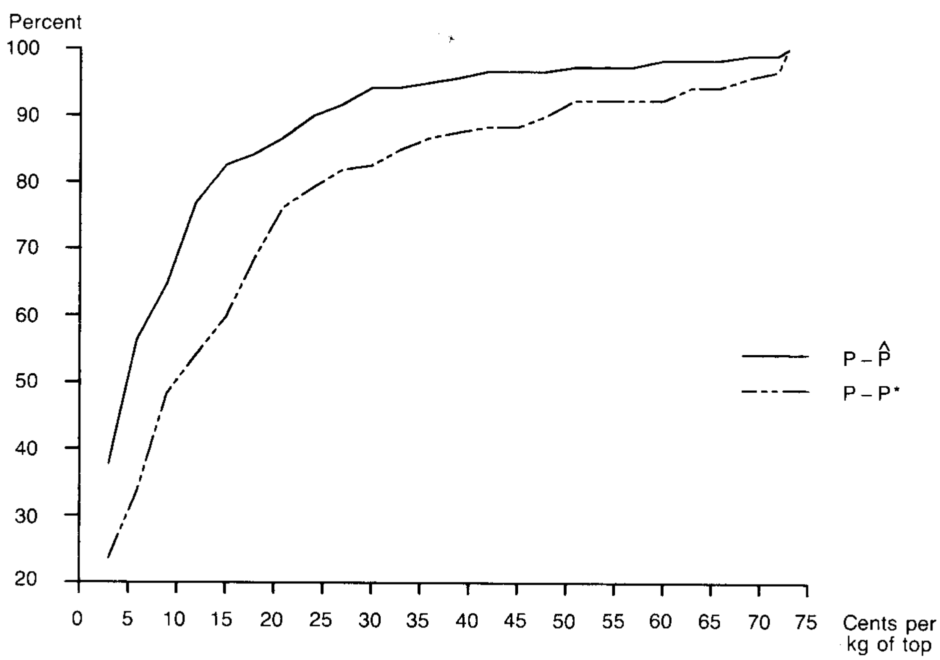

FIGURE 3—Cumulative Density Function of Price Effects (all mills).

relationships will also probably have to be updated through time as spinners change their preferences concerning specification tolerances. In other words, the technical specifications and hence prices paid for hauteur may be refined as increased specification enables improved accuracy of prediction of top outcomes. The results presented here are, therefore, both time and mill specific.

Second, the conclusions of this analysis are confined to mill level gross returns from increased predictability. In the short term, increased predictability may increase processors' confidence, particularly top-makers', in achieving top results leading to higher productivity and more efficient wool blending procedures. Further research is being undertaken to examine the latter aspect as it relates to the principal commercial objective of processors of satisfying technical top requirements at minimum cost.

Risk considerations have been partly incorporated in the analysis by estimating the distribution of errors and associated costs. However, while it can be inferred from these procedures whether or not risk has been reduced by additional measurement, it cannot be concluded that the attitudes to risk of individual mill managers will be the same. Ideally, the risk preferences of mill managers would need to be elicited through a separate study.

Significant average gains to wool processors from the use of additional measurement were identified from increased predictability in the conversion of greasy wool to top. For four out of the five mills in the sample, additional measurement improved technical predictability. There was also a significant reduction in the variation around mean top results with additional measurement compared with using core-test information only. Based on estimated price premiums for European tops, the benefits to processors from increased predictability were estimated to be about 4c/kg greasy (about 6c/kg clean). Current testing charges for additional measurement are $22.00 per lot pre-sale (less than 2c/kg greasy) and $35.50 per lot post-sale (about 2.6c/kg greasy). On this basis, there would seem to be some incentive for wool processors to demand additional measurement.

The stochastic nature of top outcomes, however, means that the benefits from additional measurement also depend on the scope for improved prediction efficiency in relation to risk attitudes. The analysis indicates that additional measurement improves processors' chances of achieving expected top results. However, it was also shown that, at least for some mills, the results are sensitive to the assumption that individual processing firms are risk averse. The authors have no objective basis for assuming wool processors prefer more or less risk in a commercial top making environment, although the latter seems plausible given the tendency of firms in this sample to underestimate hauteur production.

At present, pre-sale testing costs for additional measurements are borne by wool growers while post-sale testing costs are charged directly to processors. Thus, an issue in wool marketing is the extent to which the benefit from increased predictability of processing outcomes is passed back to wool growers in the form of a price premium for wool offered pre-sale with additional measurement information available to the buyer in advance.

In the short term, the possible absence of substantive price information has not prevented a significant number of sale lots being offered for sale with additional measurement. During the first half of the 1985–86 season about 5 per cent of the offering has been sold with additional measurement which could indicate that, initially, the adoption of pre-sale additional measurement by growers is following a similar pattern to that observed for objective measurement. Previous research by Findlay (1980) on the adoption of sale by sample has shown that wool broker policies and grower characteristics, for example, age and contact with other growers, have been significant explanators of the adoption of objective measurement.

In the long term, the commercial incentive for growers to use additional measurement will depend on the emergence of a price premium for additional measurement *vis-à-vis* core-tested wool. It will also depend on the extent to which gains through pricing efficiency can increase the profitability of wool production and marketing as more wool is sold with additional measurement.

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