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A METHOD FOR EVALUATING SUPPLY RESPONSE TO PRICE UNDERWRITING

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In this paper a method for evaluating the supply response of individual producers to a price underwriting scheme is presented. The method includes precise formulae to take account of the impact of price underwriting on the producer's uncertain conditions. The Australian Wheat Board's guaranteed minimum price scheme is taken as a specific example of price underwriting in practice. Results show the scheme to lead to only relatively small supply responses. The impact on producer behaviour of an increase in price uncertainty in the presence of an underwriting scheme is also demonstrated in the paper.

The contribution of Newbery and Stiglitz (1981) to the welfare evaluation of price stabilisation schemes represents an important milestone in the assessment of government policies which influence the riskiness of market participation. Expanding the focus of the welfare effects of such policies to include not just changes in consumer and producer net returns (or surplus), but also changes in the riskiness of those returns, clearly results in a more complete welfare evaluation (see also Gilbert 1985; Hinchy and Fisher 1985). An acknowledged limitation of the Newbery-Stiglitz methodology is, however, that it is based on an assumption of no supply response by producers to the policy (Fraser 1986).

Price support schemes are more widespread in agricultural marketing than price stabilisation schemes, yet their welfare evaluation, at least from the perspective of producers, seems to have received less attention (see, however, Gallagher 1978; Quiggin 1983; Martin and Urban 1984; Hinchy 1987). This is perhaps because, as far as producers are concerned, the nature of the welfare impact of a price support scheme would seem less contentious than that of a price stabilisation scheme. In particular, not only does a price support scheme generally act to increase expected per unit price, it also acts to reduce the variability of that price (typically by eliminating unusually low price outcomes), both of which result in favourable welfare effects on a risk averse producer. By contrast, the claim that such schemes encourage unjustified output expansion and have negative market consequences has been widely stated (for example, Anderson and Tyers 1986; Sarris and Freebairn 1983). However, such claims are typically derived from an aggregated view of supply response, rather than from the supply response of individual producers to price support. Moreover, it can be argued that the latter perspective is required for the multiple effects of price support on supply in uncertain conditions to be adequately captured and that an understanding of individual supply responses represents a foundation for determining the aggregate response.

It is the principal objective in this paper to present a method for evaluating the supply response of individual producers to a price support scheme, and specifically that of price underwriting, thereby providing a basis for a more complete assessment of such schemes. An additional

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objective in the paper is to investigate the way in which the presence of a price underwriting scheme affects the response of both risk neutral and risk averse producers to increased uncertainty of that price.

The paper is organised as follows. The model to be used in analysing producer behaviour is set out first. In the second section a method for incorporating the effects of a price underwriting scheme into this model is presented. Next the information requirements of the model are discussed and the Australian Wheat Board's guaranteed minimum price scheme is introduced as a specific example of price underwriting. The example results are then presented and discussed. Finally the theoretical and empirical consequences of increased price uncertainty when such a scheme is in place are examined.

The Model

The model of producer behaviour used in this paper is developed in Fraser (1984, 1986). It is based on the assumption that the only input to production is the farmer's own labour, ℓ , and that a single output is produced which is subject to multiplicative risk:

$$x = \Theta f(\ell)$$

where:

$f(\ell)$ = planned output [$f'(\ell) > 0$, $f''(\ell) < 0$]

Θ = multiplicative risk term [$E(\Theta) = 1$]

x = uncertain actual output [$E(x) = \bar{x} = f(\ell)$].

With price also uncertain, the producer's random income (y) is thus given by:

$$y = px$$

where:

p = uncertain price [$E(p) = \bar{p}$].

It is further assumed that the producer's utility is (additively) separable in income and leisure so that the objective is to maximise by choice of labour input:

$$(1) \quad E[U(px)] - w\ell$$

where:

w = (constant) marginal disutility of labour¹

$U(px)$ = utility of random income ($U' > 0$, $U'' \leq 0$).

¹ The previous assumption of diminishing returns to labour means that this assumption of constancy does not in effect restrict the analysis, but does simplify its presentation. Also, see Newbery and Stiglitz (1981): 'With separable utility, there is little difference between diminishing returns to effort or increasing disutility of effort' (p.307).

It is shown in Fraser (1984) that using a second-order Taylor series expansion (1) may be approximated by:

$$(2) \quad U(\bar{p}\bar{x}) + 0.5U''(\bar{p}\bar{x})\bar{x}^2(\sigma_p^2 + \sigma_\Theta^2\bar{p}^2) - \sigma_{p\Theta}\bar{x}U'(\bar{p}\bar{x})(R-1) - w\ell$$

where:

$$\begin{aligned} \sigma_p^2 &= \text{variance of } p \\ \sigma_\Theta^2 &= \text{variance of } \Theta \\ \sigma_{p\Theta} &= \text{covariance of } p, \Theta \\ R &= -U''(\bar{p}\bar{x})\bar{p}\bar{x}/U'(\bar{p}\bar{x}) = \text{the producer's coefficient of relative risk aversion (evaluated at } \bar{p}, \bar{x}). \end{aligned}$$

Note from (2) that whether a covariance of a given sign contributes positively or negatively to utility depends on whether R exceeds or is less than unity.

It is shown in Fraser (1986) that differentiating (1) with respect to ℓ gives the producer's first-order condition as:

$$(3) \quad E[U'(px)p\Theta]f'(\ell) = w$$

which, using a second-order Taylor series expansion, may be approximated by:

$$(4) \quad U'(\bar{p}\bar{x})[\bar{p} + 0.5(\sigma_p^2/\bar{p} + \sigma_\Theta^2\bar{p})[R(R-1) - \bar{p}\bar{x}R'] + \sigma_{p\Theta}[(R-1)^2 - \bar{p}\bar{x}R']]f'(\ell) = w.$$

Price Underwriting

Quiggin (1983, p.200) states that 'The crucial characteristic of an underwriting scheme is the formulation of a guaranteed minimum price. If the market price falls below this minimum, government payments are used to make up the difference'. Or more technically, (Hinchy 1987 p.2) 'Underwriting involves Winsorisation of the probability distribution of price, shifting probability mass below the underwritten price to the underwritten price' (see Figure 1 in the Appendix).

Hinchy (1987, p.2) also states that 'It is intuitively clear that underwriting will raise the mean, reduce the variance and increase the positive skewness of the price distribution for most plausible forms of probability distributions'. However, in order to incorporate the precise impact of a price underwriting scheme into the model shown in the previous section, specific formulae for characterising this impact are needed.² Unfortunately, as demonstrated by Martin and Urban (1984) in a model where there is no price-output covariation, the derivation of such formulae is not a simple procedure.³ For this reason, the analysis was confined to the case where price and output were assumed to be initially jointly normally dis-

² Note that because the model considers only the first two moments of the price and output distributions, no formula for the skewness impact is required.

³ Note also that Martin and Urban (1984) restrict their attention to the formulae for the first two moments of a standard normal price variate.

tributed. A formal derivation of the formulae listed below is contained in the Appendix:

$$(5) \quad E(p_u) = F(\hat{p})\hat{p} + [1 - F(\hat{p})] [\bar{p} + \sigma_p Z(\hat{p}) / (1 - F(\hat{p}))]$$

$$(6) \quad \text{Var}(p_u) = [1 - F(\hat{p})]\sigma_p^2 \left[1 - [Z(\hat{p}) / (1 - F(\hat{p}))]^2 + [(\hat{p} - \bar{p}) / \sigma_p] [Z(\hat{p}) / (1 - F(\hat{p}))] \right] \\ + F(\hat{p})[\hat{p} - E(p_u)]^2 + [1 - F(\hat{p})][\epsilon_2 - E(p_u)]^2$$

$$(7) \quad \text{Cov}(p_u, x) = [1 - F(\hat{p})]\rho(\sigma_x / \sigma_p)\sigma_p^2 + \rho\sigma_x Z(\hat{p})[\epsilon_2 - \hat{p}]$$

where: \hat{p} = underwritten price

$$Z(\hat{p}) = (1/\sqrt{2\pi})\exp[-0.5[(\hat{p} - \bar{p})/\sigma_p]^2]$$

$F(\hat{p})$ = cumulative probability of $p \leq \hat{p}$

$E(p_u)$ = expected price with underwriting

$\text{Var}(p_u)$ = variance of price with underwriting

$$\epsilon_2 = \bar{p} + \sigma_p Z(\hat{p}) / [1 - F(\hat{p})]$$

$\text{Cov}(p_u, x)$ = covariance of the underwritten price with output

ρ = correlation coefficient of the underlying joint normal distribution

$$\sigma_p^2 = \sigma_p^2 \left[1 - [Z(\hat{p}) / (1 - F(\hat{p}))]^2 + [(\hat{p} - \bar{p}) / \sigma_p] [Z(\hat{p}) / (1 - F(\hat{p}))] \right].$$

The impact of a price underwriting scheme on a producer's welfare and level of output can be found by substituting $E(p_u)$, $\text{Var}(p_u)$ and $\text{Cov}(p_u, x)$ for \bar{p} , σ_p^2 and $\sigma_p \Theta \bar{x}$ in (2) and (4).

Information Requirements

In order to be able to use (4) to evaluate a producer's supply response to a price underwriting scheme, three broad types of information are required:

- a specification of the producer's risk aversion as characterised by the utility function;
- a specification of the producer's initial economic circumstances. In what follows this is taken to comprise⁴ $f(\ell)$; σ_p^2 ; σ_Θ^2 ; $\sigma_{p\Theta}$; and \bar{p} ;
- a specification of the percentage of mean price at which the underwriting scheme operates, which in this case is taken to refer to the Australian Wheat Board's guaranteed minimum price scheme.

It is assumed that the producer's attitude to income risk can be adequately represented by the constant relative risk aversion function:

$$U(px) = (px)^{(1-R)/(1-R)}$$

where $R \neq 1$.

⁴ The assumption that w is constant for a producer means that information about its value will not be required.

It should be noted that this assumption simplifies (4) by eliminating the terms related to whether R is increasing or decreasing (R'). In addition, note that this function implies the producer exhibits decreasing absolute risk aversion. In what follows, a range of values of R consistent with empirical estimates is considered (see Newbery and Stiglitz 1981, ch. 7).

The specification of the producer's initial economic circumstances requires a mixture of assumptions and actual industry data. The already-simplified relationship between the producer's labour input and his output [$f(\ell)$] requires further simplification to a precise functional form. In what follows it is assumed that this form is given by:

$$\bar{x} = \ell^m$$

where it is assumed that m lies in the range 0.5 to unity, and ℓ is given a positioning value equal to unity ($\bar{x} = 1$).⁵ The producer's information about the relative size of σ_p^2 , σ_Θ^2 and $\sigma_{p\Theta}$ is based on actual industry data with the additional main assumption that the producer has rational expectations (that is, the producer's beliefs about \bar{p} , σ_p^2 , σ_Θ^2 and $\sigma_{p\Theta}$ are correct). With the Australian Wheat Board's guaranteed minimum price scheme to be used as the example price underwriting scheme, suitable details of the breakdown of the overall income variation in the Australian wheat industry are provided in Harris, Crawford, Gruen and Honan (1974). Using this breakdown, which is based on the following approximation:⁶

$$\sigma_y^2 = \bar{x}^2 \sigma_p^2 + \bar{p}^2 \sigma_x^2 + 2\bar{p}\bar{x}\sigma_{px}$$

and setting a positioning value for income variability of:⁷

$$\sigma_y^2 = 10$$

gives:

$$\begin{aligned}\bar{x}^2 \sigma_p^2 &= 0.34 \\ \bar{p}^2 \sigma_x^2 &= 10.52 \\ 2\bar{p}\bar{x}\sigma_{px} &= -0.86\end{aligned}$$

which, recalling that initially:

$$\ell = 1$$

gives:

$$\sigma_p^2 = 0.34.$$

⁵ Note that for $\bar{x} = 1$ to satisfy (4) over a range of values of R , the value of w must be assumed to be (precisely) inversely related to the value of R . However, as the results are calculated in percentage change terms, this additional assumption is not felt to be particularly restrictive. Note also that $m = 0.5$ corresponds to a deterministic supply elasticity of unity and that this elasticity tends toward infinity as m tends toward unity.

⁶ See Harris *et al.* (1974) pp.304-5.

⁷ Recalling note 3, σ_y^2 would also vary over a range of values of R but for the setting of $\bar{x} = 1$ for all producers.

However, further specification of this breakdown requires an initial setting of \bar{p} . A positioning value of:

$$\bar{p} = 10.75$$

was chosen with a view to establishing an initial coefficient of variation (CV) of each of the random variables which corresponded closely to the actual industry values calculated by Harris *et al.* (1974, p. 302). With this initial setting:

$$\begin{aligned}\sigma_x^2 &= \bar{x}^2 \sigma_\Theta^2 = 0.091 \\ \sigma_{px} &= \sigma_{p\Theta} = -0.08\end{aligned}$$

so that (with actual industry values in parentheses):

$$\begin{aligned}CV_p &= 5.4\% \quad (5.5\%) \\ CV_x &= 30.2\% \quad (30.5\%) \\ CV_y &= 29.6\% \quad (29.3\%).\end{aligned}$$

Note also that these initial settings give:

$$E(y) = \bar{p}\bar{x} + \sigma_{px} = 10.67$$

as the initial value of expected income.

Finally, in what follows the price underwriting scheme is considered to operate with a range of underwritten prices between 85 per cent and 95 per cent of the mean price.

Results and Discussion

On the basis of the information detailed in the previous section, the formulae for the impact of an underwriting scheme on the producer's uncertain conditions given in the second section and the model of producer behaviour outlined in the first section, it is possible to determine the supply response of individual producers to the introduction of a price underwriting scheme for a range of underwritten prices and attitudes to risk. Examples of these responses are presented in Table 1.

The first point to note about these responses is that in all cases their magnitude represents less than 1 per cent of initial output. The possibility that this unresponsiveness was due to relatively unproductive labour input was examined by recalculating the responses for $m = 0.99$ (that is almost constant returns to labour). A comparison with the results in Table 1 ($m = 0.5$) is given in Table 2. It can be seen from this table that, although more productive labour leads to much larger responses for $R=0$, for $R \geq 0.3$ the magnitude of the responses remains generally small despite the increase in labour productivity.⁸ Rather, the explanation of these small

⁸ Note that although $m = 0.99$ implies an unrealistically large deterministic supply elasticity of 99, an overestimate of supply response from this source has been introduced in an attempt to balance the underestimate implied by the conclusion of Hinchy (1987) 'that the producer benefits from underwriting are greater than those implied by the expected utility model' (Abstract).

TABLE 1

Impact of Price Underwriting on Supply
(percentage change in output; $m = 0.5$)

Underwritten price [% of $E(p)$]	R						
	0.0	0.3	0.6	0.9	1.2	1.5	1.8
85.0	0.007	0.004	0.002	0.000	-0.001	-0.002	-0.002
87.5	0.028	0.014	0.006	0.001	-0.002	-0.004	-0.005
90.0	0.094	0.048	0.021	0.004	-0.007	-0.014	-0.019
92.5	0.270	0.139	0.061	0.012	-0.020	-0.042	-0.056
95.0	0.661	0.340	0.151	0.030	-0.049	-0.103	-0.140

TABLE 2

*Impact of More Productive Effort on Supply Responses to
Price Underwriting*
(percentage change in output)

Underwritten price [% of $E(p)$]	m	R						
		0.0	0.3	0.6	0.9	1.2	1.5	1.8
85	0.5	0.007	0.004	0.002	0.000	-0.001	-0.002	-0.002
	0.99	0.742	0.016	0.004	0.001	-0.001	-0.002	-0.002
90	0.5	0.094	0.048	0.021	0.004	-0.007	-0.014	-0.019
	0.99	9.697	0.200	0.054	0.009	-0.012	-0.023	-0.028
95	0.5	0.661	0.340	0.151	0.030	-0.049	-0.103	-0.140
	0.99	91.961	1.435	0.396	0.063	-0.090	-0.171	-0.216

magnitudes lies in recognising that, as the information about CVs in the third section shows, the producer's price is relatively less uncertain than output so that even underwriting this price to 95 per cent of the mean level has only a small impact on the producer's initial economic circumstances.⁹

Within the range of values of R and the underwritten price there is, however, a considerable variation in the relative magnitude and the direction of the responses. For values of $R < 1$, all responses are positive, reflecting the favourable welfare impact of the scheme.¹⁰ In addition, this impact is positively related to the size of the underwritten price as can be seen from the increasing magnitude of responses down the table. This feature reflects the increasing impact of the scheme on expected price (positive) and the variation of price (negative) as the underwritten price is increased. Moreover, for a given underwritten price, the magnitude of the response decreases as R increases toward unity, reflecting the inhibiting impact of increased risk aversion on the willingness of a producer to increase supply

⁹ Note that underwriting to 95 per cent of the mean price involves 17.83 per cent of price outcomes.

¹⁰ For $\hat{p} = 85$ per cent of \bar{p} and $R = 0.9$, the response is positive but less than 0.0005.

in response to improved economic circumstances. It should be noted that this result is a specific example of the more general result that increased risk aversion is typically associated with more cautious behaviour. Other closely related examples of this general result are the demonstrations by Newbery and Stiglitz (1981) that both the elasticity of supply under uncertainty and the supply response to price stabilisation are inversely related to the coefficient of relative risk aversion (p.307 and p.310, respectively). Since it has already been noted that price underwriting represents a mixture of increased mean price and price stabilisation, it is not surprising that the inverse relationship which holds for the two changes separately also holds jointly.

For values of $R > 1$, price underwriting also has a favourable welfare impact. However, as shown in equation (4), the qualitative impact of such a scheme on a producer's optimal supply is negative for $R > 1$. As a consequence, a favourable welfare impact is indicated by a reduction in supply for $R > 1$, compared with an increase in supply for $R < 1$. Once again, this result is a specific example of a more general result.¹¹ In particular, Newbery and Stiglitz (1981) also demonstrate both that the elasticity of supply under uncertainty and the supply response to price stabilisation are positive or negative as R is less than or greater than unity (p.307 and p.310, respectively, but see also p.82), and they explain this latter result by pointing out that individuals who are very risk averse ($R > 1$) are worried 'about the worst possible contingencies (for example, starvation)' (p.82) so that when something unfavourable occurs 'they have to work harder to avoid these extreme contingencies' (p.82). That the negative supply responses in Tables 1 and 2 also increase in magnitude both with the size of the underwritten price and with the size of R can be explained in the same way. Nevertheless, the significance of these negative supply responses should not be overstated, particularly as results reported in Bond and Wonder (1980) suggest values of R among Australian farmers are typically below unity.¹²

Finally, it should be noted these results suggest that, with the Australian Wheat Board operating a guaranteed minimum price of approximately 95 per cent of the mean price, although the aggregate welfare impact of the scheme is unambiguously favourable, both the magnitude and the direction of the aggregate supply response to the scheme will depend on the distribution of attitudes to risk among producers, with the evidence of Bond and Wonder (1980) suggesting a small positive response is to be expected.

Increased Price Uncertainty

Consider a situation where a price underwriting scheme is in operation and producers experience an increase in the uncertainty of the underlying

¹¹ See Meyer and Ormiston (1983) for a demonstration of the general result, in which it is shown that the direction of response of the choice variable in such a decision model will be the same for all risk averse decision makers *only* for a very restrictive class of payoff functions (for example, the optimal choice is independent of the random variable).

¹² Note that this statement assumes a typical value of R based on Bond and Wonder's (1980) mean estimates of the coefficient of absolute risk aversion (-2.4) and mean net monetary return (x^*). Note also that Newbery and Stiglitz's (1981) survey of empirical evidence about attitudes to risk concludes that R typically varies between 0.5 and 1.2.

price distribution. If the increase in uncertainty takes the form of a symmetrical increase in the variance of this price (σ_p^2) then it follows that the underlying mean price will be unchanged but that the magnitude of the covariance of the underlying price with output will be increased.¹³ However, to determine a producer's supply response to this increase in price uncertainty, it is necessary to determine the impact of the increase on the probability distribution of the underwritten price. For example, differentiating equation (5) with respect to σ_p gives:

$$(8) \quad \begin{aligned} \partial E(p_u)/\partial \sigma_p &= [\partial F(\hat{p})/\partial \sigma_p]\hat{p} + Z(\hat{p}) + \sigma_p[\partial Z(\hat{p})/\partial \sigma_p] - \bar{p}[\partial F(\hat{p})/\partial \sigma_p] \\ &= Z(\hat{p}) + \sigma_p[\partial Z(\hat{p})/\partial \sigma_p] + [\partial F(\hat{p})/\partial \sigma_p][\hat{p} - \bar{p}]. \end{aligned}$$

If the shift in probability weight is confined to the tails of the underlying price distribution, so that there is no change in $F(\hat{p})$ and $Z(\hat{p})$, then it is clear from (8) that the mean underwritten price is increased by such an increase in uncertainty:

$$\partial E(p_u)/\partial \sigma_p = Z(\hat{p}) > 0.$$

However, while the likely impact of an increase in σ_p on $Z(\hat{p})$ is unclear, $F(\hat{p})$ would typically be increased by this increase for $\hat{p} < \bar{p}$. In other words, although it would seem reasonable to expect an increase in σ_p also to increase $E(p_u)$, the outcome is algebraically ambiguous. The same ambiguity applies to $\text{Var}(p_u)$ and $\text{Cov}(p_u, x)$. Nevertheless, it seems likely that $\text{Var}(p_u)$ would be increased by an increase in σ_p , and that the indirect impact on σ_{px} of this increase would be strong enough to be transmitted to $\text{Cov}(p_u, x)$.

These expectations are to a large extent confirmed in the results presented in Table 3. This table shows the impact of the increase in price uncertainty on the underwritten price distribution over the range of underwritten prices. A comparison of columns (1) and (4) shows that the increase in σ_p typically increases $E(p_u)$, with the magnitude of this effect increasing with the underwritten price. Similarly, columns (2) and (5) show that the increase in σ_p also increases $\text{Var}(p_u)$. However, the magnitude of this effect decreases as the underwritten price is increased, reflecting the increasing proportion of relatively low prices which is being underwritten. Finally, columns (3) and (6) show that the indirect impact on σ_{px} is transmitted to $\text{Cov}(p_u, x)$ but that, as with $\text{Var}(p_u)$, the magnitude of this effect decreases as the underwritten price increases.

Turning to the impact of these changes in the underwritten price distribution on supply, Table 4 presents the results once again for a range of values of R and underwritten prices. As in the case of introducing the underwriting scheme itself, the increase in price uncertainty leads to a generally small supply response, reflecting the relative insignificance of this price uncertainty in the producer's initial economic circumstances.

There are, however, some interesting changes in magnitude and direction of these responses across the table. For example, in the case of $R = 0$, only the response for an underwritten price of 90 per cent of \bar{p} or less

¹³ Recall that $\text{Cov}(p, x) = \rho \sigma_p \sigma_x$.

TABLE 3

Impact of Increased Price Uncertainty on the Distribution of the Underwritten Price
(underlying σ_p increased by 10 per cent)

Underwritten price [% of $E(p)$]	Before			After		
	(1) $E(p_u)$	(2) $\text{Var}(p_u)$	(3) $\text{Cov}(p_u, x)$	(4) $E(p_u)$	(5) $\text{Var}(p_u)$	(6) $\text{Cov}(p_u, x)$
85.0	10.751	0.338	-0.080	10.751	0.406	-0.087
87.5	10.752	0.334	-0.079	10.754	0.397	-0.086
90.0	10.757	0.321	-0.077	10.762	0.378	-0.084
92.5	10.772	0.293	-0.073	10.782	0.341	-0.079
95.0	10.806	0.246	-0.066	10.822	0.284	-0.070

TABLE 4

Impact of Increased Uncertainty of an Underwritten Price on Supply
(percentage change in output)
(underlying σ_p increased by 10 per cent)

Underwritten price [% of $E(p)$]	R						
	0.0	0.3	0.6	0.9	1.2	1.5	1.8
85.0	-0.064	-0.028	-0.010	-0.001	0.002	0.000	-0.003
87.5	-0.047	-0.019	-0.006	0.000	0.000	-0.003	-0.007
90.0	-0.008	-0.001	0.002	0.001	-0.003	-0.008	-0.014
92.5	0.041	0.027	0.014	0.003	-0.007	-0.017	-0.027
95.0	0.102	0.060	0.029	0.006	-0.012	-0.028	-0.042

reproduces the conventional negative response in the absence of price underwriting (that is, a negative covariance reduces expected income so that an increase in its magnitude has an unfavourable welfare impact). For underwritten prices above 90 per cent of \bar{p} , the increase in σ_p causes a large enough increase in $E(p_u)$ for this to dominate the covariance effect and result in a favourable welfare impact and a positive supply response. Moreover, this favourable impact is reinforced by the decline in the magnitude of the covariance effect as the underwritten price is increased.

For values of R greater than zero, the two conflicting effects on expected income are joined by two conflicting effects on the variance of income: the increase in $\text{Var}(p_u)$; and the increase in the magnitude of $\text{Cov}(p_u, x)$. Table 4 shows that, for an underwritten price of 85 per cent of \bar{p} , the welfare balance of these four effects is unfavourable for $R < 1.8$, but favourable for $R = 1.8$. This result implies that, of the two effects on the variance of income, the covariance effect becomes increasingly important as R increases. Note that the importance of this covariance effect may in part be attributed to the dominance of output uncertainty in determining the variance of income. Moreover, Table 4 shows that, at the 87.5 per cent and 90 per cent levels of underwritten price, the welfare balance of the four effects turns favourable at lower levels of R . This result is consistent

with the greater rate of decline in the magnitude of the $\text{Var}(p_u)$ effect compared with the $\text{Cov}(p_u, x)$ effect as indicated in Table 3. Table 4 also shows that, for the levels of underwritten price above 90 per cent of \bar{p} , the welfare balance is favourable regardless of the level of R , leading to a positive supply response for $R < 1$ and a negative supply response for $R > 1$. In other words, if a price underwriting scheme is in operation with an underwritten price of greater than 90 per cent of \bar{p} , the actual supply responses to increased price uncertainty are the reverse of the conventional responses.

Finally, it should be noted these results suggest that, with the Australian Wheat Board operating on a guaranteed minimum price scheme of 95 per cent of the mean price, an increase in the uncertainty of the underlying price distribution will have a favourable welfare impact on all producers regardless of their attitude to risk. This is principally because of the positive effect on the expected price with underwriting of such an increase in uncertainty. However, as in the case of the introduction of the underwriting scheme itself, both the magnitude and the direction of the associated aggregate supply response will depend on the distribution of attitudes to risk among producers, although the evidence of Bond and Wonder (1980) once again suggests a small positive response.

Conclusion

The main objective in this paper has been to present a method for evaluating the supply response of individual producers to a price underwriting scheme. This method required the development of precise formulae to take account of the impact of price underwriting on the producer's uncertain conditions. The Australian Wheat Board's guaranteed minimum price scheme was taken as a specific example of price underwriting in practice. Individual supply responses, although indicating a favourable welfare impact of the scheme, were shown in general to be quite small, reflecting the relative (to output) insignificance of price uncertainty in the Australian wheat industry. Nevertheless, both the magnitude and the direction of individual responses were shown to vary depending on the level of the price underwriting and the degree of risk aversion of the producer. The productivity of labour was also shown to determine the magnitude of the individual producer's supply response.

An additional objective in the paper was to investigate the way in which the presence of a price underwriting scheme affects the response of producers to increased price uncertainty. It was shown that an increase in price uncertainty affects the underwritten price distribution in three ways: (a) by increasing the expected price with underwriting, (b) by increasing the variance of price with underwriting, and (c) by increasing the magnitude of the covariance between the underwritten price and output. The strength of the first effect was shown to dominate for a level of underwriting above 90 per cent of the mean price, thus implying the unconventional result that an increase in price uncertainty has a favourable welfare impact for all producers. This in turn leads to a positive or negative supply response depending on the degree of risk aversion of each producer.

Finally, in relation to the Australian Wheat Board's guaranteed minimum price scheme it was clear, for both the introduction of the scheme (at 95 per cent of mean price) and an increase in price uncertainty in the

presence of the scheme, that not just the magnitude but also the direction of the aggregate supply response depends on the distribution of risk attitudes among producers. Nevertheless, on the basis of the Bond and Wonder (1980) estimates of attitudes to risk among Australian farmers, a small positive aggregate supply response is to be expected in each case.

APPENDIX

Winsorising a Normal Distribution

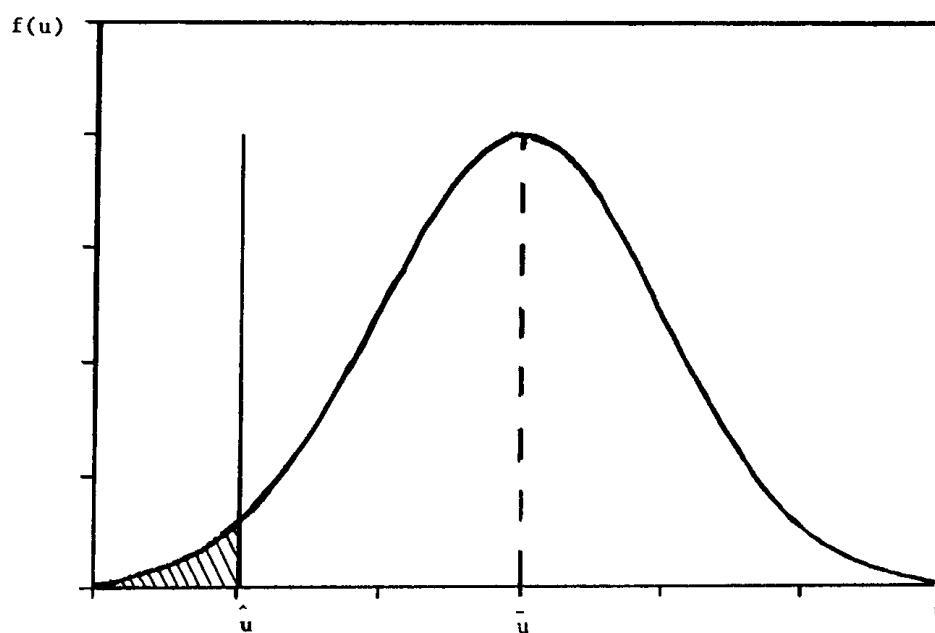


FIGURE 1—Winsorising a Normal Distribution.

Let \hat{u} be the point of Winsorising and \bar{u} be the original mean (ϵ), σ_u^2 the original variance of a normal distribution.

Then this is equivalent to mixing two distributions in the proportion $F(\hat{u})$, $(1 - F(\hat{u}))$; where:

$$\text{for } u \leq \hat{u}: \epsilon_1 = \hat{u}, \sigma_1^2 = 0$$

and:

$$\text{for } u > \hat{u}: \epsilon_2 = E(u | u > \hat{u}), \sigma_2^2 = \text{Var}(u | u > \hat{u}).$$

The second of these is a truncated normal distribution where:

$$(A1) \quad \epsilon_2 = E(u|u > \hat{u}) = \bar{u} + \sigma_u Z(\hat{u})/[1 - F(\hat{u})]$$

$$(A2) \quad \sigma_2^2 = \text{Var}(u|u > \hat{u}) = \sigma_u^2 \left(1 - \left[Z(\hat{u})/[1 - F(\hat{u})] \right]^2 + \left[(\hat{u} - \bar{u})/\sigma_u \right] \left[Z(\hat{u})/[1 - F(\hat{u})] \right] \right)$$

(see Johnson and Leone 1964, p. 128).

Note the following formulae for a mixture (x):

$$E(x) = \sum_{i=1}^k p_i \epsilon_i$$

$$\text{Var}(x) = \sum_{i=1}^k p_i \sigma_i^2 + \sum_{i=1}^k p_i (\epsilon_i - \bar{\epsilon})^2$$

where:

$$\bar{\epsilon} = \sum_{i=1}^k p_i \epsilon_i = E(x).$$

For $k=2$ and the above information:

$$(A3) \quad E(x) = F(\hat{u}) \bullet \hat{u} + [1 - F(\hat{u})] \left[\bar{u} + \sigma_u Z(\hat{u})/[1 - F(\hat{u})] \right]$$

$$(A4) \quad \text{Var}(x) = [1 - F(\hat{u})] \sigma_u^2 \left(1 - \left[Z(\hat{u})/[1 - F(\hat{u})] \right]^2 + \left[(\hat{u} - \bar{u})/\sigma_u \right] \left[Z(\hat{u})/[1 - F(\hat{u})] \right] \right) + F(\hat{u}) [\hat{u} - E(x)]^2 + [1 - F(\hat{u})] [\epsilon_2 - E(x)]^2$$

(see Johnson and Leone 1964, p. 129).

To assess the impact of Winsorising on the covariance between u and some other normally distributed variable v , let ρ be the correlation coefficient and $\rho\sigma_u\sigma_v$ the initial covariance.

$$\begin{aligned} \text{Then } \text{Cov}(x, v) &= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} [x - E(x)][v - E(v)] f_{uv} du dv \\ &= \int_{-\infty}^{\hat{u}} \int_{-\infty}^{\infty} [\hat{u} - E(x)][v - E(v)] f_{uv} du dv \\ &\quad + \int_{\hat{u}}^{\infty} \int_{-\infty}^{\infty} [u - E(x)][v - E(v)] f_{uv} du dv. \end{aligned}$$

Consider the first term:

$$\begin{aligned} &= [\hat{u} - E(x)] \int_{-\infty}^{\hat{u}} f(u) du \int_{-\infty}^{\infty} [v|u - E(v)] f(v|u) dv \\ &= [\hat{u} - E(x)] F(\hat{u}) [\bar{v}_u - E(v)] \end{aligned}$$

where:

$$\begin{aligned}\bar{v}_u &= E(v | u < \hat{u}) \\ &= E(v) + \rho(\sigma_v/\sigma_u) [\bar{u} - \sigma_u [Z(\hat{u})/F(\hat{u})] - \bar{u}]\end{aligned}$$

(see Mood, Graybill and Boes 1974, p. 167; Maddala 1983, p. 367),

$$\text{so that} \quad = [\hat{u} - E(x)]F(\hat{u})[-\rho\sigma_v \cdot Z(\hat{u})/F(\hat{u})].$$

Next consider the second term:

$$\begin{aligned}&= \int_{\hat{u}}^{\infty} \int_{-\infty}^{\infty} (u - \epsilon^2)[v - E(v)]f_{uv}dudv \\ &\quad + \int_{\hat{u}}^{\infty} \int_{-\infty}^{\infty} [\epsilon_2 - E(x)][v - E(v)]f_{uv}dudv \\ &= \text{Cov}(x, v | u > \hat{u})[1 - F(\hat{u})] \\ &\quad + [\epsilon_2 - E(x)][1 - F(\hat{u})][E(v | u > \hat{u}) - E(v)] \\ &\quad \quad \quad \{\text{Note: } f(x) = f(u)/[1 - F(\hat{u})]\} \\ &= \rho(\sigma_v/\sigma_u) \cdot \sigma_2^2[1 - F(\hat{u})] \\ &\quad + [\epsilon_2 - E(x)][1 - F(\hat{u})][\rho\sigma_v Z(\hat{u})/[1 - F(\hat{u})]]\end{aligned}$$

(see Johnson and Kotz 1972, p.112).

Bringing together the first and second terms:

$$\begin{aligned}\text{Cov}(x, v) &= -[\hat{u} - E(x)]F(\hat{u})[\rho \cdot \sigma_v Z(\hat{u})/F(\hat{u})] \\ &\quad + [1 - F(\hat{u})]\rho \cdot (\sigma_v/\sigma_u) \cdot \sigma_2^2 \\ &\quad + [1 - F(\hat{u})][\epsilon_2 - E(x)]\rho \cdot \sigma_v Z(\hat{u})/[1 - F(\hat{u})] \\ \text{(A5)} \quad &= [1 - F(\hat{u})]\rho \cdot (\sigma_v/\sigma_u) \cdot \sigma_2^2 \\ &\quad + \rho\sigma_v Z(\hat{u})[\epsilon_2 - \hat{u}].\end{aligned}$$

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