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Abstract

Based on cointegration analysis and monthly data from 1976.8 to 1999.10, a long-run equilibrium relationship was found to exist between prices for wools of 19 to 23 microns, despite the wool Reserve Price Scheme operated until February 1991. Furthermore, the prices for 19, 20 and 21 micron wools were found to be weakly exogenous. The latter result suggested that, although co-integrated, prices for finer wools tended to be less volatile than coarser wools. The implications are that wool producers would enjoy more stable prices by producing finer wools and that cross-hedging is possible given co-movements of prices.

Key Words: cointegration, error correction model, reserve price scheme, wool marketing.

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Introduction

In 1998/9, wool brought in around $4 billion in export earnings for Australia (806 kt greasy equivalent in volume); however, in 1999/2000, the value of wool exports is expected to be down to $2.764 billion (681 kt greasy equivalent in volume) (Ashton, Alexander and Gleenson 2000). Weak demand and falling profitability in recent times indicate that the wool industry may be in crisis, which prompted another review of the Australian wool industry (Wool Task Force 1999). Two key recommendations regarding wool marketing were made: that producers produce what the customers want; and that producers engage in risk management. Increasing the supply of finer wools is a key step towards meeting changing customer needs, and hedging on the futures market is a key step for managing price risk. However, these recommendations will be taken on board only when producers are convinced that the benefits for doing so outweigh the costs. The main objective of this research is to determine the linkages between prices for wools of different fibre diameter using cointegration analysis. An analysis of the price relationships over time between wools of different fibre diameter would help evaluate potential benefits of producing finer wools. Further, better understanding of the price relationships can provide information that is essential for determining hedging strategies (Lubulwa et al. 1997). In the process, the study also examines the effects on price linkages of the wool Reserve Price Scheme (RPS).

The paper begins with a stylised description of the Australian wool market and a preliminary analysis of the data. It then provides a brief introduction of the main concepts involved in the cointegration analysis and the Johansen procedure (Johansen and Juselius 1990). Estimation and discussion of the results are then provided, including implications for wool marketing. The paper ends with some concluding remarks.

The Australian wool market

Wool is not a homogeneous product. Therefore, the price at any point in time for a specific bale (typically around 500 kg clean) or lot (comprising 5-10 bales of similar wools) is determined primarily by six key quality attributes: micron (fibre diameter), strength, length, colour, style and vegetable matter content (Woolmark Company 2000; Gleeson, Lubulwa and Beare 1993). Among these physical attributes of wool, fibre diameter is by far the most important, accounting for about 60 percent of price variations (Woolmark Company 2000). It is an important attribute because it affects the spinning capacity, strength and texture of the yarns, which in turn determines the fabric quality.

Prices for finer wools are generally higher because they produce fabrics that are softer, less prickly and more comfortable and because supply of finer wools are not as abundant as coarser wools. As such, price differentials between wools of different fibre diameter are determined by the demand and supply balances of associated wools. Moreover, with the passage of time, price differentials may change in response to shifts in the supply and demand (Tomek and Robinson 1990, p.133). Indeed, it has been observed that price differentials between finer and coarser wools have increased in recent years (Griffith 1999). The main reason is the recent fashion changes from more traditional and formal wear (suits, coats and trousers) to casual wear with lighter, softer and easier-care fabrics. This shift in demand is in favour of finer wools at the expense of coarser wools. Since traditionally the Australian wool industry had concentrated on supplying wool for formal wear, the increasing demand for finer wools, not yet matched by supply, has resulted in an increase in premiums for finer wools over coarser wools.

Nevertheless, wools of different fibre diameter are, to varying degrees, potential substitutes (Beare and Meshios 1990). As such, prices of wools of different fibre diameter can be expected to move more or less in tandem over the long run, except of course where market imperfections exist. This means, if the market is efficient, a price change in one type of wool will be followed by similar changes in related wool types. The co-movement among related price series implies that a log-run equilibrium relationship exists among the series and that the series are cointegrated (Banerjee et al. 1993, p. 2-5). In cases where a market is not efficient, price linkages may be weakened or broken.

Therefore, an equilibrium relationship may not exist and the related price series may not be cointegrated. One such market imperfection in the Australian wool market may have been the RPS.

The RPS for Australian wool was introduced in the early 1970s with an aim of stabilising wool prices and thereby insulating growers, and perhaps users, from the extremities of price fluctuations (Bardsley 1994; Garnaut 1993). Under the Scheme, wool was bought and stored as buffer stock when the price was considered to be too low; the stock was later put on the market if the price improved. The Scheme appeared to work well in the early years. However, when the exchange rate was floated in the early 1980s, it became increasingly difficult to manage the Scheme due to exposures to the international financial market. The situation was worsened when the price-setting authority was handed over to the Australian Wool Council (AWC) in 1987 as a part of the general policy of reforming the statutory marketing authorities (Bardsley 1994). As an organisation that represented woolgrowers' interest, AWC soon raised the guaranteed floor price to a level far above the average market-clearing price.

For example, the market indicator (the weighted average price) for wool increased from 508 cents/kg clean in 1986/87 to 645 cents/kg clean in 1987/88, then to 870 cents/kg clean in 1988/89, resulted in a rise of over 70 percent in two years (Malcolm, Sale and Egan 1996). As sales plummeted in response to the steep price increase, the AWC purchases, as well as the borrowing that used to finance the purchases, grew rapidly. In May 1990, the floor price was dropped to 700 cents/kg clean in return for a government guarantee on the debt. However, with no improvement in demand, the Scheme was suspended in February 1991, leaving behind a stockpile of 4.7 million bales and a debt of A$2.7 million. The price of wool fell overnight from 700 cent/kg clean to 430 cents/kg.

The fact that the stockpile comprised mostly broader micron wools was an indication that the lower quality wools had been over-priced, which provided an incentive for woolgrowers to produce excess quantities of inferior wools with no regard for market requirements. Not only did it reduce incentives for growers to be market-oriented, but it inhibited commercial R&D and promotion and discouraged futures trading in favour of the auction system (Garnaut 1993, p. 6). The end result was

the progressive deterioration in the quality of marketing, a less competitive wool industry and the greater use of substitute fibres.

Data

Monthly prices for wools of different fibre diameter were used for the current analysis. The series covered the period from August 1976 to October 1999, providing a total of 279 observations. The price series are and published in the AWEX Eastern Market Indicator and Micron Price Guide and are available for purchase in electronic format from the Woolmark Company. The original price series include the Eastern Market Indicator (EMI) and prices (cents/kg clean) for wools of fibre diameter between 19 and 31 micron. However, only wools of fibre diameter from 19 to 25 micron and 30 micron are available from 1976 when the series were first compiled. These data are also available on a weekly basis.

Among all the wool types produced in Australia, the 22 micron wool is the most commonly produced, accounting for 19.1 percent of total Australian wool production (Stanton and Coss 1995). The second most commonly produced wool is 21 micron (16.5 percent), followed by 23 micron (16.2 percent), 24 micron (10.2 percent), 20 micron (10.2 percent), 25 micron (5.6 percent) and 19 micron (4.8 percent). The remaining 17 percent of total Australian wool production are made up by superfine wools of 15 to 18 micron (less than 2 percent), wools of 26 to 30 micron (about 12 percent) and wools of 31 to 41 micron (about 3 percent).

This study focussed on wools ranging from 19 to 25 micron due to data availability. Together these wool types account for about 83 percent of total wool production in Australia (Stanton and Coss 1995). Because their importance, up-to-date movements in premiums and discounts for this group of wools are published regularly by the Woolmark Company (2000). Moreover, the group is broken down into three micron ranges: fine (18.6 – 20.5 micron), medium (20.6 – 22.5 micron) and broad (22.6 – 24.5) for ease of comparison. They are also of particular interest because the Sydney Futures Exchange (SFE) offers three wool futures contracts: the greasy wool futures contract (21 micron) and the fine (19 micron) and the broad (23 micron) futures contracts (SFE 2000, p.4). The type of futures contracts on offer has significant implications for growers' hedging strategy.

Price volatility

Wool prices, like most other commodity prices, are volatile because both supply of and demand for wool vary widely over time. As such, there is indeed the need for managing price risk, although not necessarily through price stabilisation schemes such as the RPS. One alternative is hedging on the futures market (SFE 2000).

Since the primary objective of the RPS was to stabilise prices, its effectiveness is evaluated by comparing the volatility of prices and price premiums for wools of different fibre diameter before and after the suspension of the RPS. Average values and volatility for prices and price premiums are presented in Tables 1 and 2, respectively. Volatility is measured in terms of coefficient of variation (COV), defined as the ratio of mean over standard deviation. Furthermore, to account for differing levels of rate of inflation in the two sub-periods, all price series are normalised using the price for 25 micron wool as numeraire. As such all prices are in relative terms.

It can be seen that wool prices had become more variable under the RPS than without the RPS. For example, the COV for wool of 19 micron (RP19) was 0.33 with the RPS while it was 0.26 without the RPS (see Table 1). This is true across all wool types. This finding is, however, contrary to what was suggested in Lubulwa et al. (1997, p.8) where prices had become more volatile after the RPS. Also indicated in Table 1 is that price volatility increased with a decrease in fibre diameter. This finding is consistent with the finding of Lubulwa et al. (1997, p.25).

Volatility in price premiums is presented in Table 2. Again, price premiums for adjacent fibre diameter, defined as the difference between prices for wools of adjacent fibre diameter, were more variable with the RPS than without the RPS. For example, the COVs are 1.10 and 0.54 for price premiums for M19 over M20 (M19-20) with the RPS and without the RPS, respectively. Moreover, price premiums for finer wools (M19 to M22) appeared to have increased after the demise of the RPS while price premiums for coarser wools (M23 to M25) had decreased. The latter result is consistent with Griffith's finding that price differentials between finer and coarser wools have accentuated as the demand for finer wools increases. The result is also supported by recent market analysis where prices for wools of 19 micron and finer were found to have risen substantially while 21 micron and broader wools have remained steady (Thomson 2000). It is clear that when the free

market was allowed to operate, prices (premiums) better reflect the demand/supply conditions for wools.

The RPS was also found to have created artificial price linkages between prices and between price premiums. As can be seen from Table 3, with the RPS, coefficients of correlation between wool prices of different fibre diameter range from 0.78 to 0.98, except for 30 micron wool (RP30). By comparison, without the RPS, coefficients of correlation between wool prices of different fibre diameter range from 0.35 to 0.96. In particular, correlation between finer wools (RP19 to RP22) and coarser wools (RP23 to RP24) is greatly reduced (Table 4). As such, it appears that after the RPS, wools of 23 and 24 microns may be considered as a group distinct from wools of 19 to 22 microns.

Similar results are found with price premiums (Tables 5-6), except that some price premiums have moved in opposite directions after the demise of the RPS, as indicated, for example, by the negative coefficients of correlation between M19-20 and M23-24 and M24-25 (second column of Table 6).

Based on these data analyses, it is evident that the RPS had resulted in an increase in volatility of price and price premiums of Australian wool rather than stabilising them, as was intended by the Scheme. Another unintended effect of the RPS is the artificial linkages between finer and broader wools, both in terms of prices and price premiums.

Co-integration analysis

Means, standard deviations, COV and coefficient of correlation were used in the preceding section to compare changes in the price series as a result of the RPS. However, these descriptive statistics are meaningful only if the underlying random variables are stationary, ie having constant mean and variance. Many economic time series are non-stationary and do not have a constant mean or variance (Myers 1994). This is indeed the case for the prices of Australian wools that are under investigation in this research. As such, the properties of the series and relationships between them need to be re-examined based on techniques that are designed for non-stationary data. In the following section, cointegration analysis is conducted to determine the short-run and long-run dynamics of wool prices, taking into account the likely impact of the RPS on price relationships. In

particular, the primary interest is to test whether prices for wools of different fibre diameter are cointegrated.

A set of nonstationary variables are said to be cointegrated if some linear combinations of these variables are stationary (Banerjee et al. 1993). Cointegration implies that long-run equilibrium (stationary) relationships exist among the nonstationary variables. Further, because cointegrated series are linked by common stochastic trends, they do not move independently of each other. As such, one would expect to see systematic co-movements among the series. Moreover, because they are linked, the dynamic paths of those variables are influenced by any deviation from the long-run equilibrium. That is, a cointegrated system is characterised by some error correction process. The relationship between cointegration and error correction is best demonstrated by the Granger Representation Theorem (Engle and Granger 1987). The Theorem states that an error correction model (ECM) representation for a set of variables which are integrated of order one implies cointegration among the variables and vice versa. Moreover, it can be shown that, with re-parameterisation and term manipulation, the ECM can be obtained by transforming a standard vector autoregressive model (VAR) in terms of first differences and error correction factors (Enders 1995, p.367). The transformation is illustrated below.

Given a standard VAR with lag length p, VAR(p), written as:

(1) $x_t = A_0 + A_1 x_{t-1} + ... + A_p x_{t-p} + B D_t + C S_t + v_t, \quad t = 1,...,T,$

where

p = the lag length;

x_t = an (n x 1) vector of variables;

A's = (n x n) matrices of unknown parameters;

x_{t-i} = an (n x 1) vector of the i th lagged value of x_t for i = 1, 2,…, P;

D_t = a set of centred seasonal dummies;

S_t = a set of dummy variables representing structural changes;

As, B and C = unknown parameters to be estimated; and

v_t = white-noise disturbance terms which may be contemporaneously correlated.

Substracting x_{t-1} from each side of equation (1) and letting I be an (n x n) identity matrix, we get

(2) $\Delta x_t = A_0 + (A_1 - I)\,\Delta x_{t-1} + (A_2 + A_1 - I)\,x_{t-2} + \ldots + A_p\,x_{t-p} + B\,D_t + C\,S_t + v_t, \quad t = 1,\ldots,T.$

Next, adding and subtracting $(A_2 + A_1 - I)\,x_{t-3}$ on the right hand side to obtain

(3) $\Delta x_t = A_0 + (A_1 - I)\,\Delta x_{t-1} + (A_2 + A_1 - I)\,x_{t-2} + (A_3 + A_2 + A_1 - I)\,x_{t-3} + \ldots$

$+ A_p\,x_{t-p} + B\,D_t + C\,S_t + v_t,\ t = 1,\ldots,T.$

We can continue in this fashion until we get

(4) $\Delta x_t = \Pi_0 + \Pi_1\,\Delta x_{t-1} + \ldots + \Pi_{p-1}\,\Delta x_{t-(p-1)} + \Pi\,x_{t-p} + B\,D_t + C\,S_t + v_t$

$$= \Pi_0 + \sum_{i=1}^{p-1} \Pi_i\,\Delta x_{t-i} + \Pi\,x_{t-p} + B\,D_t + C\,S_t + v_t,\ t = 1,\ldots,T,$$

where

$\Pi_0 = A_0,$

$\Pi_i = -\,(I - \sum_{j=1}^{i} A_j),\ j = 1, 2, \ldots, p - 1;$

$\Pi = -\,(I - \sum_{i=1}^{p} A_i)$; and

Δx_{t-i} = an (n by 1) vector of x_{t-i} in first differences for i = 1, 2, ..., p - 1.

Other variables are as previously defined. For detailed derivations, see Enders (1995, pp. 389-90).

Therefore, without any loss of information, we have transformed a VAR(p) into a ECM(p) with an error correction term, $\Pi\ x_{t-p}$. The Π matrix is of primary importance. Firstly, the rank of Π provides the basis for determining the existence of cointegration or the long-run relationship among the variables. According to Johansen (1988), if Rank(Π) is zero, then the variables are not cointegrated and the model is equivalent to a VAR in first differences. If $0 < \text{Rank}(\Pi) < n$, then the variables are cointegrated. And if Rank(Π) = n, then the variables are stationary and the model is equivalent to a VAR in levels.

Secondly, the Π matrix can be decomposed into the product of matrices α and β, ie $\Pi = \alpha ß'$. ß is the matrix representing the cointegrating relations. When $ß'x_t = 0$, the system is in equilibrium; otherwise, $ß'x_t$ is the deviation from the long-run equilibrium (or the equilibrium error) and is stationary in a cointegrated system (Johansen and Juselius 1990). α is the matrix of speed of adjustment coefficients, which characterises the long-run dynamics of the system. A large (small) value of α means that the system will respond to a deviation from the long-run equilibrium with a rapid (slow) adjustment. On the other hand, if α is zero for some equation, it implies that the corresponding variable is weakly exogenous and does not respond to equilibrium error. In a cointegrated system, at least one α must be non-zero.

Based on these concepts, a testing procedure for cointegration (the Johansen procedure) is proposed by Johansen and Juselius (1990). The Johansen procedure involves (1) pre-testing the order of integration of individual series, (2) determining the lag length for the ECM, and (3) estimating the ECM and determining the rank of Π (Enders 1995, pp.396-400).

Empirical model and estimated results

In this section, the Johansen procedure is carried out to test the hypothesis that long-run relationships exist among prices for Australian wool.

First of all, the order of integration for wool prices (expressed in relative prices) of different fibre diameters is tested based on the augmented Dickey-Fuller (DF) test using SHAZAM (Version 8,

1997). The results indicate that the null hypothesis of a unit root cannot be rejected for all the prices considered. The same tests are performed on the first differences of these series and the rejection of the null hypothesis of a unit root verifies that all prices are integrated of order one, I(1).

After confirming that the price series under consideration are I(1), the next step is to determine the proper lag length for the ECM. This involves making pair-wise comparisons between various versions of standard VAR, each having a different lag length, based on the likelihood ratio (LR) tests (Enders 1995, pp. 312-315). For the wool data, the standard VAR in equation (1) are defined as follows:

x_t = [$RP19_t$, $RP20_t$, $RP21_t$, $RP22_t$, $RP23_t$]' = a vector of prices, expressed in relative price terms using M25 as numeraire, eg RP19 = M19/M25; t = 1, 2,…, 279.

x_{t-i} =[$RP19_{t-i}$, $RP20_{t-i}$, $RP21_{t-i}$, $RP22_{t-i}$, $RP23_{t-i}$]' for i = 1, 2, 3,..., p;

S_t = 1 for the period between 1976.8 to 1991.2 when the RPS was in operation; and S_t = 0, otherwise; and

D_t = centred monthly seasonal dummies, using December as the base period.

Other variables are as previously defined. In terms of model specification, a conscious decision was made to measure prices in terms of relative price. It is believed that the relative measure removes the deterministic time trends, as well as accounts for differing rates of inflation, as discussed earlier, and therefore is a more appropriate indicator for real changes over time. Another advantage is that the relative prices can be interpreted as price premiums in percentage terms (Gardner 1975). S_t is included in the VAR model to capture the likely impact of the RPS on the system dynamics. D_t is included to capture possible seasonality associated with monthly data. The relevance of both dummy variables are tested based on LR tests.

Using RATS (Doan 1996), the LR test results suggest that 16 months to be the appropriate lag for the model, ie p = 16. In addition, they indicate that neither seasonality nor the RPS had an impact on the price relationships. As such, both dummy variables were excluded from the ECM. The finding

that the RPS had no impact on the price relationships is surprising and contradicts the results that are presented in the price volatility section, where the RPS is shown to have increased price volatility and distorted price linkages. However, one should bear in mind that we are dealing with nonstationary data and as such some results may not be comparable with those results that assume stationarity.

With the lag length of the ECM being determined, the ECM(16), based on the wool data, is specified as:

$$(5) \qquad \Delta x_t = \Pi_0 + \sum_{i=1}^{15} \Pi_i \Delta x_{t-i} + \Pi\, x_{t-16} + v_t,$$

where

$\Delta x_t = [\Delta RP19_t, \Delta RP20_t, \Delta RP21_t, \Delta RP22_t, \Delta RP23_t]'$ = prices in first differences;

$\Delta x_{t-i} = [\Delta RP19_{t-i}, \Delta RP20_{t-i}, \Delta RP21_{t-i}, \Delta RP22_{t-i}, \Delta RP23_{t-i}]'$ for i = 1, 2, ..., and 15;

$x_{t-16} = [RP19_{t-16}, RP20_{t-16}, RP21_{t-16}, RP22_{t-16}, RP23_{t-16}]'$;

Π_i's = (5 by 5) matrices representing the short-run dynamics; and

$\Pi = \alpha ß'$ = the matrix representing the long-run dynamics.

Other variables are as previously defined.

Because the rank of Π is sensitive to the presence of exogenous variables and deterministic components, two versions of the ECM(16) are estimated using CATS in RATS (Doan 1996). The two versions (Models A and B) differ only in the way the intercept terms (Π_0) are specified. Model A is the unrestricted model where the intercept terms are incorporated as a trend drift in the equation. Model B is the restricted model where the intercept terms are incorporated in the cointegrating vector.

The estimated results regarding the rank of Π for both versions are presented in Table 7. As can be seen from the trace statistics (λ_{trace}), the rank of Π is one for both Model A and Model B. This

means that the five wool prices are cointegrated with one cointegrating relation. The same conclusion is reached based on the maximum eigenvalue statistics (λ_{max}). However, the later results are not presented here to save space. The full results from the ECM are available from the authors for interested readers.

To discriminate between Models A (with a trend drift) and B (with a constant in the cointegrating vector), the test statistic, $LR\lambda$, which is suggested in Enders (1995, pp. 393), is used. The $LR\lambda$ is defined as:

$$(6) \qquad LR\lambda = -T \sum_{i=r+1}^{n} [\ln(1 - \lambda_i^*) - \ln(1 - \lambda_i)],$$

where λ_i^* and λ_i are estimated eigenvalues of the matrix Π for the restricted (Model B) and unrestricted (Model A) models, respectively; r is the number of cointegrating vectors in the unrestricted model; and n is the number of endogenous variables. Given that n = 5 (types of wool considered) and r = 1 (one cointegrating relation), the computed value for $LR\lambda$ is 0.92, which is much smaller than the critical value of 9.49 with four degrees of freedom at the 5 per cent significance level (bottom of Table 7). Therefore, Model B (the restricted version) is not rejected. It is concluded that the data do not exhibit a linear (deterministic) time trend and that it is appropriate to specify the intercept term in the cointegrating vector.

The estimated cointegrating relation or long-run equilibrium relationship (Table 8), normalised by the β associated with the price premium for 19 micron wool, is:

$$(7) \qquad RP19 - 6.33 - 7.55\ RP20 + 20.50\ RP21 - 25.50\ RP22 + 18.23\ RP23 = 0.$$

It can also be written as:

$$(8) \qquad RP19 = 6.33 + 7.55\ RP20 - 20.50\ RP21 + 25.50\ RP22 - 18.23\ RP23.$$

As indicated in equation (8), when the wool market is in equilibrium, the prices for 19, 20 and 22 micron wools are positively related while prices for wools of 21 and 23 microns are negatively related.

The existence of the long-run relationship, as described by equation (7) or (8), means that, first, prices for different types of wool share common stochastic trends and therefore tend to move together over time. Secondly, the system can be expected to return to equilibrium after being perturbed by some exogenous shocks. The speed of adjustment is determined by the value of estimated adjustment coefficients. As shown in the bottom half of Table 8, the estimated αs are –0.01 for RP19, 0.03 for both RP20 and RP22, and 0.02 for both RP21 and RP23. This means that if there is a positive deviation from the long-run equilibrium, the system would respond with a decrease in the price premium for 19 micron wool and an increase in the prices for wools of 20 to 23 microns. Moreover, prices for 20 and 22 micron wools appear to respond faster to equilibrium error than 21 and 23 micron wools, which, in turn, respond faster than the 19 micron wool. However, the adjustment process is likely to be slow, as indicated by the relatively small values of the adjustment coefficients. Therefore, any deviation from the long-run equilibrium can be expected to persist for a relatively long period of time.

Note also that the α coefficients associated with RP19, RP20 and RP21 are statistically insignificantly different from zero at the 5% level of significance while they are highly statistically significant for RP22 and RP23. This result suggests that the prices for 19, 20 and 21 micron wools are weakly exogenous and therefore do not change in response to deviations from the long-run equilibrium. It also means that movements in the prices for 19 to 21 micron wools are less affected by events in the markets for 22 to 23 micron wools but movements in the prices for 22 to 23 micron wools are dictated by events in the markets for 19 to 21 micron wools. Furthermore, the long-run equilibrium in the Australian wool market, after an exogenous shock, is restored primarily by corrections made by wools of 22 to 23 microns. However, this does not imply that finer wools have no influence on the Australian wool market. Rather, changes in these markets are induced by the short-run dynamics of the system.

These results can help provide answers to questions for woolgrowers in two key areas: whether there is a benefit in producing finer wools and whether price risk management is feasible for most woolgrowers of various types of wool. The answer to the first question is positive. That is, if the demand for fine wool is to continue its upward trend, the price premium associated it will increase relative to coarser wools. As this happens, the increase in prices, as a result of an exogenous

demand shock, will cause the system to be out of the equilibrium. Since corrections to re-store equilibrium are made by 22 to 23 micron wools, their prices would tend to be more variable than otherwise. These results imply that woolgrowers would be better-off focusing on fine wool production where prices are relatively less volatile.

That prices for the five wool types considered are cointegrated provides useful information for price risk management. Since quality basis risk depends largely on changing premiums and discounts associated with fibre diameter (Lubulwa et al. 1997, p.25), the finding that these prices are cointegrated and tend to move together implies that cross-hedging is possible. Specific hedging strategies would depend, however, on detailed statistical analysis of the relationship between prices of wool types under consideration, which would be an interesting area for further research.

Conclusion

Wool is one of Australia's largest export commodities. However, it has been in crisis in recent years due to falling demand and prices. Using the Johansen's procedure, the cointegration analysis shows that the five types of wools, with fibre diameter ranging from 19 to 23 micron, are cointegrated of order one. This means that they are nonstationary but linked by common stochastic trends and as such tend to move together over time. Moreover, any deviation from the long-run equilibrium is temporary and will be removed by system dynamics.

Furthermore, wools of 19 to 21 micron were found to be weakly exogenous; therefore, corrections to a deviation from the long-run equilibrium are made primarily in the markets for wools of 22 and 23 microns. The latter result suggested that prices for finer wools would be less volatile, compared with coarser wools which appeared to bear the burden of making price adjustments. The implication is that wool producers would enjoy more stable prices by focusing on finer wools. Cointegration also suggests that cross-hedging is possible given that quality basis risk can be minimised when strong price linkages exist between wool types that are of interest. However, there is no clear evidence that the Reserve Price Scheme had any significant impact on the long-run equilibrium price relationship. This latter result is contradictory to the results obtained from examining variations and correlation of the same series based on the usual summary statistics. Therefore, caution should be exercised in drawing conclusions from the data without a preliminary test for stationality.

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Table 1. Means and variations of prices for wools, with and without the RPS.

	August 1976 – Feb 1991 (with RPS)	March 1991 – November 1999 (without RPS)	August 1976 – November 1999 (entire sample)
RP19	1.77 (0.33)[a]	1.89 (0.26)	1.82 (0.31)
RP20	1.54 (0.26)	1.58 (0.21)	1.56 (0.24)
RP21	1.34 (0.17)	1.35 (0.13)	1.34 (0.15)
RP22	1.28 (0.12)	1.22 (0.08)	1.26 (0.11)
RP23	1.17 (0.08)	1.08 (0.04)	1.14 (0.08)
RP24	1.10 (0.03)	1.05 (0.02)	1.08 (0.04)
RP30	0.80 (0.12)	0.88 (0.06)	0.83 (0.11)
EMI	1.36 (0.12)	1.32 (0.10)	1.35 (0.11)

[a] Figures in parentheses are coefficients of variation, defined as standard deviation/mean.

Table 2. Means and variations of price premiums for wools, with and without the RPS

	August 1976 – Feb 1991 (with RPS)	March 1991 – November 1999 (without RPS)	August 1976 – November 1999 (entire sample)
M19-20	138 (1.10)[a]	151 (0.54)	143 (0.90)
M20-21	125 (1.12)	111 (0.67)	119 (0.99)
M21-22	40 (1.51)	62 (0.78)	49 (1.17)
M22-23	59 (0.88)	69 (0.52)	63 (0.73)
M23-24	43 (1.09)	16 (0.74)	32 (1.22)
M24-25	54 (0.61)	23 (0.41)	42 (0.74)

[a] Figures in parentheses are coefficients of variation, defined as standard deviation/mean.

Table 3. Correlation between wool prices, with the RPS

	RP19	RP20	RP21	RP22	RP23	RP24	RP30
RP19	1.						
RP20	0.97	1.					
RP21	0.93	0.98	1.				
RP22	0.90	0.95	0.98	1.			
RP23	0.89	0.92	0.94	0.98	1.		
RP24	0.78	0.79	0.81	0.87	0.92	1.	
RP30	-0.01	0.13	0.19	0.19	0.11	0.01	1.

Table 4. Correlation between wool prices, without the RPS

	RP19	RP20	RP21	RP22	RP23	RP24	RP30
RP19	1.						
RP20	0.96	1.					
RP21	0.81	0.93	1.				
RP22	0.64	0.79	0.91	1.			
RP23	0.43	0.54	0.57	0.80	1.		
RP24	0.35	0.44	0.41	0.63	0.89	1.	
RP30	0.05	0.12	0.22	0.25	0.15	0.07	1.

Table 5. Correlation between wool price premiums, with the RPS

	M19-20	M20-21	M21-22	M22-23	M23-24	M24-25
M19-20	1.00					
M20-21	0.88	1.00				
M21-22	0.74	0.88	1.00			
M22-23	0.76	0.91	0.89	1.00		
M23-24	0.81	0.92	0.82	0.94	1.00	
M24-25	0.79	0.86	0.75	0.87	0.88	1.00

Table 6. Correlation between wool price premiums, without the RPS

	M19-20	M20-21	M21-22	M22-23	M23-24	M24-25
M19-20	1.00					
M20-21	0.78	1.00				
M21-22	0.56	0.74	1.00			
M22-23	0.21	0.40	0.74	1.00		
M23-24	-0.10	0.07	0.06	0.36	1.00	
M24-25	-0.17	0.03	-0.11	0.09	0.38	1.00

Table 7. Summary of rank tests on matrix Π of the ECM

Model A. Incorporating the constant as a trend drift in the equation		
	Estimated λ	λ_{trace}
λ_1	0.1459	78.58 (64.74)[a]
λ_2	0.0636	37.11 (43.84)
λ_3	0.0405	19.83 (26.70)
λ_4	0.0257	8.97 (13.31)
λ_5	0.0080	2.11 (2.71)
Model B. Restricting the constant in the cointegrating vector		
	Estimated λ	λ_{trace}
λ_1*	0.1460	79.56 (71.66)
λ_2*	0.0636	38.05 (49.92)
λ_3*	0.0406	20.76 (31.88)
λ_4*	0.0277	9.86 (17.79)
λ_5*	0.0093	2.47 (7.50)
LRλ =0.92; χ^2 (df = 4; α = 5%) = 9.49; χ^2 (df = 4; α = 10%) = 7.78		

[a] Figures in parentheses are critical values for λ_{trace} statistics at the 10 percent significance level.

Table 8. Estimated long-run parameters, αs and βs, r = 1

	RP19	RP20	RP21	RP22	RP23	CONSTANT
βs	1.00 (--)[a]	-7.55 (--)	20.50 (--)	-25.50 (--)	18.23 (--)	-6.33 (--)
αs	-0.012 (-0.40)[b]	0.033 (1.69)	0.019 (1.45)	0.033 (3.70)	0.018 (3.20)	--

[a] T-ratios for β coefficients are not calculated.

[b] Figures in parentheses are t-values.