ANALYSIS OF INTEGRATION BETWEEN QUEENSLAND FEED AND MALTING BARLEY MARKETS

Authors

Dr V Jyothi Gali

Senior Research Officer,

Business Strategy Unit,

Department of Primary Industries, Queensland

4th Floor, 80 Ann St, Brisbane 4000, Australia

Telephone: +61 7 3239 3227

Facsimile: +61 7 3239 3685

E-mail: galij@prose.dpi.qld.gov.au

and

Dr C.G. Brown

Senior Lecturer in Agricultural Economics

School of Natural and Rural Systems Management

The University of Queensland, St Lucia campus

Brisbane 4072, Australia

Telephone: +61 7 3365 2148

Facsimile: +61 7 3365 9016

E-mail: colin.brown@mailbox.uq.edu.au

ABSTRACT

Barley can be differentiated into feed and malting barley based on its end-use markets. Substitutability both in supply and in demand complicates analysis of price information in the barley market. The paper examines the price linkages between feed and malting barley in the Queensland barley market by using cointegration and error correction models. Malting barley prices respond to restore equilibrium relationships with corresponding feed barley prices in the long run, but not *vice versa*. Thus there appears to be a price leadership role for feed barley, and one-way substitutability and quality differences in the barley market.

Key words: Barley, Cointegration, Substitutability, Quality

Econ-Lit citations: L100, C22, N57, Q11

1.   INTRODUCTION

One of the most intricate set of grain market relationships occurs between malting and feed barley. Maltsters and intensive livestock feeders have very specific and different requirements. Nonetheless, at the margin, some substitution does arise between feed and malting barley. Only malting barley varieties are suitable for malting barley production, but agronomic practices and growing conditions determine whether barley grown from malting varieties meets the malting grade standards or whether it must be sold as lower priced feed barley. Higher yields of feed barley varieties can counter the lower feed barley prices, although these prices are also influenced by the close substitution relationships with other feed grains. Thus the extent of integration between malting and feed barley markets is important and non-trivial, and is a central focus of this paper.

To explore these relationships fully calls for a detailed structural analysis of barley supply and demand. For the Queensland barley industry, the task has been partly accomplished on the supply side by Jyothi-Gali and Brown (1999), and on the demand side by Jyothi-Gali (1998) and Jyothi-Gali et al. (1998). Instead, this paper examines the price interdependencies that exist in the Queensland barley market drawing on the methods employed in the growing literature on market integration[1]. Apart from being parsimonious in data requirements, the flexibility of this type of analysis allows market structure to be explored and for a number of market parameters such as market integration, arbitrage efficiency, product substitutability and competitiveness of markets to be investigated.

The case of the Queensland barley market examined here captures the problems of a relatively small industry that has experienced recent major changes[2]. Rapid growth in intensive livestock industries in the region coupled with new non-traditional malting and other barley product export markets has altered the target markets for Queensland barley[3]. The region has also experienced significant production variability with extended periods of drought in the first half of the 1990s. Furthermore, industry deregulation and restructuring has dramatically altered the relationships between the various participants in the market. Confronted with this changing agribusiness environment, barley growers cannot rely of 'best practice' or other historical based benchmarks, but must fully understand the market if they are to respond adequately and efficiently. For growers and other industry participants, this task is by no means trivial, and economic tools including market integration may be able to assist them.

A qualitative discussion of the factors that affect co-integration between feed barley and malting barley prices follows. An empirical model used to analyse the extent of market integration is then discussed. The results highlight the price leadership role played by feed barley within the Queensland barley market.

2. FACTORS AFFECTING COINTEGRATION OF FEED AND MALTING BARLEY PRICES

Prices for malting and feed barley between 1985 and 1996 are shown in Figure 1. Although the price series appear to follow a similar pattern, the 'premium' for malting barley varies markedly from year-to-year. Furthermore, it is not clear whether malting barley prices lead feed barley prices or *vice versa*. Before empirically testing these relationships in the remainder of the paper, this section discusses some of the supply, demand and market structure factors that influence the co-movement of malting and feed barley prices.

<center>***Figure 1 around here***</center>

The product requirements for malting barley are more specific than that for feed barley because of the need of maltsters and brewers for consistency in processing[4]. Malting barley can only be produced from specified malting varieties. However, the barley from such varieties must be within a specified protein range and meet other criteria before maltsters accept it.

Feed barley comes from two sources. It may be produced from a malting variety that has failed to meet the malting standards because its protein levels are outside the specified range, or its grain size is to small, or it is generally in poor condition. Intensive livestock feeders in Queensland are less concerned about protein range, as they tend to source their protein from other sources given past price relativities (Jyothi-Gali *et al.* 1998). Intensive livestock users can and do substitute feed barley for other grains in their feed rations, and so feed barley price is also affected by its close substitution with other feed grains.

Feed varieties yield higher than malting varieties.[5] In order to entice growers to grow malting varieties, end users have had to offer a premium for malting barley over feed barley. For historic, institutional and other reasons (Jyothi-Gali 1998), malting barley varieties remain the most popular, accounting for about 60 to 80 per cent of plantings. However, as breeding efforts begin to be partly

<center>4</center>

redirected at feed varieties introducing higher yielding and more and more suitable feed varieties, and as demand for feed barley increases, then interest in feed varieties grows.

In deciding on varietal choice, growers not only consider relative yields and prices but also expected yields and prices. Not all malting varieties grown produce barley that meets the malting grade standards[6]. Furthermore the probability of meeting the malting grade standards depends on the type of season (Jyothi-Gali 1998). It is the risks associated with meeting these standards, and the more demanding management practices required that determines the premium needed to encourage individual growers to plant malting varieties, to undertake appropriate management practices, and to accept the risks of not meeting the malting grade standards.

The premiums needed to attract growers appear to have widened through time. Declining soil fertility through decades of cultivation has increased the level of management and risks associated with producing malting grade barley. In addition, higher price premiums are needed to offset widening yield differentials resulting from more research into higher yielding feed varieties. Before rapid growth in the intensively fed livestock sector in Queensland in the early 1980s, the dominant market for barley was malting barley especially for the domestic market, with the feed barley market a residual market. Since the 1980s, however, feed barley demand has grown to the extent where it now accounts for 60 to 80% of total barley demand. Thus malting barley end users have to compete in the market and offer higher premiums to guarantee their barley supplies.

The type of season impacts markedly on receivals of both malting and feed barley. In good seasons, when there is plentiful malting grade barley in the market, maltsters do not have to offer large premiums to obtain sufficient supplies given that the domestic demand for malting barley is limited. However, in adverse seasons when overall barley receivals and malting grade barley receivals are low, maltsters need to offer substantive premiums to avoid leakage of the better quality barley onto the feed market. In these tight supply situations, the malting grade standards are sometimes relaxed. For instance, in the drought affected year of 1992 when there were few barley receivals, the protein range for malting barley expanded from the 9 per cent to 11.5 per cent protein range to a band of 8.5 per cent to 12.5 per cent. Although for the reasons outlined in Footnote 4 maltsters require specific quality attributes, the level of these attributes is not absolute, and there is some substitution at the margins based on relative prices and availability. The converse applies in periods of high receivals, when malting barley standards are tightened to ensure a better quality.

The amount of market information affects the co-movement of barley prices. Prices are formed efficiently when large numbers of buyers and sellers have similar access to relevant market information. The efficient price signals end-users about the costs of producing and supplying particular types of barley to them, and simultaneously sends signals to barley growers about the willingness of end-users to pay for the costs of production of various types of barley. Thus accurate price signals are essential to the efficient allocation of resources by both the barley growers and end-users of barley. According to Lang and Rosa (1981) and Goodwin and Schroeder (1991), terminal markets have a more complete set of market information in each trade than do individual direct trade markets. Thus the process of price discovery is also instrumental in determining the co-movement between malting and feed barley prices.

Since the mid-1980s, significant changes have occurred in the structure of the Queensland barley industry. Historically, there were only a limited number of market participants given that a statutory authority(ies) had vesting control of barley supplies that were subsequently sold primarily to three main maltsters. Although the small number of buyers and sellers limited competition and impacted on the degree of integration, all of the buyers and sellers were relatively well informed. Although its statutory marketing powers have all but disappeared, GRAINCO[7] still represents the major buyer of barley in Queensland, and especially of malting barley. Thus prices in the malting barley market still involve trade between relatively few buyers and sellers each of which have extensive information and where prices are relatively uniform.

Although GRAINCO is involved in the sale of feed barley, the feed barley market differs as there is much more direct trade between barley growers and intensive livestock feeders. Thus trade in feed barley trade comprises a larger number of smaller transactions involving less informed buyers and sellers. Although feed barley prices may be set more competitively and be more closely aligned with other feed grain prices, the variance of price quantity combinations is likely to be larger than is the case for malting barley. Integration of feed and malting barley markets will be influenced by the different market structures in each of these barley markets.

3.   APPROACH

Factors influencing co-integration between malting and feed barley prices were discussed in the previous section. However, only a rigorous empirical analysis can reveal the existence and extent of any co-integration.

Co-movements of commodity prices and trended data represent potentially major problems for empirical econometrics. Deterministic or stochastic trends can cause non-stationarity in the time series data that can lead to "spurious regressions" (Granger and Newbold 1974). Conventional approaches such as correlation to test integration misrepresent or ignore the time series properties of price data. Conversely, the cointegration approach accommodates deviations from equilibrium condition for two economic variables that are non-stationary when taken by themselves. The intuition behind the cointegration approach is that economic forces should prohibit persistent long-run deviations from the equilibrium condition, although significant short run deviations may be observed due to seasonal variations. The two price series are cointegrated if they share the same stochastic trend. The mean, variance and covariance in the stochastic process for the two variables increase similarly over time. In such cases, ordinary least squares co-efficient estimators do not normally follow a normal distribution and are biased, creating problems in validating statistical inference using standard t and F tests.

Thus typical regression analyses make sense only for data not subject to a trend. Since almost all time series contain trends, it follows that these series have to be de-trended before sensible regression analyses can be performed. The convenient way of removing a trend in a series is by first differences, namely the differences between successive observations. However, this leads to the loss of long-run properties from the data since the model in differences does not have a long-run solution. A reconsideration of regression approaches led to models combining both short-run and long-run properties and which at the same time maintain stationarity in all of the variables. The link between non-stationary process and the concept of long-run equilibrium is cointegration. Analysis of cointegration in time series econometrics emerged in the mid-1980s and has been regarded as one of the most important recent developments in empirical modeling.

After testing both series are integrated of the order I (1), the Engle and Granger (1987) two step procedure was used to estimate the cointegration relationship between feed and malting barley prices. In the first step, the cointegration relationship was estimated using data at their original level. The error term from the estimated model was then tested for stationarity, using Durbin Watson (DW), Dicky Fuller (DF), and Augmented Dicky Fuller (ADF) tests. Stationary of the error term is

especially important in the error correction mechanism (ECM) model. The fact that variables are cointegrated implies that there is some adjustment process that prevents errors in the long-run relationship becoming larger and larger. Thus cointegration is a necessary condition for error correction models to hold.

If the error term is stationary according to the Dicky Fuller and Augmented Dicky Fuller tests, the second step involves modeling short run dynamics in the ECM using data in difference form. Differencing of data leads to a loss of long-run information, but this information is reintroduced via the inclusion of lagged residuals from the cointegration regression. The error correction term measures the extent to which the dependent and independent variables have temporarily departed from the long run relationship. Since all the variables in the ECM model are stationary, the standard t test of coefficient significance is valid. However, the Engle-Granger method does not provide any proof that the cointegration is long-run. In order to do so, an alternative means of deriving the long run relationships between feed and malting barley prices is used based on the unrestricted error correction model (UECM) (Gunawardana *et al.* 1995). A Granger causality test checks the direction of causality when the feed and malting barley prices are cointegrated. This test employs two regressions on the explanatory variables, namely with and without restrictions.

4.   DATA SOURCES

Data availability influences the type of market analysis that can be conducted (Barrett 1996). Intermarket linkages are commonly modeled as equilibrium either in spatial, temporal or product dimensions in which transport, transaction costs and demand and supply jointly determine prices and trade flows. Data for this analysis of the barley market consisted of 144 monthly observations from the period January 1985 to December 1996. Even though data efforts were able to be focussed on price data alone, the relevant data could not be sourced from one place because of the small crop, restructuring of marketing organizations, and drought conditions in the first half of the 1990s meant that there was no single source of monthly recorded price data for feed and malting barley in Queensland. From 1985 to 1991, data was pooled from the Queensland Country Life weekly magazine and from published information by FARMARCO enterprises for barley traded at Toowoomba. The remaining data for 1992 to 1996 came from receival dockets of GRAINCO

following the establishment of this grain marketing organization in 1991. Summary statistics used in the analysis appear in Table 1.

Table 1 around here

5.   ANALYSIS

Monke and Petzel (1984), and Diakosavvas (1995) argue that a sequence of tests rather than a single test are required to confirm market integration and full price transmission. First, the pair of prices under consideration needs to be tested for co-integration. Second, the stationarity of the error correction term requires testing. Third, the response of the two price series to departures in equilibrium conditions needs to be examined.

In the first case, a straightforward test for whether barley prices are integrated and whether the integration has changed over time is to compute the correlation coefficients over time. The correlation coefficient between feed and malting barley was estimated to be 0.93721 in the period from 1985 to 1991, and 0.98289 in the period from 1992 to 1996. Tests revealed a significant difference between the correlation coefficients implying that both barley markets have become more integrated over time.[8] Various factors may have led to the greater integration of feed and malting barley prices in the latter period, including the partial deregulation of the barley market in the early 1990s. Adverse production conditions in the first half of the 1990s, that meant maltsters had to compete more actively in the barley market for supplies of malting grade barley, may also be responsible. However, identification of the key factors is clouded by the different data series required for the two periods.

Despite these findings the correlation analysis may yield unreliable results insofar as it fails to explore fully the time series properties. Cointegration tests examine these time series properties based on the assumption that a long run relationship exists between the prices of feed and malting barley, and that they have the same inter-temporal characteristics. The estimated cointegration regressions and the relevant test statistics for both feed and malting barley appear in Equations 1 and 2.

The Durbin Watson, Dicky Fuller and Augmented Dicky Fuller tests indicate the non-stationarity of the residuals, suggesting that there is a relationship between feed and malting barley

prices. If feed and malting barley markets were perfectly integrated then the cointegration parameter, β, would be approximately equal to one. However, in both cointegration Equations (1 and 2), the co-integration parameter is not equal to one. Given the differences in product attributes, end use markets and institutional structure outlined in Section 2, then *a priori* a cointegration parameter equal to one was not expected.

The t test cannot be used to test the significance of $\hat{b}$ in the cointegrated system. To provide consistent parameters for this non-stationary data, recourse must be made to the Engle and Granger (1987) two step procedure. The Granger causality test examines whether past changes in the price of feed barley help to explain current price changes in malting barley, over and above the explanation provided by the past changes in the price of malting barley. If this is not the case, then it can be concluded that the price of feed barley does not Granger cause the price of malting barley. If feed and malting barley prices are found to be cointegrated, then the price of feed barley can be used as a "base" price or "reference" price to measure the level of premium offered for malting barley.

(1) $Pmba_t = -4.9396 + 1.2271Pfba_t + m_1$

          Test statistics for cointegration:

          $R^2 = 0.9549$

          DW = 0.25345

          DF = -3.1088 (95 per cent critical value is –2.64)

          ADF = -2.7716 (95 per cent critical value is –2.64)

(2) $Pfba_t = 9.779 + 0.77820Pmba_t + m_2$

          Test statistics for cointegration:

          $R^2 = 0.9549$

          DW = 0.27721

          DF = -3.2550 (95 per cent critical value is –2.64)

          ADF = -2.9060 (95 per cent critical value is –2.64)

The third test raised by Monke and Petzel (1984) and by Diakosavvas (1995) involves an examination of the short run dynamic relationships. Based on Engle and Granger (1987), the error correction models for malting and feed barley were specified as;

$$(3) \qquad \Delta Pmba_t = \mathbf{b}_0 + \sum_{k=0}^{n}(\mathbf{b}_1\Delta Pfba_{t-k} + \mathbf{b}_2\Delta Pmba_{t-k}) + \mathbf{b}_3\mathbf{m}_{1-1} + \mathbf{e}_t$$

$$(4) \qquad \Delta Pfba_t = \mathbf{b}_0 + \sum_{k=0}^{n}(\mathbf{b}_1\Delta Pmba_{t-k} + \mathbf{b}_2\Delta Pfba_{t-k}) + \mathbf{b}_3\mathbf{m}_{1-1} + \mathbf{e}_t$$

where Δ is the first difference term, μ_{t-1} is the error correction variable estimated by the residuals from the cointegration regression of equation 1, and ε_t is a white noise error term. The coefficient, β_3, measures the extent to which changes in price of malting barley and the price of feed barley respond to departure from the equilibrium condition. If β_3 is significant, then there is confirmation of cointegration suggesting interdependence of the two price series. The long run convergence (divergence) process of the two price series to the equilibrium condition is assured when β_3 is negative (positive). The size and statistical significance of the coefficient β_3 measures the tendency of each price to return to equilibrium. In addition to testing for co-integration, the hypothesis of full price transmission can also be tested. This requires that the coefficient of the long-run relationship between the cointegrated series equal unity, namely that the independent variables are proportional to the dependent variable in equilibrium.

Independence of the two price series requires that price movements are distributed randomly with respect to each other, and that the β_3 coefficient is expected to be zero. A significant t-statistic for the β_3 coefficient suggests interdependence of the two prices. If the β_3 coefficient is significant, various price relationships may exist. If β_3 is not significantly different from one and the constant term is not significantly different from zero, then the two price series are statistically identical. If β_3 is significantly different from one and zero, and the constant term is not significantly different from zero, a pure percentage premium is suggested. An absolute premium results when β_3 is equal to one and β_0 is not equal to zero, reflecting a fixed differential between the two types of barley.

Results from the ordinary least squares regression of Equations 3 and 4 appear in Table 2. The error correction term has a positive sign implying that the price of malting barley diverges from the equilibrium. However, the insignificance of the lagged error term provides evidence of the lack of influence of the malting barley market on feed barley prices. As indicated in Section 2, factors other than malting barley prices influence feed barley prices including the prices of other feed grains. Thus

the estimated ECM in equation 3 cannot be used to forecast the price of feed barley from malting barley prices.

The coefficient for lagged feed barley price (0.6331) suggests that it has more influence on the price of malting barley than does the lagged price of malting barley. The coefficient associated with the lagged price of malting barley indicates that price adjustment to changes in the price of feed barley is not instantaneous.

Conversely, the error correction term in the feed barley equation is significant, suggesting that the price of feed barley influences the price of malting barley. Hence, it is possible to forecast the price of malting barley from the price of feed barley but not vice versa. The negative sign on the error correction term implies that malting and feed barley prices converge to the equilibrium conditions in the feed barley equation. In addition, because the error correction term is significantly different from one and the intercept term is not significantly different from zero in the feed barley equation, then a fixed differential or premium exists between the two price series.

$$(5)\ \Delta Pmba_t = b_0 + \sum_{k=0}^{n}(b_1 \Delta Pfba_{t-k} + b_2 \Delta Pmba_{t-k}) + b_3 m_{t-1} + b_4 Pfba_{t-1-k} + b_5 Pmba_{t-1-k} + e_t$$

The long run price relationships between feed and malting barley can be determined from the unrestricted error correction model (equation 5) as the ratio $-\beta_4/\beta_5$. This value is close to unity in the malting barley equation (row 8 of Table 2) suggesting that full price transmission is possible from feed to malting barley markets in the long-run. However, the same is not the case for malting barley to feed barley (last row in Table 2).

$$(6)\qquad \Delta Pmba_t = b_0 + b_1 \Delta Pmba_{t-k} + b_2 m_{t-1} + e_t$$

To further test the hypothesis that the malting barley market does not lead the feed barley market and vice versa, a restricted error correction model shown in Equation 6 restricts the independent variables to be only the past price changes in the dependent variables.[9] The significant F value for Equation 5 shown in Table 2 indicates that the feed barley price leads the malting barley price. However, in the feed barley equation, the calculated F value is less than that in the malting

barley equation inferring that past changes in the malting barley price do not explain the changes in feed barley prices, and that one way Granger causality exists in the barley market.

6.   CONCLUDING COMMENTS

Out of the intricate set of supply and demand relationships that exists between malting and feed barley, the cointegration approach highlights the price leadership role of feed barley. Highlighting these price relationships will aid barley market participants, from growers through to end-users, better understand these grain market relationships, and so enable them to make more informed and efficient choices. Apart from these direct benefits, the usefulness of the analysis extends to those interested in investigating these relationships in more depth through more extensive supply and demand systems estimation by guiding model specification.

Despite the many benefits of the cointegration analysis in elucidating market structure, it can only reveal so much. According to Monke and Petzel (1984) and Diakosavvas (1995), cointegration analysis represents necessary rather than sufficient conditions for aggregation of markets, since imperfectly competitive pricing behavior in these two markets could also generate constant price discounts and premiums. Thus additional information on market structure is needed to complement the tests for market integration.

Although cointegration tests provide evidence about the linkages among the prices of feed and malting barley, cointegration is not an absolute test but a matter of degree. Understanding the factors that influence the degree of cointegration among feed and malting barley prices allows more conclusive arguments to be developed regarding the price relationships between the two price series. Thus the cointegration analysis presented here is an initial attempt in examining the extent to which barley markets are integrated in Queensland. Further research is needed to identify the factors contributing to the various degrees of cointegration and the evidence of market integration must be assessed against additional information on barley market structure and production technology.

REFERENCES

Barrett, C. B. (1996). Market analysis methods: Are our enriched toolkits well suited to enliven markets? American Journal of Agricultural Economics, 7, 825-829.

Diakosavvas, D. (1995). How integrated are world beef markets? The case of Australian and U.S. beef markets. Agricultural Economics, 12, 37-53.

Engle, R.F., & Granger, C.W.J. (1987). Cointegration and error correction: Representation, estimation and testing. Econometrica, 55, 252-276.

Goodwin, B.K., & Schroeder, T.C. (1991). Price dynamics in the international wheat market. Canadian Journal of Agricultural Economics, 39, 237-254.

Granger, C.W.J., & Newbold, P. (1974). Spurious regressions in econometrics. Journal of Econometrics, 2, 111-120.

Gunawardana, P.J., Kidane, H., & Kulendran, N. (1995). Export supply response of the Australian citrus industry. Australian Journal of Agricultural Economics, 39, 247-261.

Jyothi-Gali V. (1998). Integrated demand, supply and market analysis for Queensland barley. Unpublished Ph.D. thesis. The University of Queensland, St Lucia. Brisbane.

Jyothi-Gali, V., Brown, C.G., & Wegener, M. (1998). The value of barley protein in livestock feeding in Queensland. Australasian Agribusiness Review, 6, Paper 15.

Jyothi-Gali, V., & Brown, C.G. (1999). Assisting decision making in Queensland barley production through chance constrained programming. Australian Journal of Agricultural and Resource Economics, (in process).

Lang, M.G., & Rosa, F. (1981). Price variation in direct and terminal Markets for cattle and hogs: An Illinois case. American Journal of Agricultural Economics, 63, 704-707.

Mohanty, S., Peterson, E. W. S., & Smith, D. B. (1996). Relationships between U.S. and Canadian wheat prices: Cointegration and error correction approach. Canadian Journal of Agricultural Economics, 44, 265-276.

Monke, E., & Petzel, T. (1984). Market integration: An application to international trade in cotton. American Journal of Agricultural Economics, 66, 481-487.

Taylor, E. L., Bessler, D. A., Waller, M. L., & Rister, M. E. (1996). Dynamic relationships between US and Thai rice prices. Agricultural Economics, 14, 123-133.
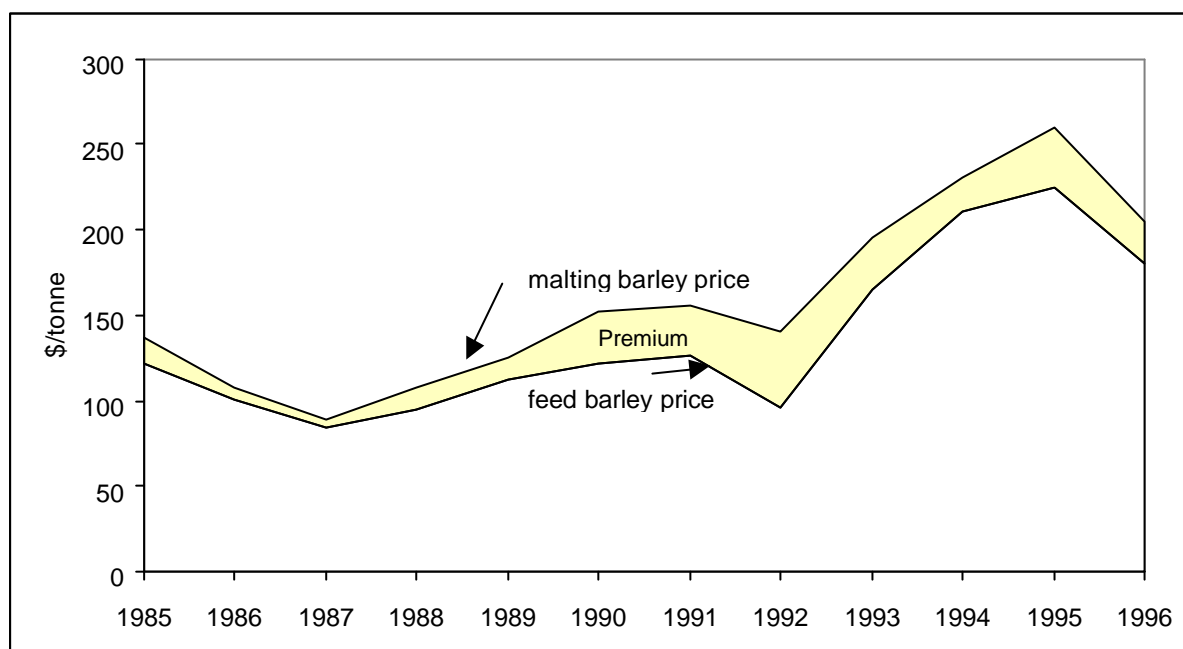
Figure 1: Barley prices in Queensland market

Table 1: Summary statistics for barley prices

	Mean ($/t)	Maximum ($/t)	Minimum ($/t)	Standard deviation
		--- $ per tonne ---		
Malting barley	156.5	257	81.7	48.56
Feed barley	131.6	214	79.8	38.67

Table 2: OLS estimates of barley prices using the Error Correction Method (ECM)

Dependent variable	Equation	Intercept	$\Delta PFBA_{t-12}$	$\Delta PMBA_{t-12}$	μ_{t-1}	$PFBA_{t-1-k}$	$PMBA_{t-1-k}$	DW	ESS
			Estimated parameters						
Price of malting barley	SRD	0.67206	0.6331	-0.3769	0.09306			1.9040	9852.4
		(0.8606)	(3.5145)***	(-2.088)**	(1.197)				
	URECM	4.2283	0.63932	-0.35944	0.24553	-0.17122	0.17655	1.8994	9550.3
		(1.550)*	(3.5757)***	(-2.004)**	(1.5922)*	(-1.1197)	(0.94371)		
	RECM	0.59758		0.18063	0.073901			1.9876	10810.6
		(0.73369)		(2.0102)**	(0.91328)				

F cal (SRD and RECM) = 12.44 ; F test (132, 4)= 2.45
F cal (URECM and RECM) = 8.309; F test (132, 6)= 2.18
Long run relationship = -0.17122/0.17655 = 0.9698

Dependent variable	Equation	Intercept	$\Delta PFBA_{t-12}$	$\Delta PMBA_{t-12}$	μ_{t-1}	$PFBA_{t-1-k}$	$PMBA_{t-1-k}$	DW	ESS
Price of feed barley	SRD	0.47509	0.43546	-0.31984	-0.24112			1.9366	10324.6
		(0.59459)	(2.3612)**	(-1.7312)**	(-2.4262)**				
	URECM	1.2924	0.43753	-0.30836	-0.422561	0.2139	-0.18496	1.8588	10119.2
		(0.40892)	(2.3772)**	(-1.6702)*	(-2.2292)**	(1.1386)	(-1.2523)		
	RECM	0.34696	0.15506		-0.24004			1.9556	10568.2
		(0.43275)	(1.7445)*		(-2.3968)**				

F cal (SRD and RECM) = 3.02 ; F test (132, 4)= 2.45
F cal (URECM and RECM) = 2.7954; F test (132, 6)= 2.18
Long run relationship = -0.8647

*** Significant at 1 per cent
** Significant at 5 per cent
* Significant at 10 per cent

FOOTNOTES

[1] For some examples, see Mohanty *et al.* (1996) and Taylor *et al.* (1996).

[2] In 1997, Queensland produced 428 600 tonnes of barley valued at $ 66.7 million. Around two-thirds of the barley was sold for feed barley.

[3] The number of intensively fed livestock in southern Queensland (Brisbane, Moreton, Wide Bay Burnett and Darling Downs statistical divisions) where barley is grown increased from around 8000 in 1989 to 14000 in 1997 (Source: Australian Bureau of Statistics)

[4] Malting barley must meet a range of requirements including high standard of purity, freedom from insect infestation, and regular size, shape and colour of individual grains. For example, GRAINCO, the major marketer of barley in Queensland, specifies that 75 to 85 per cent by weight of grain is above 2.5mm, while screenings, defined as matter passing through a 2.2mm screen, is less than 3 to 5 per cent. One of the main requirements is protein level, however, and these are often set at between 8.5 and 12.5 per cent. To achieve a uniform rate of modification from barley to malt, both maltsters and brewers demand a narrow band of protein content. In malthouses, the level of protein affects the rate at which grain changes from barley to malt. In the brewery, protein in its degraded form is required for yeast nutrition and for producing beer foam. Too much protein causes haze formation in beer, while too little protein increases the risks of undernourishing the yeast.

[5] Feed varieties such as Gilbert, Kaputar, Corvette and Skiff generally yield 20 to 30 per cent higher than malting varieties such as Grimmett and Tallon (Jyothi-Gali 1998, Chapter 6).

[6] Of the 60 to 80 per cent of malting barley planted in Queensland, only about 20 to 30 per cent meet the malting grade standards.

[7] GRAINCO was established in 1991 with the merger and corporatisation of the Queensland Barley Marketing Board, Queensland Wheat Board, Central Queensland Grain Sorghum Board, and Queensland Bulk Grain Handling Board. Its subsequent transition to a grower owned co-operative and public company has seen it lose most of its statutory powers except its sole seller status of barley for export.

[8] Denoting two sample periods under the null hypothesis $H_0 = \rho_1 = \rho_2$, the following test statistic:

$$Z = \frac{\ln\left(\frac{(1+r1)}{(1-r1)}\right) - \ln\left(\frac{(1+r2)}{(1-r2)}\right)}{2\sqrt[2]{(1/T1-2)+(1/T2-2)}},$$

where r1 and r2 are correlation coefficients and T1 and T2 are sample sizes for period 1 and 2 respectively (Diakosavvas 1995 p. 40)
was found to be significant with a value of –3.73276.

[9] This is evaluated through a combined F test as follows: F calculated $= (N - n)\dfrac{(ESS_R - ESS_{UR})}{q(ESS_{UR})}$

where N is the total number of observations; n is the number of parameters in the unrestricted regression; ESS_R is the error sum of squares from the restricted regression; ESS_{UR} is the error sum of squares from the unrestricted regression; and q is the number of parameter restrictions. For both dependent variables, the F value is calculated and provided in Table 2. The calculated F value is highly significant in the malting barley equation.