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Seasonal variability, land values and willingness-to-pay for a forward wheat contract with protein premiums and discounts†

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This article investigates the impact of a protein premiums and discounts system on the income stream from growing wheat. Based on a biological relationship between protein and yield in uncertain seasonal conditions, it shows that such a system reduces the expected level and variability of wheat income. It is subsequently argued, using a numerical analysis, that protein payments affect both the attraction to wheat growers of forward contracts and the value of land used for wheat. The nature of both of these impacts is related to the level of seasonal variability affecting the land. Consequently, wheat growers in the more unreliable regions of the wheatbelt may have been particularly disadvantaged by the system.

1. Introduction

A recent change in Australian wheat marketing has been the introduction of substantial premiums and discounts for protein content. For example, for the 1996–97 season from a standard protein content of 10 per cent for Australian Standard White, the Australian Wheat Board (AWB) offers symmetrical payments of \$10 per tonne extra for 12 per cent protein and \$10 per tonne less for 8 per cent protein (Australian Wheat Board 1996). This change has affected the income stream from land used for growing wheat. In particular, because the biological impact of seasonal variability is to create an inverse relationship between yield and protein level (for given nitrogen availability), for a grower producing wheat with 10 per cent protein in a typical season, protein premiums are more likely in seasons of relatively low yield, and discounts more likely in seasons of relatively high

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yield. The existence of this inverse relationship has been established scientifically by plot trials in a range of wheat-growing areas for a number of wheat varieties.[1] Consequently, by creating such a negative correlation between price and yield, the protein payments system effectively introduces a form of income stabilisation scheme, while at the same time reducing the expected level of income for growers producing wheat with the AWB's standard protein content in typical seasons.

This consequence of the protein payments system has several implications for wheat growers, two of which are the focus of this article. First, although the direct impact of the protein payments system is to increase the level of price variability, overall, the system acts to reduce the level of income variability. Therefore, it might be expected that the protein payments system has affected the attractiveness to wheat growers of price risk management instruments. On the assumption that wheat growers are interested in price risk management for the purpose of income stabilisation, the analysis in this article investigates the impact of the protein payments system on a wheat grower's willingness-to-pay for a price risk management instrument such as a forward contract. Particular attention is paid to the AWB's Multigrade Contract which was introduced in association with the protein payments system. In this context it is argued that the dominant effect of the system for growers producing wheat with the AWB's standard protein content in typical seasons is a reduction in expected income, thereby increasing the attractiveness to such growers of price risk management. Moreover, as this effect is stronger in more seasonally unreliable regions, it is suggested that the Multigrade Contract could be differentially priced across the wheatbelt.

The second implication of the protein payments system relates to its impact on land values. Because the system reduces both the expected level and the variability of income from land producing wheat with the AWB's standard protein content in a typical season, it would appear to have had an ambiguous impact on the value of such land for a risk-averse farmer. The analysis in this article investigates these effects of the protein payments system on agricultural land values, with particular emphasis on the level of seasonal variability. It is suggested that, although the introduction of the system appears to have an ambiguous impact on the value of land with relatively low levels of seasonal variability, this impact is more

[1] See, for example, Perry and Hillman (1991, pp. 108–12) and Holford, Doyle and Leckie (1992). Note that although the existence of this inverse relationship is established, its precise specification is currently a key component of nitrogen nutrition research. Recent evidence from Western Australia suggests some sort of hyperbolic form. See Robinson (1995).

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likely to be negative for land with higher levels of seasonal variability. Consequently, because such land is likely to be relatively low-priced compared to land which has a more reliable yield, it is suggested that the introduction of the protein payments system has had the overall effect of widening the range of land values across wheat-growing areas.

The article ends with a brief conclusion which focuses specifically on the issues raised in connection with the protein payments system as they relate to growing wheat in less seasonally reliable regions.

2. Modelling the impact of a protein payments system

In the Introduction it was suggested that the AWB's protein payments system and the inverse biological relationship between yield and protein level (for given nitrogen availability) have combined to create a negative correlation between price and yield for wheat grown in uncertain seasonal conditions. Moreover, this negative correlation has the effect of decreasing both the expected level and variability of income for growers producing wheat with the AWB's standard protein content in a typical season.

To develop this argument systematically it is assumed in what follows that in the absence of the protein payments system the grower's uncertain price and season are independent. Such a simplification seems reasonable given the structure of the Australian wheat growing industry and the relatively minor role of Australian wheat exports in the world market.

In addition, it is assumed that yield uncertainty has a multiplicative relationship with seasonal uncertainty:

$$y = \theta\bar{y} \tag{1}$$

where:

y = uncertain yield per hectare

θ = random parameter representing seasonal uncertainty ($E(\theta) = 1$)

$\bar{y}$ = planned (expected) yield per hectare.

Note that multiplicative production uncertainty is typically the preferred specification in the context of agricultural production (e.g. Newbery and Stiglitz 1981, p. 65). Furthermore, in what follows θ is assumed to be symmetrically distributed. While this assumption is unlikely to hold in regions with a significant probability of drought, empirical evidence suggests that symmetrical yield distributions are associated with warmer, drier climates such as prevails in much of the Australian wheatbelt (Park and Sinclair 1993).

On this basis a grower's expected level ($E_0(I)$) and variance ($Var_0(I)$) of wheat income per hectare in the absence of protein payments are given by:

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$$E_o(I) \quad = \bar{p}\,\bar{y} \tag{2}$$

$$\mathrm{Var}_o(I) = \bar{y}^2\mathrm{Var}(p) + \bar{p}^2\mathrm{Var}(y) + \mathrm{Var}(p)\mathrm{Var}(y) \tag{3}$$

where:

$\bar{p}$ = expected price per tonne

$\mathrm{Var}(p)$ = variance of price

$\mathrm{Var}(y)$ = variance of yield = $\bar{y}^2\mathrm{Var}(\theta)$.

Note from (3) that an increase in the level of either price or seasonal variability increases the level of income variability.

In recognising the impact of introducing protein premiums and discounts, it is necessary to specify the inverse biological relationship between yield and protein. As indicated previously, preliminary scientific evidence suggests some sort of hyperbolic relationship, which is conditional on soil type and available nitrogen (Robinson 1995).[2] A simple functional form which satisfies these requirements is given by:

$$r = \gamma / y \tag{4}$$

where:

r = protein level

γ = parameter relating to soil type and available nitrogen.

In the absence of scientific evidence to the contrary, this simple form is maintained in what follows. However, it should be recognised that a negative correlation between price and yield in the presence of protein payments is a general consequence of an inverse relationship between protein and yield and is not dependent on this particular functional form.[3]

Although the AWB's existing protein payment scales are based on protein payment increments for each 0.1 per cent of protein, in what follows it is assumed that the quality structure of wheat can be represented by only three grades of wheat (high, medium and low protein). This simplifying assumption is made solely on grounds of giving priority to analytical tractability over a more realistic representation. However, the

[2] Nitrogen nutrition researchers at Agriculture Western Australia support this approach (pers. comm.).

[3] I am grateful to an anonymous referee for clarifying this point. Note that the simplest functional form which represents the inverse biological relationship is given by:

$$r = \gamma - y.$$

However, in this case the indicated hyperbolic feature is lost. Note also that an inverse relationship is implicit in Hertzler and Coad's (1996) assumption of a negative covariance between yield and protein payments.

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size of the protein premium is set equal to the size of the discount which is consistent with the symmetrical feature of the AWB's payment scale:

$$\begin{aligned} \overline{p}_H &= \overline{p} + x \text{ if } \theta && < \gamma / r_H \overline{y} \\ \overline{p}_M &= \overline{p} \text{ if } \gamma / r_H \overline{y} \leqslant \theta && < \gamma / r_L \overline{y} \\ \overline{p}_L &= \overline{p} - x \text{ if } \theta && > \gamma / r_L \overline{y} \end{aligned} \tag{5}$$

where:

x = size of protein premium/discount

$\overline{p}_H$ = expected price with protein premium

$\overline{p}_L$ = expected price with protein discount

r_L = critical low protein level

r_H = critical high protein level.

Finally, the critical protein levels are set symmetrically in relation to the protein level associated with the grower's expected yield ($\gamma/\overline{y}$).[4] This can be done in either of two ways:

(i) setting the probability of a premium equal to the probability of a discount:

$$F(\gamma/r_H\overline{y}) = (1 - F(\gamma / r_L\overline{y})) \tag{6}$$

where:

$F(\gamma/r_H\overline{y})$ = cumulative probability of θ being less than $\gamma/r_H\overline{y}$

$F(\gamma/r_L\overline{y})$ = cumulative probability of θ being less than $\gamma/r_L\overline{y}$,

or:

(ii) setting r_L and r_H symmetrically with respect to $\gamma/\overline{y}$.

With θ assumed to be symmetrically distributed, these two approaches give approximately the same results as long as r_L and r_H are relatively close to $\gamma/\overline{y}$.[5] Since the protein payments system will have little impact unless r_L

[4] This assumption focuses the impact of protein payments on income through the negative correlation between price and yield. For growers with typical protein levels below the AWB standard, the negative expected income effect of the system will be stronger, while the reverse applies for typical protein levels above this standard. Consequently, the implications of relaxing this assumption are fairly straightforward.

[5] With θ symmetrically distributed, (i) requires setting $\gamma / r_L\overline{y}$ and $\gamma / r_H\overline{y}$ symmetrically about unity, whereas (ii) requires setting $\gamma / r_L\overline{y}$ equal to the inverse of $\gamma / r_H\overline{y}$. Consequently, for values of $\gamma / r_L\overline{y}$ and $\gamma / r_H\overline{y}$ up to about 20 per cent away from unity, (i) and (ii) give similar values. Note also that it is not statistically precise to refer to $\gamma/\overline{y}$ as the expected protein level because r is a hyperbolic function of y.

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and r_H are relatively close to $\gamma/\bar{y}$, in what follows the equal probability approach is adopted as this approach features the additional simplification that the expected protein payment per tonne ($E(z)$) is precisely zero:

$$E(z) = F(\gamma/r_H\,\bar{y})x - (1 - F(\gamma/r_L\bar{y}))\,x = 0. \tag{7}$$

where:

$$\begin{aligned} z &= x \quad \text{if } \theta < \gamma/r_H\bar{y} \\ &= -x \quad \text{if } \theta > \gamma/r_L\bar{y}. \end{aligned}$$

On this basis, expected income in the presence of protein payments ($E_1(I)$) is given by:

$$\begin{aligned} E_1(I) &= E((p + z).y) \\ &= \bar{p}.\bar{y} + E(z.y) \\ &= \bar{p}.\bar{y} + \bar{y}\,x(w_1 - w_3) \end{aligned} \tag{8}$$

where:

$$w_1 = \int_0^{\gamma/r_H\bar{y}} \theta f(\theta)\,\mathrm{d}\theta$$

$$w_3 = \int_{\gamma/r_L\bar{y}}^{\infty} \theta f(\theta)\,\mathrm{d}\theta.$$

Since $w_3 > w_1$, the second term on the right-hand side of (8) is negative so that recalling (2) gives:

$$E_1(I) < E_0(I). \tag{9}$$

This result confirms the suggestion that the introduction of protein payments in combination with the negative biological relationship between protein and yield reduces expected income from growing wheat which would typically yield a standard protein content in uncertain seasonal conditions.[6]

Next, notice on the basis of (5) that the variance of price in the presence of protein payments ($\mathrm{Var}_1(p)$) is given by (see Mood, Graybill and Boes 1974, p. 179):

$$\begin{aligned} \mathrm{Var}_1(p) &= \mathrm{Var}\,(p + z) \\ &= \mathrm{Var}(p) + \mathrm{Var}(z) + 2\mathrm{cov}(p,z). \end{aligned} \tag{10}$$

Since price and season have been assumed to be independent in the absence of protein payments and θ is symmetrically distributed:

$$\mathrm{Var}_1(p) = \mathrm{Var}(p) + 2x^2F(\gamma/r_H\bar{y}). \tag{11}$$

[6]Note that the specification in this article assumes the optimal level of variable inputs is unchanged by the introduction of the protein payments system. This impact remains to be investigated.

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It is clear from (11) that the variance of price in the presence of protein payments exceeds the variance of price in their absence. However, it is shown in the Appendix that the variance of income in the presence of protein payments ($\mathrm{Var}_1(I)$) is given by:

$$\mathrm{Var}_1(I) = \mathrm{Var}_o(I) + 2\bar{y}^2\bar{p}x(w_1 - w_3) + 2\bar{y}^2x^2(m_1 + (w_1 + w_3) - F(\gamma / r_H\bar{y})) \tag{12}$$

where:

$$m_1 = \int_0^{\gamma/r_H\bar{y}} (\theta - 1)^2 f(\theta)\mathrm{d}\theta.$$

Equation (12) shows that the impact of introducing a protein payments system on the variance of income will be positive or negative depending on the second and third terms on the right-hand side. Since $w_3 > w_1$, the second term is negative, while the third term may be positive or negative. However, for x small relative to $\bar{p}$, the magnitude of the second term will dominate the third regardless of its sign and so the impact of the protein payments system will be to reduce the variance of income:

$$\mathrm{Var}_1(I) < \mathrm{Var}_0(I). \tag{13}$$

This result confirms the suggestion that the introduction of protein payments in combination with the negative biological relationship between protein and yield also reduces the variability of income from growing wheat in uncertain seasonal conditions.

The remainder of the article investigates numerically the implications of these findings both for the use by growers of price risk management instruments such as forward contracts, and for the value of land used for growing wheat.

3. Protein payments and forward contracts

In the previous section it was shown that the introduction of a protein payments system decreases both the level of expected income and the level of income variability from growing wheat which would typically yield a standard protein content in uncertain seasonal conditions. It is argued here not only that these changes will affect the attractiveness of price risk management instruments such as forward contracts for growers who are seeking income stabilisation, but also that the magnitude of the overall effect is positively related both to the level of seasonal variability faced by the grower and to the magnitude of the protein payments.[7] To support

[7]Specifically, that the divergence between w_1 and w_3 increases with a shift of probability weight to the tails of the distribution of θ, and that an increase in x increases the magnitude of the second term on the right-hand side of (8) and (12).

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this argument, consider a numerical analysis of the effects of the protein payments system identified previously.

In order to undertake a numerical analysis of a grower's willingness-to-pay for a forward contract using the previous findings, it is necessary to specify the probability distribution for seasonal uncertainty. Assuming a normal distribution for θ gives (see Fraser 1988):

$$w_1 = F(\gamma/r_{\mathrm{H}}\bar{y})(1 - \sigma_\theta \,.\, Z(\gamma/r_{\mathrm{H}}\bar{y}) \,/\, F(\gamma/r_{\mathrm{H}}\bar{y}))$$

$$w_3 = (1 - F(\gamma/r_{\mathrm{L}}\bar{y}))(1 + \sigma_\theta Z(\gamma/r_{\mathrm{L}}\bar{y}) \,/\, (1 - F(\gamma/r_{\mathrm{L}}\bar{y})))$$

$$m_1 = F(\gamma/r_{\mathrm{H}}\bar{y})\sigma_\theta^2\left(1 - \frac{(\gamma/r_{\mathrm{H}}\bar{y} - 1)}{\sigma_\theta}\,\frac{Z(\gamma/r_{\mathrm{H}}\bar{y})}{F(\gamma/r_{\mathrm{H}}\bar{y})} - \left(-\frac{Z(\gamma/r_{\mathrm{H}}\bar{y})}{F(\gamma/r_{\mathrm{H}}\bar{y})}\right)^2\right)$$

where:

σ_θ = standard deviation of θ

σ_θ^2 = Var(θ)

$Z(\gamma/r_{\mathrm{H}}\bar{y})$ = ordinate of the standard normal distribution at the value of θ corresponding to the critical high protein level

$Z(\gamma/r_{\mathrm{L}}\bar{y})$ = ordinate of the standard normal distribution at the value of θ corresponding to the critical low protein level.

In addition, it is assumed that the grower's utility of profit (π) takes the mean-variance form:

$$E(U(\pi)) = U(E(\pi)) + \tfrac{1}{2}U''(E(\pi)).\mathrm{Var}(\pi) \tag{14}$$

where:

$\pi = py - c(\bar{y})$

$c(\bar{y})$ = cost of expected yield per hectare,

and that the utility function is given by the constant relative risk aversion form:

$$\mathrm{U}(\pi) = \frac{\pi^{1-R}}{1 - R} \tag{15}$$

where:

R = coefficient of relative risk aversion.

See Hanson and Ladd (1991) and Pope and Just (1991) for arguments supporting these assumptions.

The following parameter values are chosen for a base case:

$\bar{p} = 200 \quad (= \bar{p}_{\mathrm{M}})$

$\bar{y} = 100$

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$$c(\bar{y}) = 10\,000$$
$$\mathrm{Var}(p) = 3\,600 \quad (CV_p = 30\%)$$
$$R = 0.7.$$

Note that the expected price level has been chosen to approximate actual values, while Hazell, Jaramillo and Williamson (1990) provide supporting estimates of world wheat price variability, and Bardsley and Harris (1987) provide supporting estimates of attitudes to risk in the wheatbelt of Australia.

In addition, based on the estimates of Anderson, Dillon, Hazell, Cowie and Wan (1988) two representative levels of seasonal uncertainty are chosen:

$$\sigma_\theta = 0.2 \quad (CV_y = 20\%)$$
$$\sigma_\theta = 0.4 \quad (CV_y = 40\%).$$

Finally, the protein payments system is specified by the critical protein levels:

$$\gamma / r_{\mathrm{H}}\bar{y} = 0.8$$
$$\gamma / r_{\mathrm{L}}\bar{y} = 1.2$$

and, for illustrative purposes, two different levels of premiums and discounts:

$$x = 10 \quad (5\% \quad \text{of } \bar{p})$$
$$x = 20 \quad (10\% \quad \text{of } \bar{p}).$$

On the basis of these specifications, equation (14) can be evaluated in the presence and absence of the protein payments system using equations (8) and (12) and (2) and (3), respectively. This gives the expected utility of profits in the absence of any forward contracting. The willingness-to-pay for a forward contract in the absence of protein payments can be evaluated by eliminating the Var(p) terms from equation (3) and adjusting downwards the level of $\bar{p}$ until expected utility is equal to the level in the absence of forward contracting. The difference between this price level and the expected price is the amount the grower is willing to pay to secure a fixed price for each tonne of expected wheat yield. Similarly, the willingness-to-pay for a multigrade forward contract in the presence of protein payments can be evaluated by eliminating the Var(p) terms from equation (12) and adjusting downwards the level of $\bar{p}$ until expected utility is equated to the level in the absence of forward contracting. The difference between this price level and the expected price is the amount the grower is willing to pay

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Table 1 Estimates of willingness-to-pay for a forward contract in the absence and presence of a protein payments system

	Size of protein payments ($/tonne) (1)	(2)	(3)
Level of seasonal uncertainty	$x = 0$	$x = 10$	$x = 20$
$\sigma_\theta = 0.2$			
w-t-p ($/tonne)	12.01	12.28	12.52
w-t-p (% certainty equivalent of profit)	14.56	14.90	15.22
$\sigma_\theta = 0.4$			
w-t-p ($/tonne)	11.91	12.56	13.22
w-t-p (% certainty equivalent of profit)	17.63	18.75	19.98

to secure a fixed price with respect to each quality of wheat for each tonne of expected yield.[8]

Table 1 gives details of the results of the numerical analysis, featuring the grower's willingness-to-pay (w-t-p) for a forward contract both in terms of $ per tonne and as a percentage of the certainty equivalent of profit. Note that the certainty equivalent of profit (s) is given by the value of s which solves:

$$U(s) = E(U(\pi)) \tag{16}$$

where $E(U(\pi))$ is calculated from (14) using (15). Consider first the results in column (1) of table 1 which represent the situation prior to the introduction of a protein payments system. They reflect the previous finding (equations (2) and (3)) that an increase in the level of seasonal uncertainty (i.e. $\sigma_\theta = 0.2$ to $\sigma_\theta = 0.4$) increases the variability of income, but leaves expected income unchanged, and so a grower in the latter situation is willing-to-pay a greater proportion of the certainty equivalent of profit to remove price risk with a forward contract. Note the $ per tonne amounts being almost equal reflects the fact that the certainty equivalent of profit is smaller in the latter case.

Now consider the results which represent the situation following the introduction of a protein payments system. For both levels of seasonal

[8]Note that for both the ungraded and the multigrade contracts it is assumed that there is no penalty in the event of failure to deliver the contracted amount. This omission may affect the absolute level of willingness-to-pay but not the relative level for the two contracts.

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uncertainty it can be seen that the introduction of protein payments increases the willingness-to-pay for a forward contract. For example, for the lower level of seasonal uncertainty (i.e. $\sigma_\theta = 0.2$), with protein payments equal to 5 per cent of the expected price (i.e. $x = 10$), the willingness-to-pay for a multigrade contract is 14.90 per cent of the certainty equivalent of profit (or \$12.28 per tonne) compared with 14.56 per cent (or \$12.01 per tonne) for an ungraded contract in the absence of protein payments.

This comparison clearly illustrates the dominance in the context of willingness-to-pay for price risk management of the impact of protein payments on expected income over the impact on the variability of income for a grower producing wheat which would typically yield the AWB's standard protein content. In the presence of protein payments such a grower is evaluating the perceived benefits of a forward contract from a lower level of expected income. The attractiveness of risk management is enhanced at this level, so much so that even though the overall level of income variability is also lower, the willingness-to-pay for a reduction in this level is greater.

Moreover, the results in table 1 also show that this positive impact of the protein payments system on the willingness-to-pay for a forward contract is itself positively related both to the size of the protein payments and to the level of seasonal uncertainty. Although in these situations the magnitude of both the expected income and variability of income effects is greater, the results in table 1 suggest that proportionately the former impact exceeds the latter. Note, however, that if the negative impact of the system of protein payments on expected income is diminished, then the potential exists for the impact of the system on the variability of income to dominate, thus resulting in a reduced willingness-to-pay for a forward contract in the presence of protein payments. For example, further numerical analysis shows that for a grower facing the higher level of seasonal uncertainty ($\sigma_\theta = 0.4$), the introduction of a protein payments system at the level of $x = 20$ but which has no impact on expected income (say, because the grower's typical protein content is sufficiently above the standard content) results in a willingness-to-pay for a forward contract of 17.56 per cent of the certainty equivalent of profit compared with 17.63 per cent in the absence of protein payments.

Nevertheless, for growers producing wheat which typically yields the AWB's standard protein content, the results in table 1 clearly show a dominance of the expected income effect of a protein payments system, and the associated increase in the willingness-to-pay for a forward contract. Moreover, the potential exists for the AWB to discriminate between regions with different levels of seasonal uncertainty in terms of the

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price of its multigrade contract, with the implementation of such discrimination seeing growers with more unreliable seasonal conditions paying more for this type of contract.

4. Protein payments and land values

It was shown previously that a protein payments system reduces both the expected level and variability of income from growing wheat which would typically yield the AWB's standard protein content in uncertain seasonal conditions. On the basis that these effects on the income stream from land used for growing wheat affect its value, it is argued here that on balance the effect of the system on land values is ambiguous.[9] However, it is also argued that this effect is more likely to be negative in situations where there is greater unreliability of seasonal conditions. To support these arguments, consider an extension of the numerical analysis undertaken previously. In particular, let the certainty equivalent of profit (s) from land used for wheat growing act as a proxy for its value.

On this basis, the impact of the protein payments system on the value of land used for wheat growing is represented by the percentage difference in the values of s which solve (16) using (14) and the pairs of equations (2) and (3), and (8) and (12) respectively, along with the specified parameter values. Table 2 contains details of the percentage change in the certainty equivalent of profits associated with the introduction of the protein payments system ($x = 10$) for the two levels of seasonal variability ($\sigma_\theta = 0.2$; 0.4) and a range of values of risk aversion ($R = 0.5$; 0.7; 0.9).

It can be seen from table 2 that, at the lower level of seasonal variability, the impact on the certainty equivalent of profits depends on the

Table 2 Impact of protein payments on the certainty equivalent of profits: $x = 5\%$ of $\overline{p}$ (% change)

Level of seasonal uncertainty	R		
	0.5	0.7	0.9
$\sigma_\theta = 0.2$	–0.28	–0.02	+0.21
$\sigma_\theta = 0.4$	–1.41	–0.88	–0.48

[9] See Tegene and Kuchler (1993) for details of the use of the so-called 'present value' model for determining land values.

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attitude to risk of the grower. For a less risk-averse grower ($R = 0.5$), the negative impact of protein payments on expected income dominates overall and the certainty equivalent of profits is reduced with the introduction of the system. However, for a more risk-averse grower ($R = 0.9$), the positive impact of the system in reducing the variability of income dominates and the certainty equivalent of profits increases. Consequently, for growers faced with this level of seasonal variability, but with a spread of attitudes to risk around the central value of $R = 0.7$, there is no unambiguous impact of the system on these growers' perceptions of the value of their wheat growing land.

By contrast, table 2 also shows that, at the higher level of seasonal variability, there is no such ambiguity of impact across growers with the indicated diversity of attitudes to risk. Instead, it is clear that all these growers would agree that the negative impact of the system on the expected income from wheat-growing dominates and so their united perception is of a decrease in the value of their land.

Therefore, the results in table 2 provide support for the conclusion that the overall impact of protein payments on a grower's certainty equivalent of profits from producing wheat on land which would typically yield the AWB's standard protein content is more likely to be negative, the larger is the level of seasonal variability of that land. Since such land is also likely to be relatively low-priced compared to other wheat-growing land, one effect of the protein payments system may have been to widen the range of land values across the wheatbelt.

5. Conclusion

This article has considered the impact of introducing a system of protein payments both on a wheat grower's willingness-to-pay for a forward contract and on the value of land used for growing wheat.

Using a particular specification of the biological relationship between seasonal, yield and protein uncertainty, it was shown that introducing protein payments decreased both the expected level and variability of income from growing wheat which would typically yield the AWB's standard protein content in uncertain seasonal conditions.

In the context of forward contracts, it was argued that the dominant effect of the system is on the expected level of income. As a consequence, the attraction to wheat growers of forward contracts would be enhanced. By contrast, in the context of land values it was argued that the effect of the system on the value of land used for growing wheat is ambiguous.

However, in both cases it was indicated that the nature of the impact of introducing a protein payments system was related to the level of seasonal

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variability. In particular, it is wheat growers in the more seasonally unreliable regions of the wheatbelt who not only would have experienced proportionately larger increases in their willingness-to-pay for a forward contract, but also are more likely to perceive the system to have reduced their land values. This suggests that such growers have been particularly disadvantaged by the system. Moreover, it may be that a case exists for differentially pricing the AWB's Multigrade Contract across the wheatbelt in order to reflect its divergent levels of seasonal variability.

Appendix: Derivation of the variance of income in the presence of protein payments

The variability of income in the presence of protein payments ($\mathrm{Var}_1(I)$) is given by:

$$\begin{aligned}\mathrm{Var}_1(I) &= \int_p \int_0^{\gamma/r_{\mathrm{H}}\bar{y}} (p_{\mathrm{H}}\theta\bar{y} - \bar{p}\,\bar{y})^2 f(\theta)\,\mathrm{d}\theta \\ &+ \int_p \int_{\gamma/r_{\mathrm{H}}\bar{y}}^{\gamma/r_{\mathrm{L}}\bar{y}} (p_{\mathrm{M}}\theta\bar{y} - \bar{p}\,\bar{y})^2 f(\theta)\,\mathrm{d}\theta \\ &+ \int_p \int_{\gamma/r_{\mathrm{L}}\bar{y}}^{\infty} (p_{\mathrm{L}}\theta\bar{y} - \bar{p}\,\bar{y})^2 f(\theta)\,\mathrm{d}\theta \qquad \text{(A1)}\end{aligned}$$

which may be expanded to give:

$$\begin{aligned}\mathrm{Var}_1(I)) &= \bar{y}^2\Big(\int_p \int_0^{\gamma/r_{\mathrm{H}}\bar{y}} (p_{\mathrm{H}}{}^2\theta^2 f(\theta)\,\mathrm{d}\theta - 2\bar{p}_{\mathrm{H}}w_1\bar{p} + \bar{p}^2 F(\gamma/r_{\mathrm{H}}\bar{y}) \\ &+ \int_p \int_{\gamma/r_{\mathrm{H}}\bar{y}}^{\gamma/r_{\mathrm{L}}\bar{y}} (p_{\mathrm{M}}{}^2\theta^2 f(\theta)\,\mathrm{d}\theta - 2\bar{p}_{\mathrm{M}}w_2\bar{p} + \bar{p}^2(F(\gamma/r_{\mathrm{L}}\bar{y}) - F(\gamma/r_{\mathrm{H}}\bar{y})) \\ &+ \int_p \int_{\gamma/r_{\mathrm{L}}\bar{y}}^{\infty} (p_{\mathrm{L}}{}^2\theta^2 f(\theta)\,\mathrm{d}\theta - 2\bar{p}_{\mathrm{L}}w_3\bar{p} + \bar{p}^2(1 - F(\gamma/r_{\mathrm{L}}\bar{y}))) \qquad \text{(A2)}\end{aligned}$$

where:

$$\begin{aligned}w_1 &= \int_0^{\gamma/r_{\mathrm{H}}\bar{y}} \theta f(\theta)\,\mathrm{d}\theta \\ w_2 &= \int_{\gamma/r_{\mathrm{H}}\bar{y}}^{\gamma/r_{\mathrm{L}}\bar{y}} \theta f(\theta)\,\mathrm{d}\theta \\ w_3 &= \int_{\gamma/r_{\mathrm{L}}\bar{y}}^{\infty} \theta f(\theta)\,\mathrm{d}\theta.\end{aligned}$$

Noting that:

$$w_1 + w_2 + w_3 = E(\theta) = 1,$$

and that since it has been assumed the protein payments are symmetrically distributed about the expected price:

$$\bar{p}_{\mathrm{H}}w_1\bar{p} + \bar{p}_{\mathrm{M}}w_2\bar{p} + \bar{p}_{\mathrm{L}}w_3\bar{p} = \bar{p}^2 + x\bar{p}(w_1 - w_3), \qquad \text{(A3)}$$

(A2) can be simplified to:

$$\begin{aligned}\mathrm{Var}_1(\mathrm{I}) &= \bar{y}^2\Big(\int_p \int_0^{\gamma/r_{\mathrm{H}}\bar{y}} p_{\mathrm{H}}{}^2\theta^2 f(\theta)\mathrm{d}\theta + \int_p \int_{\gamma/r_{\mathrm{H}}\bar{y}}^{\gamma/r_{\mathrm{L}}\bar{y}} p_{\mathrm{M}}{}^2\theta^2 f(\theta)\,\mathrm{d}\theta \\ &+ \int_p \int_{\gamma/r_{\mathrm{L}}\bar{y}}^{\infty} p_{\mathrm{L}}^2\theta^2 f(\theta)\mathrm{d}\theta - \bar{p}^2 + 2\bar{p}x(w_3 - w_1)\Big). \qquad \text{(A4)}\end{aligned}$$

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Using the substitutions:

$$E(p^2) = \mathrm{Var}(p) + \bar{p}^2$$

and

$$\mathrm{Var}(p) = \mathrm{Var}(p_{\mathrm{H}}) = \mathrm{Var}(p_{\mathrm{M}}) = \mathrm{Var}(p_{\mathrm{L}})$$

and recalling the independence of p and θ gives:

$$\begin{aligned}\mathrm{Var}_1(I) = \ & \bar{y}^2((\mathrm{Var}(p) + \bar{p}_{\mathrm{H}}{}^2)\int_0^{\gamma/r_{\mathrm{H}}\bar{y}} \theta^2 f(\theta)\, \mathrm{d}\theta \\ & + (\mathrm{Var}(p) + \bar{p}_{\mathrm{M}}{}^2)\int_{\gamma/r_{\mathrm{H}}\bar{y}}^{\gamma/r_{\mathrm{L}}\bar{y}} \theta^2 f(\theta)\, \mathrm{d}\theta \\ & + (\mathrm{Var}(p) + \bar{p}_{\mathrm{L}}{}^2)\int_{\gamma/r_{\mathrm{L}}\bar{y}}^{\infty} \theta^2 f(\theta)\, \mathrm{d}\theta - \bar{p}^2 + 2\bar{p}x(w_3 - w_1)). \qquad \text{(A5)}\end{aligned}$$

Noting that:

$$\begin{aligned}\int_0^{\gamma/r_{\mathrm{H}}\bar{y}} \theta^2 f(\theta)\mathrm{d}\theta &= \int_0^{\gamma/r_{\mathrm{H}}\bar{y}} (\theta - 1)^2 f(\theta)\, \mathrm{d}\theta + 2w_1 - F(\gamma/r_{\mathrm{H}}\bar{y}) \\ \int_{\gamma/r_{\mathrm{H}}\bar{y}}^{\gamma/r_{\mathrm{L}}\bar{y}} \theta^2 f(\theta)\mathrm{d}\theta &= \int_{\gamma/r_{\mathrm{H}}\bar{y}}^{\gamma/r_{\mathrm{L}}\bar{y}} (\theta - 1)^2 f(\theta)\, \mathrm{d}\theta + 2w_2 - (F(\gamma/r_{\mathrm{L}}\bar{y}) - F(\gamma/r_{\mathrm{H}}\bar{y})) \\ \int_{\gamma/r_{\mathrm{L}}\bar{y}}^{\infty} \theta^2 f(\theta)\mathrm{d}\theta &= \int_{\gamma/r_{\mathrm{L}}\bar{y}}^{\infty} (\theta - 1)^2 f(\theta)\, \mathrm{d}\theta + 2w_3 - (1 - F(\gamma/r_{\mathrm{L}}\bar{y})) \qquad \text{(A6)}\end{aligned}$$

gives:

$$\begin{aligned}\mathrm{Var}_1(I) = \ & \bar{y}^2((\mathrm{Var}(p) + \bar{p}_{\mathrm{H}}{}^2)(m_1 + 2w_1 - F(\gamma/r_{\mathrm{H}}\bar{y})) \\ & + (\mathrm{Var}(p) + \bar{p}_{\mathrm{M}}{}^2)(m_2 + 2w_2 - (F(\gamma/r_{\mathrm{L}}\bar{y}) - F(\gamma/r_{\mathrm{H}}\bar{y}))) \\ & + (\mathrm{Var}(p) + \bar{p}_{\mathrm{L}}{}^2)(m_3 + 2w_3 \\ & - (1 - F(\gamma/r_{\mathrm{L}}\bar{y}))) - \bar{p}^2 + 2\bar{p}x(w_3 - w_1)) \qquad \text{(A7)}\end{aligned}$$

where:

$$\begin{aligned}m_1 &= \int_0^{\gamma/r_{\mathrm{H}}\bar{y}} (\theta - 1)^2 f(\theta)\, \mathrm{d}\theta \\ m_2 &= \int_{\gamma/r_{\mathrm{H}}\bar{y}}^{\gamma/r_{\mathrm{L}}\bar{y}} (\theta - 1)^2 f(\theta)\, \mathrm{d}\theta \\ m_3 &= \int_{\gamma/r_{\mathrm{L}}\bar{y}}^{\infty} (\theta - 1)^2 f(\theta)\, \mathrm{d}\theta.\end{aligned}$$

Next, substituting $\bar{p} + x$ and $\bar{p} - x$ for p_{H} and p_{L} respectively gives:

$$\begin{aligned}\mathrm{Var}_1(I) = \ & \bar{y}^2[(\mathrm{Var}(p) + \bar{p}^2)(m_1 + m_2 + m_3 \\ & + 2(w_1 + w_2 + w_3) - F(\gamma/r_{\mathrm{H}}\bar{y}) \\ & - (F(\gamma/r_{\mathrm{L}}\bar{y}) - F(\gamma/r_{\mathrm{H}}\bar{y})) - (1 - F(\gamma/r_{\mathrm{L}}\bar{y}))) \\ & + 2\bar{p}x(m_1 - m_3 - F(\gamma/r_{\mathrm{H}}\bar{y}) + (1 - F(\gamma/r_{\mathrm{L}}\bar{y})) + 2(w_1 - w_3)) \\ & + x^2(m_1 + m_3 + 2(w_1 + w_3) - F(\gamma/r_{\mathrm{H}}\bar{y}) - (1 - F(\gamma/r_{\mathrm{L}}\bar{y}))) \\ & - \bar{p}^2 + 2\bar{p}x(w_3 - w_1)]. \qquad \text{(A8)}\end{aligned}$$

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With θ assumed to be symmetrically distributed:

$$m_1 = m_3$$

and

$$F(\gamma/r_{\mathrm{H}}\bar{y}) = (1 - F(\gamma/r_{\mathrm{L}}\bar{y})).$$

Moreover, as:

$$\mathrm{Var}(\theta) = m_1 + m_2 + m_3$$

and

$$2(w_1 + w_3 + w_3) - F(\gamma/r_{\mathrm{H}}y) - (F(\gamma/r_{\mathrm{L}}\bar{y}) - F(\gamma/r_{\mathrm{H}}\bar{y})) - (1 - F(\gamma/r_{\mathrm{L}}\bar{y})) = 1,$$

(A8) may be simplified to:

$$\begin{aligned} \mathrm{Var}_1(I) &= \bar{y}^2((\mathrm{Var}(p) + \bar{p}^2)(\mathrm{Var}(\theta) + 1) - \bar{p}^2) \\ &+ 2\bar{y}^2\bar{p}x(w_1 - w_3) + \bar{y}^2x^2(m_1 + m_3 \\ &+ 2(w_1 + w_3) - F(\gamma/r_{\mathrm{H}}\bar{y}) - (1 - F(\gamma/r_{\mathrm{L}}\bar{y})))). \end{aligned} \tag{A9}$$

Since the first term on the right-hand side of (A9) is equal to the variance of income in the absence of protein payments ($\mathrm{Var}_0(I)$ as given by equation (3)):

$$\begin{aligned} \mathrm{Var}_1(I) &= \mathrm{Var}_0(I) + 2\bar{y}^2\bar{p}x(w_1 - w_3) \\ &+ 2\bar{y}^2x^2(m_1 + (w_1 + w_3) - F(\gamma/r_{\mathrm{H}}\bar{y})). \end{aligned} \tag{A10}$$

Equation (A10) is reproduced in the main text as equation (12).

References

Anderson, J.R., Dillon, J.L., Hazell, P.B.R., Cowie, A.J. and Wan, G.H. 1988 'Changing variability in cereal production in Australia', *Review of Marketing and Agricultural Economics*, vol. 56, no. 3, pp. 270–86.

Australian Wheat Board 1996, *The Growers Survival Guide to the AWB (WA)*, Belmont, Western Australia.

Bardsley, P. and Harris, M. 1987, 'An approach to the econometric estimation of attitudes to risk in agriculture', *Australian Journal of Agricultural Economics*, vol. 31, no. 2, pp. 112–26.

Fraser, R.W. 1988, 'A method for evaluating supply response to price underwriting', *Australian Journal of Agricultural Economics*, vol. 32, no. 1, pp. 22–36.

Hanson, S.D. and Ladd, G.W. 1991, 'Robustness of the mean-variance model with truncated probability distributions', *American Journal of Agricultural Economics*, vol. 73, no. 2, pp. 436–45.

Hazell, P.B.R., Jaramillo, M. and Williamson, A. 1990, 'The relationship between world price instability and the prices farmers receive in developing countries', *Journal of Agricultural Economics*, vol. 41, no. 2, pp. 227–41.

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Hertzler, G. and Coad, A. 1996, 'Financial risk management for Australian wheat growers', Invited paper presented at the 40th Annual Conference of the Australian Agricultural and Resource Economics Society, University of Melbourne, Victoria, February.

Holford, I.C.R., Doyle, A.D. and Leckie, C.C. 1992, 'Nitrogen response characteristics of wheat protein in relation to yield responses and their interactions with phosphorus', *Australian Journal of Agricultural Research*, vol. 43, no. 4, pp. 969–86.

Miranda, M.J. 1991, 'Area-yield crop insurance reconsidered', *American Journal of Agricultural Economics*, vol. 73, no. 2, pp. 233–42.

Mood, A.M., Graybill, F.A. and Boes, D.C. 1974, *Introduction to the Theory of Statistics*, 3rd edn, McGraw-Hill, Kogakusha.

Newbery, D.M.G. and Stiglitz, J.E. 1981, *The Theory of Commodity Price Stabilization*, Clarendon Press, Oxford.

Park, W.I. and Sinclair, T.R. 1993, 'Consequences of climate and crop yield limits on the distribution of corn yields', *Review of Agricultural Economics*, vol. 15, no. 3, pp. 483–93.

Perry, M. and Hillman, B. 1991, *The Wheat Book: A Technical Manual for Wheat Producers*, Department of Agriculture, Western Australia.

Pope, R.D. and Just, R.E. 1991, 'On testing the structure of risk preferences in agricultural supply analysis', *American Journal of Agricultural Economics*, vol. 73, no. 3, pp. 743–8.

Robinson, S.D. 1995, 'Selecting wheat varieties in a stochastic environment', paper presented to the 39th Annual Conference of the Australian Agricultural Economics Society, University of Western Australia, Perth.

Tegene, A. and Kuchler, F. 1993, 'A regression test of the present value model of US farmland prices', *Journal of Agricultural Economics*, vol. 44, no. 1, pp. 135–43.

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