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Potential demand for hedging by Australian wheat producers[†]

Phil Simmons and Alicia Rambaldi*

The potential for hedging Australian wheat with the new Sydney Futures Exchange wheat contract is examined using a theoretical hedging model parametrised from previous studies. The optimal hedging ratio for an 'average' wheat farmer was found to be zero under reasonable assumptions about transaction costs and based on previously published measures of risk aversion. The estimated optimal hedging ratios were found by simulation to be quite sensitive to assumptions about the degree of risk aversion. If farmers are significantly more risk averse than is currently believed, then there is likely to be an active interest in the new futures market.

1. Introduction

Historically, the Australian wheat industry has been exposed to high levels of price and production risk. Price per tonne received by growers over the last five years varied between A\$132 and A\$212 and national average yields over the same period varied between 1.11 and 1.97 tonnes per hectare (ABARE 1995). Price variability is caused by unstable world supply, the inelastic nature of demand and protection by governments of consumers and producers in important markets. Yield variability for Australian producers arises primarily from climatic risk and, as indicated by wide swings in national averages, tends to be highly correlated across producers.

There is only limited scope for the management of either production or price risk. Other grain crops are subject to the same climatic risk and, as close substitutes for wheat in both production and consumption, face similar price risks. The traditional form of production diversification is wool. Since the late 1960s and early 1970s there has been a steady increase in area planted to coarse grains, legumes and oilseeds reflecting increased

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*Phil Simmons works in the Department of Agricultural and Resource Economics and Alicia Rambaldi works in the Department of Econometrics, both at the University of New England, Armidale.

diversity in the Australian grains sector (ABARE 1995). However, in the absence of specific research, it is not clear whether this development represents a desire to diversify risk or a response to changes in relative prices.

The scope for management of price risk is also limited. Futures markets exist overseas, however, there is no evidence that Australian wheat growers have made use of them. Indirect use of these markets has occurred through Australian Wheat Board hedging activities. However, this type of activity has been small relative to the size of the harvest.

Bond, Thompson and Geldard (1985) examined the potential for hedging Australian wheat on the Chicago market by the Board and found that basis risk would be a significant deterrent to such trade. Basis risk occurs when futures and spot prices differ because of quality differences between farm produce and futures contract specification and the stochastic nature of these differences increases risks associated with hedging. Perkins, Sniekers and Geldard (1984) argued that basis risk makes hedging of Australian wheat on the Chicago futures market too risky and that the Kansas City market, trading hard red winter wheat, could be a more appropriate venue.

Price risk has also been managed through lobbying of government for favourable commercial policies. However, microeconomic reform has removed much of the legislation in this area over the last decade (Whitwell and Sydenham 1991). Virtually the only commercial policy remaining that may be favourable to price stabilisation is the export monopoly of the Australian Wheat Board. This monopoly, through its scale of operation, may result in economies in hedging and forward selling of Australian wheat in foreign markets. Approximately 80 per cent of the harvest is exported (ABARE 1995).

In April 1996 a new wheat futures contract was introduced at the Sydney Futures Exchange. The contract size is 50 tonnes (one truckload) and is for Australian Standard White wheat with a minimum of 9 per cent protein based on 11 per cent moisture. The new wheat contract is designed to meet the specific hedging needs of Australian growers and hence basis risk should be low. The contract is based on physical delivery rather than 'cash settlement' and maturity dates may be up to 18 months ahead of the spot month. Contracts mature in the months of January, March, July, September and November. This new market has the potential to play an important role in the management of price risk in Australian wheat production.

In section 2 a theoretical model of the optimal hedging rule for the Australian wheat market is developed. The model is in the spirit of previous work by Telser (1955), Heifner (1972) and Peck (1975), however, the framework has been adapted to provide an improved treatment of

production risk and to include explicit costs of hedging. In section 3 an empirical analysis is conducted to identify 'in principle' grower interest in a futures market. The values of the coefficients in the theoretical model were obtained from previously published work and the model was used to forecast optimal hedging ratios under a range of assumptions about transaction costs and risk aversion. Conclusions are presented in section 4.

2. Theoretical model

It was assumed that wheat growers' expected utility could be described using the expected value of, and the unanticipated variation in, wheat profits. Let $E(U)$ be expected utility, $E(\pi)$ expected profit and k the Pratt (1964) coefficient of absolute risk aversion:

$$E(U) = E(\pi) - \frac{k}{2} E[(\pi - E(\pi))^2]. \quad (1)$$

The function is a member of a general class ($E-V$) of utility functions that can be viewed as second order approximations to more complex (and presumably more realistic) forms. All the previous research on hedging reviewed for this study was based on quadratic utility functions except Telser (1955), who used a safety-first rule, and Grant (1985), who used a general utility function. Grant (1985) focused on the optimal level of hedging when farmers, viewed collectively, are price makers.¹ Issues associated with the $E-V$ framework are discussed in Markowitz (1959), Tsiang (1972), Anderson, Dillon and Hardaker (1977) and others and, in the context of hedging, in Peck (1975) and Newbery and Stiglitz (1981).

Production occurs within a one-year cycle so that producers maximise utility in period t conditional on information available in period $t-1$:

$$E_{t-1}(U_t) = E_{t-1}(\pi_t) - \frac{k}{2} E_{t-1}[(\pi_t - E_{t-1}(\pi_t))^2]. \quad (2)$$

Prices were assumed to follow a naïve expectations model with a multiplicative error term where u_{1t} is a random variable with zero mean and variance of σ_1^2 :

$$p_t = p_{t-1}(1 + u_{1t}) \quad (3)$$

It was necessary to make the simplifying assumption that prices are normally distributed so that the mean variance utility framework could be used. We assumed that proportional changes in price over time were

¹Newbery and Stiglitz (1981) showed that a hedge ratio of one was sub-optimal when farmers, because they share the same risks, have an inverse relationship between their individual outputs and realised prices. Grant (1985) increased the generality of this result.

normally distributed which, in our view, is more plausible than the more commonly used specification with additive errors where price changes are assumed to be independent of the level of prices. However, we acknowledge the point made by one reviewer that the distribution of prices is ultimately an empirical question.

Realised production was specified as:

$$q_t = A_t Y_t \quad (4)$$

where A_t is area sown in $t-1$ resulting in the area of wheat in t , and Y_t is yield per hectare. The equation for yield was assumed to have a similar functional form to the equation for price. However, the equation was specified with a linear trend, T , to capture improvements in crop husbandry over time. Both equations (4) and (5) are used below in the equation for expected profit and the incorporation of the trend was necessary so that the latter equation could have empirical content. The trend variable also allows greater generality since it allows the effect of improved crop productivity on the optimal hedging ratio to be considered.

$$Y_t = (d + eT)(1 + u_{2t}). \quad (5)$$

u_{2t} is a random variable with zero mean and variance of σ_2^2 . The Australian wheat industry contributes less than 3 per cent of world supply, therefore growers are price takers both individually and collectively. Hence u_{1t} and u_{2t} are assumed to be independent so that $E_{t-1}(u_{1t}, u_{2t}) = 0$.

Remembering that A_t is known in period $t-1$, planned production is:

$$q_t = A_t(d + eT). \quad (6)$$

Using h to denote the quantity hedged, fp the futures price in $t-1$ for a futures contract maturing in t and tc transaction costs, total profits are:

$$\pi_t = p_{t-1}(1 + u_{1t})q_t(1 + u_{2t}) - a - bq_t - cq_t^2 + h(fp - p_{t-1}(1 + u_{1t}) - tc). \quad (7)$$

Thus, wheat profits are revenue minus costs where costs are assumed to be a quadratic function of planned production. This treatment of costs involves two simplifications. First, cost savings from failed production are ignored. This is reasonable given that low yielding crops may be as costly to harvest as high yielding crops. The second simplification is the quadratic form which can be viewed as a second order approximation to any higher order differentiable cost function. Hedging profits or losses are the difference between the futures price in $t-1$ and realised price in t minus transaction costs all multiplied by quantity hedged. Conditional expected profits are:

$$E_{t-1}(\pi_t) = p_{t-1}q_t - a - bq_t - cq_t^2 + h(fp - p_{t-1} - tc). \quad (8)$$

Conditional expected utility is found by substituting 7 and 8 into 2:

$$E_{t-1}(U_t) = p_{t-1}q_t - a - bq_t - cq_t^2 + h(fp - p - tc) - \frac{k}{2} p_{t-1}^2 [(q_t - h)^2 E_{t-1}(u_{1t}^2) + q_t^2 E_{t-1}(u_{2t}^2 + u_{1t}^2 u_{2t}^2)] \tag{9}$$

Following Kahl (1983), decisions about the amount to produce and the amount to hedge are made simultaneously implying two first order conditions:

$$\frac{\delta E_{t-1}(U_t)}{\delta q_t} = p_{t-1} - b - 2cq_t - kp_{t-1}^2((q_t - h)E_{t-1}(u_{1t}^2) + q_t E_{t-1}(u_{2t}^2 + u_{1t}^2 u_{2t}^2)) = 0 \tag{10}$$

and

$$\frac{\delta E_{t-1}(U_t)}{\delta h} = fp - p_{t-1} - t + kp_{t-1}^2(q_t - h)E_{t-1}(u_{1t}^2) = 0. \tag{11}$$

Equations 10 and 11 are solved simultaneously for planned production and quantity hedged:

$$q_t = \frac{p_{t-1} - b + (fp - p_{t-1}) - tc}{2c + kp_{t-1}^2 E_{t-1}(u_{2t}^2 + u_{1t}^2 u_{2t}^2)} \tag{12}$$

$$h = q_t + \frac{(fp - p_{t-1}) - tc}{kp_{t-1}^2 E_{t-1}(u_{1t}^2)}. \tag{13}$$

Thus, planned production increases with expected price and declines with production and price risk. (For very high values of k , the supply curve could tilt backwards because of the squared price term in the denominator, however, previous estimates of k are extremely small.) Newbery and Stiglitz (1981, p.82) show that under special circumstances, when the coefficient of relative risk-aversion is constant, increased risk may cause highly risk-averse individuals to increase effort to avoid worst possible contingencies. This may mean that increased risk results in higher levels of planned production. This effect is not captured with the utility function used in this study.

Price risk only has a relatively small influence on planned production compared to the unhedged planning position (see equation 18 below). This reflects that most price risk is now covered by the hedge. Intuitively, the remaining influence of price risk results from the possibility that losses in the futures market cannot be offset by gains in the physical market because of a crop loss. Hence, price risk continues to be important through its interaction with production risk even when the farmer has ‘full cover’ in the futures market.

As futures market transaction costs increase, both planned production and the size of the hedge decline. The first right-hand side term in 13, q_t ,

can be viewed as the hedge that would occur if transaction costs were zero and if the futures price was unbiased and hence equivalent to the production planning price. In this situation 'insurance' is free and risk-averse growers have full cover regardless of the magnitude of the risk coefficient (Kahl 1983). From the second RHS term in 13, growers take less than full cover when transactions costs are positive, futures markets are biased against them due to, say, a risk premium, or when there is basis risk. Newbery and Stiglitz (1981) argue that $fp-p$ may also be interpreted as a speculative term when the hedger believes that he or she has superior information about future prices.

Keynes's (1927) theory of normal backwardation shows that if hedgers are predominantly short and underwriters are predominantly long, then a risk premium may emerge in the market and reduce futures prices. However, Newbery and Stiglitz (1981) examined the empirical evidence for bias in agricultural futures markets and concluded that the evidence was mixed. The new futures market in wheat is likely to be used by both short and long hedgers in as yet unknown proportions and hence the direction of any bias, if it were to emerge, cannot be predicted.

Another scenario where growers take less than full cover is where they are 'price makers'. Grant (1985) has shown that if production risk is correlated across producers and when the industry, viewed as a whole, can influence prices, then a perfect hedge is likely to be sub-optimal. For the case of Australian wheat, stochastic production is likely to be correlated across growers because of the geographical distribution of rainfall. However, with less than 3 per cent of world production, the industry is unlikely to be influential in determining world prices (ABARE 1995).

From our perspective, the important question is whether transaction costs, including direct costs of communicating and transacting, and indirect costs of learning and adopting a new marketing strategy, make futures markets 'too costly'.

3. Empirical results

The model was then specified without a futures market so that elasticities from previous studies could be used to obtain parameters that could be used in simulation. Profits were rewritten as:

$$\pi_t = p_{t-1}(1 + u_{1t})q_t(1 + u_{2t}) - a - bq_t - cq_t^2 \quad (14)$$

and conditionally expected profits as:

$$E_{t-1}(\pi_t) = p_{t-1}q_t - a - bq_t - cq_t^2. \quad (15)$$

Substituting 14 and 15 into 2, conditional expected utility was:

$$E_{t-1}(U_t) = p_{t-1}q_t - a - bq_t - cq_t^2 - \frac{k}{2}q_t^2p_{t-1}^2E_{t-1}[u_{1t}^2 + u_{2t}^2 + u_{1t}^2u_{2t}^2]. \quad (16)$$

This was maximised with respect to the decision variable, planned production:

$$\frac{\partial E_{t-1}(U_t)}{\partial q_t} = p_{t-1} - b - q_t(2c + kp_{t-1}^2E_{t-1}[u_{1t}^2 + u_{2t}^2 + u_{1t}^2u_{2t}^2]) = 0 \quad (17)$$

which was solved for planned production, q_t :

$$q_t = \frac{-b + p_{t-1}}{2c + kp_{t-1}^2E_{t-1}[u_{1t}^2 + u_{2t}^2 + u_{1t}^2u_{2t}^2]} \quad (18)$$

Thus, as with the hedging model, increases in the coefficient of absolute risk aversion, k , or ‘noise’ arising from prices or climate reduce the level of planned production.

The residuals from estimates of 5 and 3 (discussed below) were found to be homoscedastic and hence the squared error terms were assumed to be constant over time. For simulation purposes, these were viewed as sample variances.

Mean values of price, area and yield for the period 1990–91 to 1994–95 (with prices inflated to 1994–95 values using the Consumer Price Index) were calculated using data from ABARE (1995). These values are reported in table 1. The values of σ_1^2 and σ_2^2 were calculated using data on price and yield from 1955–56 to 1994–95 from ABARE (1994) and ABARE (1995). The value of σ_1^2 was obtained from 5 using a spread sheet and d and e , from 7, were estimated with regression analysis (see table 2). Equation 7 was then used to calculate σ_2^2 . The values of σ_1^2 and σ_2^2 are reported in table 1.

The key parameters were c and k , since these values are of central importance in the hedging decision. They were obtained using previously published estimates of the coefficient of absolute risk aversion and of the elasticity of supply. It was then possible to calculate b as a residual using the variable values described above.

Table 1 Mean values of model variables

Variable	Mean value
P_{t-1}	\$204/tonne
A_t	8482 hectares
Y_t	1.59 tonnes/hectare
σ_1^2	0.040
σ_2^2	0.062

Source: The model was ‘parametised’ using mean values for price, area and yield between 1990–91 and 1994–95. The variance terms were derived using regression analysis as described in the text.

Table 2 Model parameters

Coefficient	Value
<i>b</i>	117.617
<i>c</i>	0.0117
<i>d</i>	1.000
<i>e</i>	0.0124
<i>k</i>	9.633E-8

Source: The model parameters were based on published measures of the elasticity of supply and coefficient of absolute risk aversion and on regression results for yield and trend in yield.

Ten studies reporting estimates of elasticities of supply of wheat with respect to own price were reviewed and divided into two groups loosely termed 'more rigorous' and 'less rigorous'. Of the five studies in the 'more rigorous' group, Vincent, Dixon and Powell (1980), McKay, Lawrence and Vlastuin (1982), Fisher and Wall (1990) and Johnson, Powell and Dixon (1990) had supply elasticities that were clustered in a range between 0.46 and 0.77. The mean of this cluster was 0.60 which was used as the basis for calculation of *c* in our model.

Only two studies reporting coefficients of risk aversion for Australian farmers were found. The results reported by Bond and Wonder (1980) were preferred as a basis for obtaining a value for *k* over those of Bardsley and Harris (1987) which was 'too pioneering' in its approach for our purposes. The elicitation technique in Bond and Wonder (1980) has been used extensively in previously published work.

The values for *A* (Bond and Wonder (1980), table 3) and information on hypothetical income levels (Bond and Wonder (1980), Appendix 1) were used to measure *k*. In the first step, their *A* values were converted to coefficients of absolute risk aversion by multiplying them by -2 . In the second step, the coefficients obtained in step 1 were converted to coefficients of relative risk aversion by multiplying by income levels obtained from the Appendix. In step three, these values were averaged and then divided by the expected income level from our study. This provided the value of the coefficient of absolute risk aversion, *k*, relevant to our study. The coefficient of absolute risk aversion used in this study was 9.633E-8 (see table 2). This corresponded to a coefficient of relative risk aversion of 0.265 after removing the effects of income.

The values of the elasticity of supply and coefficient of absolute risk aversion were used with the values of the variables and 18 to calculate *c* directly and *b* as a residual (see table 2). The coefficients and variable

values were then used to make 12 and 13 operational so that optimal hedging ratios could be obtained through simulation.

Farmers incur a variety of direct costs other than brokerage when hedging including interest payments on margin calls and communication charges. However, on a per tonne basis, these charges are relatively small and aggregate direct costs are likely to be around A\$5 per tonne depending on the scale of the hedging operation.

Simulation of 12 and 13 using transaction costs of A\$5 per tonne resulted in a hedge ratio of zero. As shown in figure 1, the hedge ratio approaches zero when transaction costs reach A\$2.15 per tonne. Since some farmers will have greater than average risk aversion, some hedging may still occur, however, an 'average' farmer will not sell contracts for hedging purposes. An average hedge ratio of zero is consistent with casual observation and surveys of farmer participation in futures markets. Berck (1981) reports that futures markets are not used by 95 per cent of American farmers.

The only contentious value used in our simulation was the coefficient of absolute risk aversion. Thus, a sensitivity analysis was conducted in which the analysis was repeated for alternative values of the coefficient of

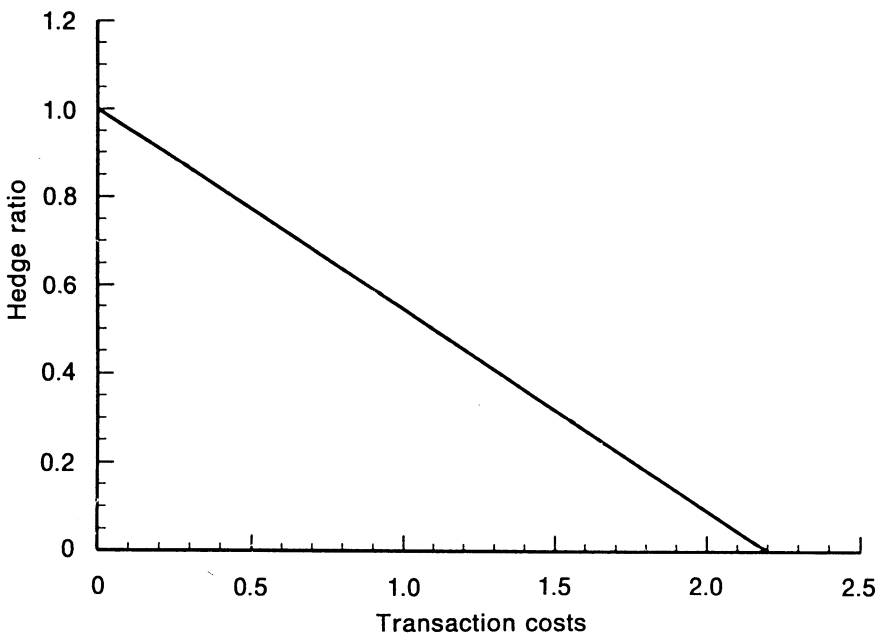


Figure 1 Optimal hedging ratios with a range of transaction costs

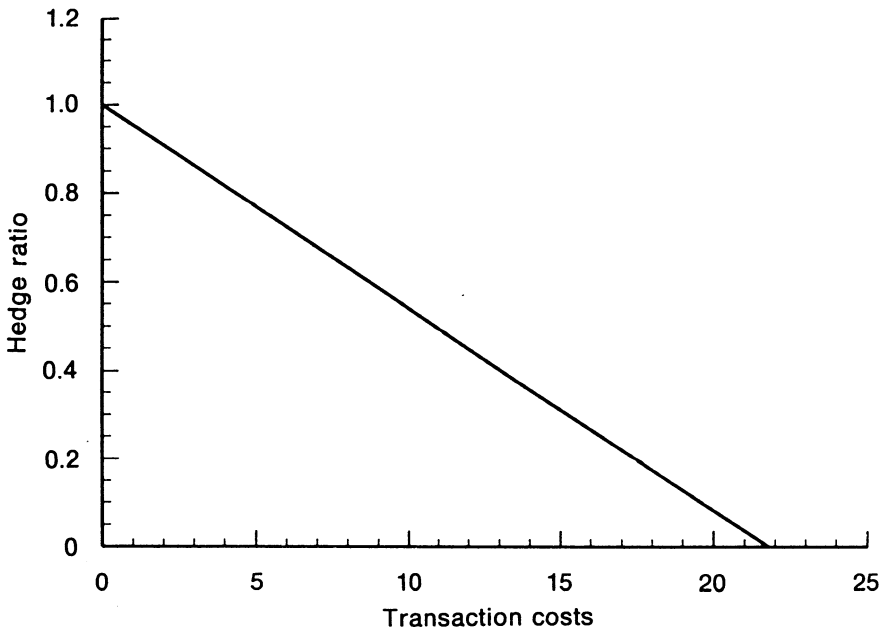


Figure 2 Sensitivity analysis of optimal hedging ratios

absolute risk aversion, k . The coefficient was first increased by a factor of ten to $9.63\text{E-}7$ and then reduced below our initial value for k of $9.63\text{E-}8$ to $9.63\text{E-}9$. The model coefficients were recalculated and the simulations undertaken across a range of transaction costs. Increasing k to $9.63\text{E-}7$ with transaction costs of A\$5 per tonne resulted in a hedge ratio of 0.81 (see figure 2). This indicated a relatively high degree of sensitivity in our conclusions to changes in the degree of risk aversion. When k was reduced by a factor of ten, the hedge ratio remained zero.

4. Conclusions

Our results show that, under reasonable assumptions about transaction costs, and based on previously published results for risk aversion, there is unlikely to be significant interest from Australian wheat growers in the new futures contract. However, some caution in interpreting this result is in order. First, the results are sensitive to assumptions about the degree of risk aversion and the integrity of the results hinges on the results reported in Bond and Wonder (1980). As indicated by the sensitivity analysis, if farmers are, on average, more risk averse than we have assumed, then

there may be active interest in the contract. Second, Bond and Wonder (1980) reported that risk aversion was likely to show a high level of variability across Australian broad-acre farming industries. It was not possible to derive the variance of our k from the information in Bond and Wonder (1980), however, their reported standard errors indicate a high level of variability. Thus, while interest on average in the contract is likely to be zero, our results are consistent with a proportion of the industry with above-average risk aversion making use of the contract. The third cautionary note is that our assumptions about transaction costs do not include indirect costs associated with learning or with overcoming prejudice against new entry to futures markets. If such indirect costs were large, then the optimal hedging ratio could be considerably smaller even for farmers who were very risk averse. However, it is not clear what price should, or even could, be placed on learning and overcoming prejudice. This is a topic for further research.

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