Australian Journal of Agricultural Economics, Vol. 29, No. 3 (December, 1985), pp. 199-209

BASIS RISK AND HEDGING STRATEGIES FOR AUSTRALIAN WHEAT EXPORTS

GARY E. BOND, STANLEY R. THOMPSON and JANE M. GELDARD*

Bureau of Agricultural Economics, Canberra, ACT 2601

Basis risk can play a significant role in the determination of effective hedging strategies. In this paper a portfolio framework is developed to examine the effect of basis risk on hedging strategies for Australian wheat exports. Monthly data for the period 1977 to 1984 were used to implement the analytical framework. While the traditional definition of hedging implies a hedge ratio of unity, the results of this research show that the average ratio of optimal hedge to stockholding is well below unity. Evolving market conditions can also cause the optimal hedge ratio to vary substantially over time.

Amendments to the Wheat Marketing Act in June 1982 empowered the Australian Wheat Board to undertake selective hedging of export wheat on overseas futures exchanges. The purpose of these amendments was to enable the Board to reduce the risks associated with price variation.

However, there are limits to the extent to which offshore futures transactions can provide revenue stability, because of the presence of basis variation (Perkins 1984). This is largely attributable to the fact that the prices received by the Australian Wheat Board on export sales do not always move in line with the prices posted on US futures exchanges. A discussion of the factors underlying variations in the Australian–US (spot–futures) basis is presented in Perkins, Sniekers and Geldard (1984).

The presence of basis risk implies that traders, attempting to stabilise revenue flows by means of hedging activities, will seek trading rules which incorporate basis risk explicitly. As outlined in Kamara (1982), this usually leads to hedging decisions more complex than those commonly referred to as routine hedging, where the position in the spot (physical commodity) market is offset by an equal but opposite position in the futures market. Under this traditional hedge rule the ratio of futures commitments to expected sales is defined as unity.

The purpose of this analysis is to evaluate the effect of basis risk on decisions to hedge Australian export wheat using the Chicago futures market. The analysis focuses on the derivation of optimal hedge ratios and how these may differ from the traditional hedge rule of unity. The analytical framework extends the previous literature in this field by allowing for optimal hedging decisions to be determined jointly with decisions to store and sell grain. In this way, the futures transactions are consistent not only with the desire to stabilise revenue streams, but also with the desire to maximise expected revenue. Considerable attention is also given to the modelling of price expectations.

* G. E. Bond is now at the Livestock and Grain Producers' Association and S. R. Thompson is at Michigan State University. The authors wish to acknowledge the contribution of Mr David Browne of the Australian National University for his assistance in the identification of the statistical models.

As the analytical framework used in this study is an abstract representation of real world relationships, the results should not be regarded as a prescription for optimal behaviour by the Australian Wheat Board. The decisions which are actually taken by the Board will be based on considerations which are far more complex than those presented here. Nevertheless, the analysis provides insight into the extent of the basis risk the Board could encounter and the possible implications for selective hedging strategies.

Basis Variation for Australian Wheat Export Prices

Currently, more than 80 per cent of Australia's wheat production is exported. Consequently, world wheat trading conditions have a large effect on returns to the Australian Wheat Board and Australian wheat growers. Despite the high degree of confluence which exists among the prices of different types of wheat on the world market, not all wheat types are subject to the same supply and demand conditions at a point in time (Perkins et al. 1984). Differences in the prices of different wheats occur and these in turn are reflected in futures exchange quotations.

For effective hedging it would be desirable to utilise futures exchanges which deal primarily in wheat which closely resembles Australian wheat classes. For Australian standard white wheat, this would imply hedging activities at the Kansas City futures exchange where hard red winter wheat contracts are traded. Hard red winter wheat is the US wheat class with which Australian standard white wheat prices are closely correlated (Bond, Love and Perkins 1984). However, as Perkins et al. (1984) indicate, the Chicago futures exchange, even though it deals mostly in soft red winter wheat, will be more appropriate than the Kansas City futures exchange to the Australian Wheat Board. This is because of the Chicago Board of Trade's greater liquidity (larger trade volume and open interest) and its consequent lower level of susceptibility to price influences from potentially large traders, such as the Australian Wheat Board. For this analysis, it is assumed that the Board treats spot and futures prices as exogenous.

The basis faced by the Board is defined as the margin between the Australian standard white wheat f.o.b. export quote and the nearby futures quote on the Chicago exchange (both expressed in US dollars). The behaviour of the basis between January 1977 and December 1984 is shown in Figure 1. It is clear that the basis has been highly variable over this period, ranging from −\$6 in the first quarter of 1979 to almost \$50 in late 1982 and early 1983. On average, the Australian standard white quotation has been some 13 per cent above the nearby Chicago futures quotation over the period shown.

The main implication of the data in Figure 1 is that the Board will be faced with a great deal of uncertainty regarding the relative value of spot sales and futures contracts at the time the hedge is to be lifted. As basis movements affect the overall profitability of revenue-stabilising hedging activities, it is desirable that basis risk be incorporated explicitly into selective hedging rules. An example of how this might be achieved is presented below.

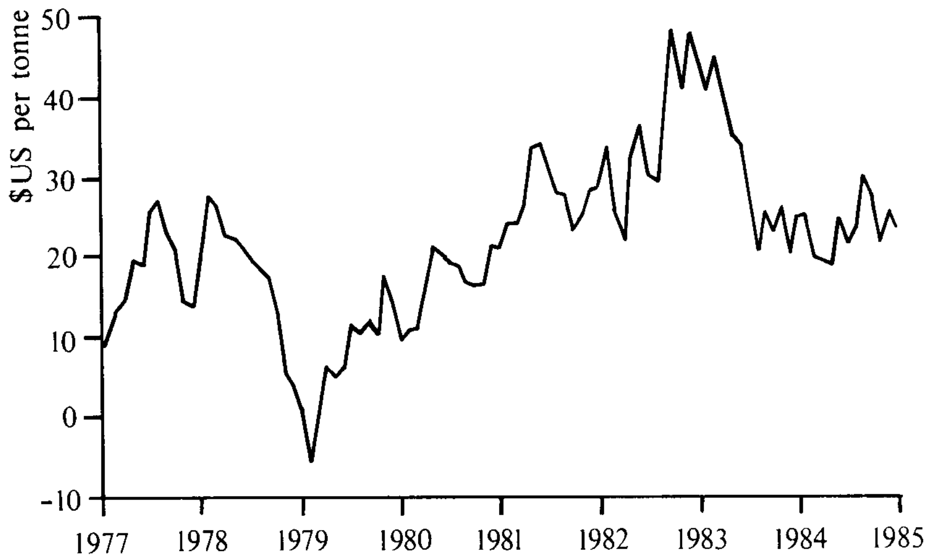

FIGURE 1 — Variation in the Basis.

Optimal Hedging in a Portfolio Framework

As discussed in Kamara (1982), Rolfo (1980), Peck (1975) and Kahl (1983), the standard approach for deriving a selective hedging strategy requires specification of an objective function in which both the level and variability of total returns are recognised. For this purpose a mean–variance framework is suitable, implying that the decision maker's objective function is to maximise expected returns from trading and hedging activities, subject to the risk (as measured by the variance) associated with those returns.

The objective function may therefore be stated as the maximisation of:

(1) $$\Omega = E_t\,(R_{t+1}) - \lambda V_t\,(R_{t+1})$$

where R_{t+1} = the (random) level of returns in period t+1;
E_t = the expectation operator;
V_t = the variance operator; and
λ = the decision maker's risk aversion coefficient ($\lambda > 0$ under risk aversion).

Note that estimates of the expected value of returns and the variance of returns are conditional on the information available at time t.

The level of returns that eventuates in period t+1 depends on the activities undertaken at time t. For this analysis, it is assumed that the decision maker has available stocks of grain (Q_t) which can be sold or stored and that the quantity stored may be covered to varying degrees by futures contracts. Within this limited portfolio, these options may be described as follows.

(a) Sell an amount $(1-\alpha)Q_t$, for a price p_t and invest the proceeds at a one-period rate of interest of $r_t (0 \leq \alpha \leq 1)$. The (certain) return from this activity in period t+1 is given by $(1-\alpha)\ Q_t p_t(1+r_t)$.
(b) Store an amount αQ_t to be sold (or valued) in period t+1 at price p_{t+1}. Assuming that the marginal cost of storage is zero, the (uncertain) return from this activity in period t+1 is given by $\alpha Q_t p_{t+1}$.
(c) Sell a quantity H_t of futures contracts in period t for a price f_t to be bought back at t+1 for a price f_{t+1}. Assuming that the futures transaction involves little or no investment cost (real or opportunity), the (uncertain) return in period t+1 is given by $H_t(f_t - f_{t+1})$.

In period t+1, the expected return from engaging in these three activities may be specified as:

$$(2) \qquad E_t(R_{t+1}) = (1-\alpha)Q_t p_t(1+r_t) + \alpha Q_t E_t p_{t+1} + H_t(f_t - E_t f_{t+1})$$

Defining the basis as:

$$(3) \qquad B_t = p_t - f_t$$

such that the expected basis is:

$$(4) \qquad E_t B_{t+1} = E_t p_{t+1} - E_t f_{t+1}$$

equation (2) may then be rewritten in terms of the spot price and the basis as:

$$(5) \quad E_t(R_{t+1}) = (1-\alpha)\ Q_t p_t(1+r_t) + (\alpha Q_t - H_t)E_t p_{t+1} + H_t(p_t - B_t + E_t B_{t+1})$$

Corresponding to (5), the estimated variance of returns in t+1 is given by:

$$(6) \qquad V_t(R_{t+1}) = (\alpha Q_t - H_t)^2 V_t(p) + H_t^2\ V_t(B) + 2H_t(\alpha Q_t - H_t)\ \mathrm{Cov}_t(p,B)$$

where $V_t(p)$ = the one-period-ahead estimate of price variance;
$V_t(B)$ = the one-period-ahead estimate of basis variance; and
$\mathrm{Cov}_t(p,B)$ = the one-period-ahead estimate of price–basis covariance.

Note from (6) that, while the risk (that is, the variance) of returns in t+1 will be greater with high basis variance, the covariance effect may either increase or decrease the overall variability of returns.

The optimal futures and storage positions can be obtained by substituting (5) and (6) into (1), differentiating with respect to H_t and αQ_t, and setting the first-order conditions equal to zero to obtain the following optimal hedge ratio:

$$(7) \quad \frac{H_t}{\alpha Q_t} = \frac{V_t(p)[E_t B_{t+1} - B_t - p_t r_t] + \mathrm{Cov}_t(p,B)[p_t(1+r_t) - E_t p_{t+1}]}{[V_t(p) - \mathrm{Cov}_t(p,B)][E_t B_{t+1} - B_t - p_t r_t)] + V_t(B)[E_t p_{t+1} - p_t(1+r_t)]}$$

Hence, under the mean–variance rule, the optimal ratio of futures contracts (H_t) to physical stocks (αQ_t) is dependent upon the means, variances and covariances of the price and basis variables.

Note that the optimal hedge ratio given in (7) is independent of the risk aversion parameter λ. As demonstrated by Kahl (1983), the risk aversion parameter is irrelevant to the optimal hedge ratio (despite being present in the individual expressions for optimal stocks and optimal futures contracts positions) whenever both stocks and futures contracts are determined endogenously. This result depends, however, on the absence of non-linear storage and transaction costs (Bond and Thompson 1985).

A simplification of (7) can be achieved in cases where the current futures price (f_t) represents an unbiased predictor of the expected futures price ($E_t f_{t+1}$). That is, if

$$E_t f_{t+1} = f_t \tag{8}$$

then (7) reduces to:

$$H_t/\alpha Q_t = [V_t(p) - \mathrm{Cov}_t(p,B)]/[V_t(p) - \mathrm{Cov}_t(p,B) + V_t(B)] \tag{9}$$

The expression in (9) indicates that an increase in basis risk (given by $V_t(B)$) will generally lead to a fall in the proportion of stocks hedged. In cases where basis risk is zero, a hedge ratio of unity (that is, a routine hedge) is optimal. More generally, however, the existence of basis risk necessarily implies hedge ratios less than unity whenever (8) holds.

Empirical Findings

Monthly data on spot and futures prices for the period January 1977 to December 1984 were used to simulate the optimal hedge ratio. Because misleading results can be obtained from tests with averaged data, all price information was taken as close as possible to the same end-of-month point in time.[1] Spot prices are for Australian standard white wheat in US dollars per tonne. Futures prices are for soft red winter wheat quoted on the Chicago Board of Trade. To obtain a continuous data series for each month of the year, the nearby futures contract price was used.[2]

It should be noted that the Australian standard white wheat spot price quotations offered by the Australian Wheat Board do not always coincide with the actual prices at which business has been transacted. The 'real' basis facing the Board (at time t) is the difference between the weighted average sales price (across wheat contracts made at time t) and the weighted futures price (across futures contracts held at time t). For reasons of commercial confidentiality, neither of these data are publicly available; hence, for this analysis public quotations of spot and futures prices are used.

[1] For example, daily commodity prices averaged over a month will not follow a random walk even though the daily price series can be characterised as a random walk (Working 1960).

[2] One implication of this procedure is that the interval to maturity of a futures contract varies slightly from month to month. While this variation may create some difficulties for the analysis of short-term (that is, daily) behaviour, it has negligible implications for the longer term perspectives derived here.

In order to simulate the optimal hedge ratio, a procedure is required to generate the expectation, variance and covariance terms. For this analysis, the requirements are that expectations be made on the basis of information at time t; forecasts be unbiased; and forecast errors be characterised as white noise.

Following Peck (1975) and Rolfo (1980), it is assumed that the appropriate variance and covariance terms appearing in the hedge ratio formula refer to the variances and covariances of the forecast errors associated with each of the expectations. In other words, if forecast errors are defined by:

$$p_{t+1} - E_t p_{t+1} = \varepsilon_{t+1} \tag{10}$$

and

$$B_{t+1} - E_t B_{t+1} = \upsilon_{t+1} \tag{11}$$

then for given values of $E_t p_{t+1}$ and $E_t B_{t+1}$, the variance and covariance terms appearing in the hedge ratio formula are given by the variances and covariance of the forecast error terms ε and υ. Hence in terms of the optimal hedge ratios given in (7) and (9),

$$V_t(p) = V_t(\varepsilon) \tag{12}$$

$$V_t(B) = V_t(\upsilon) \tag{13}$$

and

$$\mathrm{Cov}_t(p,B) = \mathrm{Cov}_t(\varepsilon,\upsilon) \tag{14}$$

A convenient way to identify an expectations structure that will ensure white noise residuals is to use a vector autoregression procedure. The vector autoregression method was used to explore the existence of own-equation and cross-equation interactions defined by:

$$p_{t+1} = g(p_{t-n}, f_{t-n}, \varepsilon_{t+1}) \quad n=0,1,2\ldots 12 \tag{15}$$

and

$$f_{t+1} = k(p_{t-n}, f_{t-n}, \mu_{t+1}) \quad n=0,1,2\ldots 12 \tag{16}$$

Using the entire 1977–84 data set, the vector autoregression model identification procedure suggested that the optimal first-difference model of both spot and futures prices was a random walk and no significant cross-equation correlations existed. The vector autoregression model software package used for estimation is given in Penm and Terrell (1982).

Using Zellner's (1962) seemingly unrelated regression procedure (in this case equivalent to ordinary least squares), the first difference relationships were regressed on a constant term. The following regression results yielded white noise residuals:

(17) $p_{t+1} - p_t = \underset{(0.79)}{0.5098}$ $d = 2.11$, $Q(12) = 9.85$, $Q(24) = 22.01$

(18) $f_{t+1} - f_t = \underset{(0.35)}{0.3127}$ $d = 2.23$, $Q(12) = 9.29$, $Q(24) = 30.88$

The figures under the coefficient estimates in parentheses are t-ratios, d is the Durbin–Watson statistic, and Q(df) is the Ljung–Box statistic. Neither the regression nor the Q statistics were significant at the 10 per cent level of significance and there was no significant autocorrelation in the errors of the equations. The white noise error structure implies that both spot and futures prices are random walks consistent with the basic martingale result. Thus, apart from the insignificant constant term, the best one-step-ahead predictor of both spot and futures prices is the current value of each variable.

These empirical results imply that for the data series under consideration:

(19) $$E_t p_{t+1} = p_t$$

and

(20) $$E_t f_{t+1} = f_t$$

such that:

(21) $$E_t B_{t+1} = B_t$$

Hence, the forecast error terms defined in (10) and (11) will correspond to the residuals of the following equations:

(22) $$\varepsilon_{t+1} = p_{t+1} - p_t$$

(23) $$\upsilon_{t+1} = p_{t+1} - f_{t+1} - p_t + f_t$$

Estimates of the error term (ε) are therefore obtained directly from the residuals of equation (17), while estimates of the error term (υ) are obtained by subtracting the residuals of equation (17) from those of equation (18). Hence the basis error embodies the covariance among cash and futures price forecast errors.

Note that in view of (19) and (20), equation (8) is satisfied, enabling simulation of the optimal hedge ratio to be conducted using the simplified expression given in (9).

As previously noted, estimates of the variance–covariance terms entering the optimal hedge ratios should be conditional upon information available at time t. Accordingly, it is assumed that at the end of each month, the decision maker forms estimates of the variance –covariance terms on the basis of information obtained during a given preceding period. If only the most recent observations on actual prices are used to form next period's variance and covariance estimates, a rolling assessment of the optimal hedge ratio is obtained.

Although it was necessary to use the entire data set to identify the appropriate expectations structure, the simulation results are derived using information set sub-periods. In other words, as each month passes, the information set is revised by the addition of a new observation and the deletion of an old observation. This procedure overcomes the inconsistencies which emerge from forming expectations early in the sample period based on an assumed complete knowledge of the entire data set (see Makin 1982; Mishkin 1982; Sheffrin 1979).

In order to test the sensitivity of results to the length of the observation period, simulations were conducted using information sets covering observations over the previous 12 and 24 months. At time t, therefore, the decision maker forms estimates of the variance and covariance terms in (9) on the basis of information prevailing over the previous 12 or 24 months. This procedure implies that as the information set evolves, the perceived risks of spot and futures transactions change, and this in turn leads to variations in the optimal hedge ratio.

Simulation Results

In the case where expectations are based on the previous 12 observations, the optimal hedge ratio varied from -0.08 (in February 1983) to 0.76 (in March 1980) with a coefficient of variation of 0.75. While a negative ratio implies a net speculative position, the February 1983 figure was not significantly different from zero. The mean optimal hedge ratio for the 12-month information set was 0.30, implying that over this period short futures equivalent to 30 per cent of stocks would have been optimal. A plot of the 12-month rolling hedge ratio is shown in Figure 2. Alternatively, if the previous 24 observations are used, the hedge ratios range from 0.03 to 0.63 with a mean of 0.34 and a coefficient of variation of 0.56. Although the mean of the 24-month hedge ratio was marginally greater than that based on the 12-month information set, the latter was decidely more variable. Hence, as the period used to form price expectations shortens, the more volatile the hedge ratio becomes and the more sensitive it becomes to recent market experience.

In an attempt to examine the reasons underlying the temporal nature of the 12-month hedge ratio displayed in Figure 2, the ratio is compared with its corresponding rolling basis variance. In Figure 2, a clear inverse relationship between the basis variance and the optimal hedge ratio is observed. The simple correlation coefficients between the basis variance and the optimal 12-month and 24-month hedge ratios are -0.34 and -0.62, respectively. This relationship reflects rational hedging behaviour in the sense that, as the risk in hedging increases (increased basis uncertainty), the prescribed hedge ratio decreases.

Comparing these results with the small number of optimal hedging studies previously published, it is evident that the presence of significant basis risk is likely to have a substantial effect on the prescribed level of hedging of Australian standard white wheat exports. Peck (1975), for instance, derived optimal hedge ratios of between 75 per cent and 95 per cent of total production for US egg producers, reflecting to some extent the limited degree of basis variation in that market. Rolfo (1980) also derived relatively high optimal hedge ratios of between 60 per cent and 94 per cent for four cocoa producing countries, although in his analysis the results reflected price and quantity risk rather than basis risk.

By contrast, Berck (1981) estimated that optimal hedge ratio for Californian cotton producers to be very low, ranging from 11 per cent to negative (indicating a speculative position). Berck's results reflect variations in the mean return of farming activities and the large magnitude of price changes that can occur between the time that planting (hedging) decisions are made and harvest. As noted by Berck, the risks which underly his low estimated hedge ratios represent a valid reason for the low level of observed farmer participation in futures markets. Similarly Carter and Loyns (1985) found that a high degree of basis risk exists in the hedging of Canadian cattle in Chicago. Their analysis indicates that due to poor cross-hedging potential, there is little incentive for Canadian feedlot operators to use futures contracts. This result is consistent with the observation that in the past Canadian cattle producers have shown little inclination to make use of US cattle futures.

A final point to note from this analysis is that size and variability of the basis variance have tended to increase in recent years (see Figure 2). This observation can, in part, be attributed to the changing price relationship between soft red winter wheat (the standard in the Chicago futures contract) and hard red winter wheat (closely related to Australian standard white wheat) on US markets. In particular, the premium of hard wheat over soft wheat has varied substantially in recent years and this characteristic has limited the usefulness of Chicago futures contracts for hedging Australian standard white wheat exports.

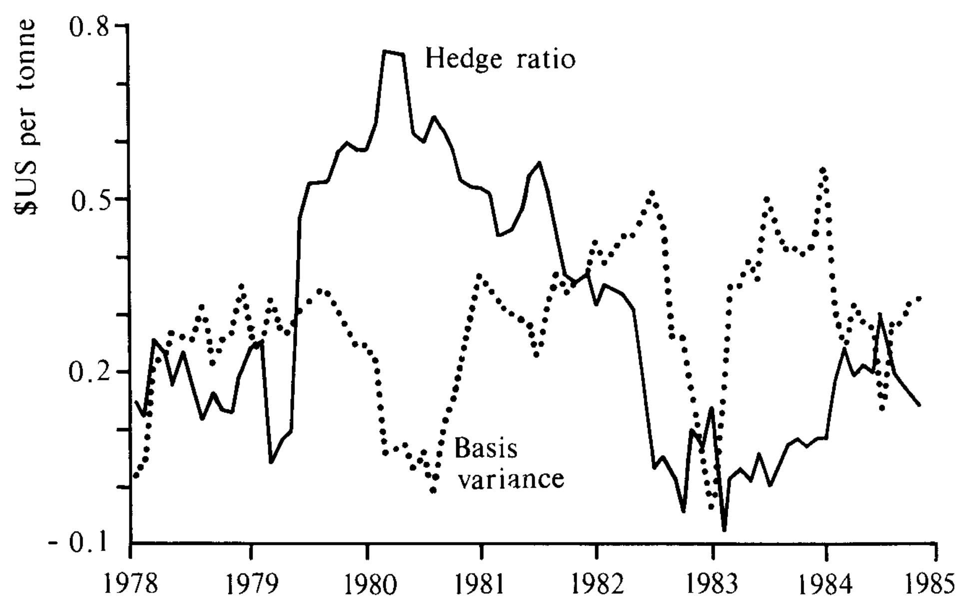

FIGURE 2 — Basis Variance and Optimal Hedge Ratio.

Note: Data estimated using 12-month information sets; see text. Basis variance has been scaled by a factor of 100.

Conclusions

The major finding is that the high degree of basis risk faced by the Australian Wheat Board on offshore futures markets can play a significant role in the determination of hedging strategies. Unpredictable movements in the basis preclude routine hedging as an optimal strategy and, within the limitations embodied in this analysis, hedge ratios well below unity are implied.

Based on the model presented above and the actual prices (spot and futures) which prevailed during the period 1977–84, the analysis indicates that short futures contracts equivalent to approximately 30 per cent of wheat stockholdings would, on average, have been optimal. In the context of decisions taken in the light of evolving market conditions, the analysis reveals that the optimal hedge ratio would have varied substantially over time, ranging from zero to 76 per cent of stockholdings. In general, the longer the time period of observations used by the decision maker to form estimates of parameter risk, the more stable and less sensitive to recent market developments the hedge ratio becomes.

It is emphasised that, in view of the simplifying assumptions contained in this analysis, the results reported here should not be interpreted as being prescriptive for the Australian Wheat Board. The Board's decision environment is substantially more complex than has been portrayed here and a more complete analysis would require incorporation of exchange rate and interest rate risks as well as allowance for endogenous price impacts created by large Board transactions. Other potential extensions include analysis in a multiperiod decision framework and the implications of basis trading for futures market participation. It is considered that these would be fruitful areas for further research. Notwithstanding the abovementioned qualifications, the results of this analysis provide confirmation of the importance of basis variation to the Board's activities. Research aimed at clarifying the determinants of spot price–futures price movements should perhaps be receiving higher priority.

References

Bond, G. E., Love, G. C. and Perkins, P. R. (1984), *Some Implications of the New Marketing Arrangements*, Australian Institute of Agricultural Science Occasional Publication No. 17, Sydney.

Bond, G. E. and Thompson, S. R. (1985), 'Risk aversion and the recommended hedging ratio', *American Journal of Agricultural Economics* 67(4), 870–2.

Berck, P. (1981), 'Portfolio theory and the demand for futures: the case of California cotton', *American Journal of Agricultural Economics* 64(3), 466–74.

Carter, C. A. and Loyns, R. M. A. (1985), 'Hedging feedlot cattle: a Canadian perspective', *American Journal of Agricultural Economics* 67(1), 32–9.

Kahl, K. H. (1983), 'Determination of the recommended hedging ratio', *American Journal of Agricultural Economics* 65(3), 603–5.

Kamara, A. (1982), 'Issues in futures markets: a survey', *Journal of Futures Markets* 2(3), 261–94.

Makin, J. H. (1982), 'Anticipated money, inflation uncertainty and real economic activity', *Review of Economics and Statistics* 64(1), 126–34.

Mishkin, F. S. (1982), 'Does anticipated monetary policy matter? an econometric investigation', *Journal of Political Economy* 90(1), 22–51.

Peck, A. E. (1975), 'Hedging and income stability: concepts, implications, and an example', *American Journal of Agricultural Economics* 57(3), 410–19.

Penm, J. H. W. and Terrell, R. D. (1982), 'On the recursive fitting of subset autoregression', *Journal of Time Series Analysis* 3(1), 43–60.

Perkins, P. (1984), American futures markets and their role in the pricing of Australian agricultural exports. Paper presented to the 28th Annual Conference of the Australian Agricultural Economics Society, University of Sydney, 7–9 February.

Perkins, P., Sniekers, P. and Geldard, J. (1984), 'Commercial link between Australian and US wheat prices', *Quarterly Review of the Rural Economy* 6(4), 321–9.

Rolfo, J. (1980), 'Optimal hedging under price and quantity uncertainty: the case of the cocoa producer', *Journal of Political Economy* 88(1), 100–16.

Sheffrin, S. M. (1979), 'Unanticipated money growth and output fluctuations', *Economic Inquiry* 17(1), 1–13.

Working, H. (1960), 'A note on the correlation of first differences of averages in a random walk', *Econometrica* 28(4), 916–8.

Zellner, A. (1962), 'An efficient method for estimating seemingly unrelated regressions and tests for aggregation bias', *Journal of the American Statistical Association* 57(298), 348–68.