Australian Journal of Agricultural Economics, Vol. 34, No. 3 (December 1990), pp. 212–222

UNDERWRITING ASSISTANCE TO THE AUSTRALIAN WHEAT INDUSTRY – AN APPLICATION OF OPTION PRICING THEORY

PETER BARDSLEY and PAUL CASHIN*
Department of Agriculture and Rural Affairs, East Melbourne, Vic. 3002

For the ten crop seasons 1979–80 to 1988–89, returns to producers in the Australian wheat industry were underwritten by a government-guaranteed price floor. Similar schemes operate in other rural industries (dairy, apples and pears, dried fruits). Although the underwriting provisions have only been triggered once (in the 1986–87 season), the provision of this scheme has acted to reduce the risk normally associated with returns to producers of wheat in all years of its operation. This reduction in risk has been granted free-of-charge by the Commonwealth Government.

The guaranteed price can be viewed as a put option taken out by the Government on behalf of growers – it gives growers the option to sell to the Australian Wheat Board at this floor price. The aim of this paper is to apply to this underwriting arrangement the Black–Scholes formula for valuing options, in order to estimate the cost that growers would otherwise have had to pay to obtain cover (through put options) equivalent to the guaranteed price. We also estimate the magnitude of this form of assistance to the industry, which (until now) has not been taken into account unless the returns to growers fell below the guaranteed price.

A common form of assistance to agriculture has been the provision of government-guaranteed price floors. In attempting to measure the extent of public assistance, the accepted practice has often been for no assistance from floor prices to be taken into account unless the actual price falls below the price floor and government contributions are required to make up the difference.

This practice neglects to measure the assistance given by the introduction and maintenance of a price floor. This raised expected return is given *gratis* to producers, and the value of such assistance can be measured by the Black–Scholes (1972, 1973) formula for valuing put options. In this paper we apply this methodology to examine the assistance given to the Australian wheat industry by a government-guaranteed price floor.

Background to the Underwriting of Prices for Australian Wheat

For the ten crop seasons from 1979–80 to 1988–89, returns to producers in the Australian wheat industry were underwritten by the Australian Government in the form of a guaranteed minimum price (GMP). The GMP acted as a price floor, with payments (for each tonne of wheat) made by the Government equal to the difference between the GMP and the actual price received by producers (which is the net pool

*The authors gratefully acknowledge helpful comments from Jim Chalfant, Julian Alston, Nico Klijn, and Alistair Watson.

return from wheat sold in a given season).[1,2,3] The underwriting provisions for wheat were triggered for the first time in the 1986–87 season, amounting to a government contribution of some $167 million.[4] Underwriting has traditionally been the main method of price support used in the Australian wheat, apple and pear industries. It also contributes to supporting prices in the dairy and dried fruits industries.

The GMP for wheat was designed to be a short-term means of assistance to the industry which maintained (or limited any decrease in) production of wheat when prices were falling rapidly, without obscuring trends in returns. Although payments to growers under the scheme were infrequent, the GMP did operate to reduce the risk of low returns to producers and so raised both price expectations and production (Industries Assistance Commission 1988).

Valuing Government Price Guarantees

Government price guarantees can be viewed from several different perspectives, each of which suggests a different approach to valuation. From a government point of view, the expected budgetary outlay would seem to be an appropriate measure. From the farmer's point of view some measure of willingness to pay would seem natural, and this might be derived from an expected utility framework which incorporated both risk aversion and the extent to which price guarantees flowed through to farm incomes. From a general equilibrium perspective the appropriate valuation is the price at which the service would be offered in an efficient financial market.

A commodity option is a contract granting the right, but not the obligation, to purchase (call option) or sell (put option) a fixed amount of a given commodity on a given future date at a fixed price. To obtain this privilege the buyer of the right pays a premium to the writer (seller) of the option.

A forward contract is an unconditional contract to buy or sell at an agreed price on a future date. An option, on the other hand, is a con-

[1]The Australian Wheat Board (AWB) controls the marketing of Australian wheat and averages gross returns from sales of each season's crop on domestic and export markets (pooling of returns), from which the costs of marketing and distributing wheat are deducted to calculate the net pool return.

[2]Between the 1979–80 and 1983–84 seasons the GMP was determined at 95 per cent of the average of the estimated net pool returns for Australian Standard White (ASW) wheat from the previous two seasons and an estimate for the subject season, provided that the GMP was not more than 15 per cent above or below the GMP of the previous season. The calculation of the GMP was later modified so that between the 1984–85 and 1988–89 seasons it is determined at 95 per cent of the average of the estimated gross pool return for ASW wheat for the subject season and the estimated gross pool return for the two lowest of the three previous seasons, less an estimate of administration and marketing charges of the AWB for the subject year.

[3]New arrangements for the marketing of wheat were enacted in June 1989, with government arrangements for underwriting, albeit in a different form, continuing to apply. The Commonwealth Government will guarantee the borrowings of the AWB for the 1989–90 to 1993–94 seasons. The amount payable by the government will not exceed 90 per cent of the estimated net pool return for wheat of that season, with this proportion to be phased down to 80 per cent at the end of this period. The 1993–94 season will be the last season for which the underwriting arrangements will apply.

[4]Underwriting payments of some $167·4 million have been made for the 1986–87 wheat crop. It is expected that a further Commonwealth payment of $41·4 million will be made in 1990–91 in support of the 1986–87 crop.

tingent contract. It need only be exercised if it is favourable to the holder. The holder of a put option, for example, has locked in a minimum price for the commodity but the option will never be exercised if the commodity price remains above the exercise price. For a farmer with a stock of a certain commodity to sell, going long on put options is a hedge against falls in the market price below the exercise price of the option. The profit on the put compensates for losses in the cash market. Commodity futures contracts and options are discussed in some detail by Black (1976).

Underwriting (a government-guaranteed price floor) is directly analogous to farmers' purchase of put options on commodities, except that in the case of underwriting farmers receive their hedge free-of-charge, as all premiums on the puts are paid by taxpayers. Both Petzel (1984) and Hinchy (1987) have pointed out that by truncating the distribution of prices at the price floor, underwriting will (for most forms of probability distribution) not only raise the mean and reduce the variance of the distribution of prices, but also increase the positive skewness of their distribution.

Although both put options and underwriting have similar effects on the second and third moments of the distribution of prices, it is clear that farmers would prefer government underwriting to purchasing a put option. Underwriting is free and has the 'merit' of introducing sizeable implicit transfers from taxpayers to farmers. The taxpayer becomes the *de facto* writer of the option, yet receives no premiums.

It may be worthwhile to make quite explicit the relationship between the expected payout on a price guarantee and the Black–Scholes valuation of the corresponding option. If the government guarantees a commodity price, then it takes on a contingent liability. The expected value of this liability is the expected payout under the price guarantee. However, prudent financial management suggests that the government could take on a corresponding contingent asset. Variations in the value of the asset could offset variations in the value of the liability, reducing the total exposure to risk. The Black–Scholes model shows how to completely offset the risk of a put option by going short on the commodity (which can be done either by trading in a futures market or by 'borrowing' and selling the physical commodity), and by holding bonds (see Jarrow and Rudd 1983).

Put simply, if the government merely guarantees the price then it is foregoing an opportunity to trade in the commodity which is not only profitable but reduces its risk exposure. The profits from such trading could be used to reduce the cost to the government of guaranteeing the price. By failing to follow a Black–Scholes hedging strategy, the government is providing the price guarantee inefficiently, at a cost higher than that at which it would be provided in an efficient market.

If there is a market in which options are actively traded, then it is quite clear that the corresponding put option price is the correct valuation for the government price guarantee. Options are actively traded in wheat in the northern hemisphere, but not in Australian wheat. It is possible that the government price guarantee has prevented the emergence of an options market closely related to Australian wheat. However, it is likely that the different wheats are reasonably close substitutes. In any case, while an active market is a sufficient condition for using a Black–Scholes valuation it is not a necessary condition. It is enough that trading opportunities exist to exploit the arbitrage profits which emerge if valuations deviate significantly from the Black–Scholes value.[5]

Previous Studies

Apart from early work by Gardner (1977), there have been few previous studies which used put options to value government-guaranteed price floors for commodities. Most researchers have concentrated on analyses of call options for financial instruments. However, recent contributions by Petzel (1984), Marcus and Modest (1986), Fackler (1987) and Gardner (1988) have looked at the usefulness of put options as an alternative to forward sales, futures contracts and government programs as tools for transferring price risk away from farmers.

Petzel (1984) cited the two main advantages of options and futures as market-based solutions to managing risk: farmers have the opportunity to select and pay for the extent of risk-reduction they desire; and the volatility of spot prices is unaffected by the introduction of these hedging instruments. He then uses the Black–Scholes model to estimate the value of the implicit annual premium paid by taxpayers through government schemes for support of prices for United States corn, wheat, cotton and soybeans and finds that such assistance in 1984 ranged from US$106 million for cotton to US$1100 million for corn and soybeans.

Marcus and Modest (1986) argued that as the United States system of support for agricultural prices by nonrecourse loans can be interpreted as the provision of a random number of put options to producers, the contingent claims methodology of finance theory provides a more accurate measure of the implicit assistance than the standard Black–Scholes formula. This is because the number of options written (the size of the crop) may be correlated with the price at which the crop sells. Marcus and Modest analysed a number of agricultural commodities and found that the system of nonrecourse loans increased *ex ante* values of certain crops by even greater amounts than calculated by Petzel.

More generally, both Fackler (1987) and Gardner (1988) have analysed the similarities and differences between commodity futures, commodity options and government-guaranteed price floors, the relative abilities of each of these alternatives as financial tools for reducing the risks faced by agricultural producers, and the incentives that individual agricultural producers have to use or to participate in each of these alternatives.

Gardner (1977, 1988) argues that a general view of put options as price insurance links them more closely to underwriting (or deficiency payments) than to nonrecourse loans. This is because a support program of either deficiency payments or put options does not interfere with the market price, whereas nonrecourse loans require the government to hold the commodity and so directly influence market

[5]A recent paper by Dixit (1989) has used option pricing theory to evaluate (in the absence of an active market for options) investment by firms under uncertainty.

prices. This result implies that an analysis similar to Petzel (1984) is more applicable to Australia than one similar to Marcus and Modest (1986).

Further, Marcus and Modest claim that the random number of price guarantees given by the government invalidates the use of the Black–Scholes formula to value the assistance given by price supports. While this may be true for the 'large country' case of the United States, Australia is essentially a price taker on export markets for almost all of its commodities (including wheat), and so invoking the 'small country' assumption enables the Black–Scholes formula to be used as a valid measure of the assistance given by price floors.

The Model

The formula for pricing European put options on commodities can be derived from the Black–Scholes formula for pricing European call options, and by invoking the put/call parity theorem. Assuming that the risk-free rate of interest is constant over the life of the option, and that the price of the commodity follows a smooth random walk, then the price of a European call expressed in present value terms is given by the formula derived by Black and Scholes (1972, 1973):

(1) $C_t = S_t\Phi(I_1) - Ke^{-r\tau}\Phi(I_2)$

where

$$I_1 = \log(S_t/Ke^{-r\tau})/\sigma\sqrt{\tau} + 0{\cdot}5\sigma\sqrt{\tau}$$
$$I_2 = I_1 - \sigma\sqrt{\tau}$$
$$\Phi(I) = \int_{-\infty}^{I} 1/\sqrt{2\pi}e^{-x^2/2}\,dx$$

C_t the premium for the call option
S_t the current spot price for the commodity
K the exercise price at which the commodity may be purchased
r the riskless rate of interest
T time at maturity
t current time
τ the time to maturity of the option ($T-t$)
σ the standard deviation of the log of the commodity price.

The put/call parity theorem states that (in the absence of dividends):

(2) $C_t = P_t + S_t - Ke^{-r\tau}$

where

P_t the premium for the put option.

By substituting (2) into (1) and rearranging we obtain:

(3) $P_t = S_t(\Phi(I_1) - 1) - Ke^{-r\tau}(\Phi(I_2) - 1)$

Note that the parameters σ, r, τ and K are fixed for the assumed life of the option. Given the values of the above parameters, the price of the put option is uniquely determined by those variables which can change: the price of the commodity and time (Jarrow and Rudd 1983).

Application to the Underwriting of Wheat

As shown in the Black–Scholes formula of equation (3), data on the following variables are necessary to calculate the put price: the commodity price in period t (S_t); the exercise (guaranteed minimum) price (K); the risk-free rate of interest (r); the time to maturity (τ); and the volatility of the logarithm of the price of the underlying commodity (σ).

The commodity price (S_t) is the net pool return from wheat delivered to the Australian Wheat Board in season $t-1$ (that is, lagged one season) and is taken from Australian Wheat Board (1988, 1990). The lagged net pool return has been chosen because it is assumed that at the time that the guaranteed minimum price (GMP) is announced the best information available on the likely net pool return for season t is the net pool return in season $t-1$.

The exercise price (K) is the (GMP) for wheat of ASW quality (see Australian Wheat Board 1988). The interest rate (r) is the annual yield on two-year Treasury bonds, as the appropriate rate is one from a financial instrument that matures close to the expiration date of the option (see Reserve Bank of Australia 1990). Accordingly, the time to maturity (τ) is two years, which is assumed to be the time during which growers are unsure whether $S > K$.

Finally, the volatility of commodity prices (σ) is assumed to be constant over the life of the option and independent of the level of prices. A Dickey–Fuller (1981) test for unit roots, using the series of net pool returns (S_t) for Australian wheat from 1960–61 to 1988–89, failed to reject the hypothesis that log S_t followed a random walk. Accordingly, the volatility was estimated using the following formula (see Shastri and Tandon 1986):

$$(4) \quad \hat{\sigma} = \left[\sum_{j=1}^{n} (R_j - \bar{R})^2/n\right]^{0 \cdot 5}$$

where

$$R_j = \ln(S_j/S_{j-1})$$

$$\bar{R} = \sum_{j=1}^{n} R_j/n$$

$$n = 29$$

Butler and Schachter (1986) demonstrate that this estimate of the true standard variation is biased. However, they found that the resulting bias in the estimate of the value of the option was small (typically around 2 per cent) and decreases with the size of the sample. Equation (4) yields $\hat{\sigma} = 0 \cdot 2105$.

Results

The value (in nominal dollar terms) of the implicit transfer from taxpayers to wheatgrowers is set out in Table 1. For example, in 1985–86 the total cost of the premiums (and the implicit transfer) to hedge total planned Australian production against falls in the price of wheat below an exercise price set at the GMP amounts to the aggregate value of the put options, viz. A\$33·57 million.

The use of actual, *ex post* production rather than *ex ante* production distorts estimates of the implicit subsidy to agricultural producers,

TABLE 1

Value of the Put Premium and Implicit Assistance to the Australian Wheat Industry, 1979–80 to 1988–89

Year	Net pool return (A$/t)	Guaranteed minimum price (A$/t)	Put Premium (implicit subsidy) (A$/t)	Planned Australian production ('000 t)	Total implicit subsidy (A$'000)
1979–80	129·55	114·71	2·34	15 391	36 015
1980–81	154·55	131·92	1·70	15 909	27 045
1981–82	147·42	141·55	2·98	15 094	44 980
1982–83	149·92	141·32	1·66	14 976	24 860
1983–84	178·23	150·00	1·23	14 483	17 814
1984–85	162·38	145·35	2·29	15 339	35 126
1985–86	165·05	149·87	2·09	16 066	33 578
1986–87	159·60	139·83	1·77	15 894	28 132
1987–88	126·40	144·29	7·74	13 247	102 532
1988–89	165·27	153·37	3·25	16 067	52 218

Source: Data in column 3 has been calculated from equation (3); data in column 4 is calculated as set out in footnote 3; data in columns 1 and 2 are taken from Australian Wheat Board (1988, 1990).

depending on seasonal conditions. In years of favourable climate use of *ex post* data would overstate the extent of the implicit subsidy to agricultural producers, and understate them in less favourable years (when *ex post* production is lower than the *ex ante* area sown). Accordingly, *ex ante* or planned production is used in Tables 1 and 2 to derive the ERA (effective rate of assistance) and NSE (net subsidy equivalent) measures of assistance to the Australian wheat industry.[6]

Implications for the Measurement of Assistance to the Wheat Industry

The Industries Commission (IC), formerly the Industries Assistance Commission, has undertaken a series of detailed estimates of assistance to Australian agricultural industries, including the wheat industry (Industries Assistance Commission 1983, 1987, 1988). Its findings indicate that assistance to the industry increases producers' gross returns directly by assisting output (mainly by raising domestic prices for wheat above export parity prices) or indirectly by reducing the cost of inputs (mainly by fertiliser subsidies) and by assisting value-adding factors (mainly funds for research and the allowance of certain taxation concessions). However, this assistance is also partly balanced by tariffs on materials and capital equipment used in the production of wheat.

The effective rate of assistance (ERA) and the net subsidy equivalent (NSE) are two of the key measures of assistance used by the IC. The ERA is the percentage change in returns per unit of output to an

[6]Following Longworth and Knopke (1982) we assume that the expected yield in season t, Y_t^*, is the weighted mean of actual national average yields for the immediately preceding five seasons. The actual area sown to wheat in Australia in season t is multiplied by the expected yield to form the *ex ante* or planned production of wheat in season t. These results are reported in column 4 of Table 1.

TABLE 2

Effective Rate of Assistance (ERA) and Net Subsidy Equivalent (NSE) Measures of Assistance to the Australian Wheat Industry, 1979–80 to 1986–87

Year	ERA[a] (%)	ERA[b] (%)	NSE[a] (A$m)	NSE[b] (A$m)
1979–80	−2·9	−0·3	−40·6	−4·6
1980–81	5·4	8·6	49·6	76·65
1981–82	4·5	8·1	63·0	107·98
1982–83	10·6	14·1	86·1	110·96
1983–84	2·4	3·7	35·2	53·0
1984–85	1·7	4·3	23·7	58·2
1985–86	3·7	7·0	39·5	73·2
1986–87	25·0[c]	7·5[d]	213·5[c]	74·2[d]

[a]Excluding the implicit transfer from underwriting.
[b]Including the implicit transfer from underwriting.
[c]Preliminary estimate. Includes the government contribution of $167m to raise the actual return to wheatgrowers to the underwritten price.
[d]Preliminary estimate. Excludes the Government contribution of $167m to raise the actual return to wheatgrowers to the underwritten price.

Source: Data in columns 1 and 3 are taken from Industries Assistance Commission (1988).

activity's value-adding as a consequence of the structure of assistance, where value-adding is the increase in total revenue net of the costs involved in production. The ERA takes into account assistance to output and (positive and negative) assistance to inputs. The NSE is an estimate of the change in returns to an activity's value-added due to assistance. It is the dollar amount of the subsidy from taxpayers to producers necessary to provide a level of assistance equivalent to the ERA (see Industries Assistance Commission 1983, 1987*a*).

An inherent flaw in the IC's estimates of assistance is that they only include assistance *actually used*, when much of the worth of the assistance to the wheat industry lies in the assistance *potentially available*. The latter far exceeds the former. As noted by the Industries Assistance Commission (1988):

> Even in years where there is no prospective payout, the underwriting arrangements have the potential to influence the allocation of resources beyond that indicated by the measured levels of assistance. This is because they reduce price uncertainty and encourage higher levels of output. However, the Commission's estimates only include as assistance to output, payments which are actually made or receivable. Thus, the estimates of assistance actually received are somewhat less than the assistance potentially available. (p. 84)

The IC's estimates of assistance only include underwriting as a measured form of assistance when the return to growers falls below the price floor. This has occurred only once since 1979–80. As a result, the implicit transfer from taxpayers to growers (in the form of government-guaranteed price floors acting as put options granted free-of-charge) is excluded. If this implicit transfer is included both the ERA and NSE measures of assistance to the wheat industry are raised significantly in all years (see Table 2). These revised estimates give a more accurate indication of the true value of assistance to the industry. For example, the estimate of the ERA for the Australian wheat industry rises for

1985–86 from 3·7 per cent to 7·0 per cent and the NSE from A$39·5 million to A$73·2 million once the implicit subsidy from underwriting is taken into account.

Sensitivity Analysis

It is important to examine the sensitivity of the Black–Scholes formula to changes in the determinants of the put premium. The derivatives of (3) are:

(4) $\delta P/\delta S = (\Phi(I_1) - 1) < 0$

(5) $\delta P/\delta K = (e^{-r\tau}(1 - \Phi(I_2))) > 0$

(6) $\delta P/\delta \tau = ((S\sigma/2\sqrt{\tau})\phi(I_1) + rKe^{-r\tau}(\Phi(I_2) - 1)) \gtreqless 0$

(7) $\delta P/\delta \sigma = (S\sqrt{\tau}\,\phi(I_1)) > 0$

(8) $\delta P/\delta r = (\tau K e^{-r\tau}(\Phi(I_2) - 1)) < 0$

where

ϕ the standard normal probability density function
Φ the cumulative density function

As the commodity price increases, the price of the put option declines, because the exercise price is less likely to be above the commodity price when the option matures. As the exercise price increases, the price of the put option rises to cover the larger potential liability of the writer of the put option. Increasing interest rates would lower the present value of the exercise price received by the buyer of the option, lowering the price of the put option. More volatility in the price of the commodity would raise the price of the put option, as it increases $E(K-S)$, conditional on $S_T<K$.

The effect of a decrease in the time to maturity of the put option is ambiguous: the likelihood of favourable outcomes for the buyer of the put ($S_T<K$) is reduced (lowering the price of the put), yet the present value of the exercise price paid on maturity is raised (raising the price of the put). Jarrow and Rudd (1983) argue that for a long period to maturity the latter effect dominates, yet for a short period to maturity the former effect is stronger.

TABLE 3

Value of the Elasticities, 1979–80 to 1988–89[a]

Year	e_s (commodity price)	e_k (exercise price)	e_τ (time to maturity)	e_σ (price volatility)	e_r (interest rate)
1979–80	−6·09	7·09	0·14	3·09	−1·40
1980–81	−6·65	7·66	0·12	3·76	−1·76
1981–82	−5·96	6·96	−0·36	2·95	−1·83
1982–83	−6·64	7·65	−0·63	3·75	−2·51
1983–84	−7·16	8·16	0·03	4·40	−2·24
1984–85	−6·37	7·38	−0·09	3·42	−1·80
1985–86	−6·50	7·50	−0·23	3·57	−2·02
1986–87	−6·64	7·64	−0·08	3·75	−1·96
1987–88	−4·60	5·60	−0·64	1·63	−1·46
1988–89	−5·99	6·99	−0·14	2·99	−1·64

[a]Where the elasticity of the price of the put option with respect to the price of the commodity (e_s) is: $e_s = (\delta P/\delta S)/(S/P)$, and similarly for the other columns.

Table 3 reports the elasticity estimates of the price of the put option for Australian wheat with respect to the commodity price (e_s), the exercise price (e_k), the time to maturity (e_τ), the volatility of the price of the commodity (e_σ) and the interest rate (e_r).

As expected, those variables which have the greatest effect on the price of the put option are the commodity price, the volatility of the commodity price and the exercise price. For example, the table reveals that for 1985–86 a one per cent fall in the volatility of the commodity price would result in a 3·57 per cent fall in the price of the put option.

Concluding Comments

This paper has highlighted the subsidies inherent in government-guaranteed price floors. These subsidies arise with public programs of price support because governments implicitly offer a random number of put options to underwrite returns to producers at the price floor, yet taxpayers receive no premiums to cover the risks borne. An important consequence of such schemes for risk reduction is the distortion of market prices for the underwritten commodity.

It would be more appropriate for agricultural producers to use financial instruments such as options to select and pay for the extent of risk reduction they desire, having regard to the extent to their personal aversion to risk and financial circumstances. However, markets for such instruments are most unlikely to arise in the presence of public programs to support prices.

Results from the Black–Scholes model of option pricing indicate that inclusion of the implicit subsidy to producers arising from the underwriting scheme for the Australian wheat industry substantially raises measured assistance to the industry. Similarly, inclusion of the implicit subsidy to producers arising from farm programs or deficiency payments in the United States and other countries would also raise the measured level of assistance to these industries. This analysis demonstrates that even when market prices are *above* government-guaranteed price floors, such floors benefit agricultural producers to the detriment of taxpayers.

References

Australian Wheat Board (1988), *Annual Report 1986–87*, AGPS, Melbourne.

—— (1990), *Annual Report 1988–89*, AGPS, Melbourne.

Black, F. (1976), 'The Pricing of Commodity Contracts', *Journal of Financial Economics* 3, 167–79.

—— and Scholes, M. (1972), 'The Valuation of Option Contracts and a Test of Market Efficiency', *Journal of Finance* 27, 399–417.

—— (1973), 'The Pricing of Options and Corporate Liabilities', *Journal of Political Economy* 81, 637–59.

Butler, J. S. and Schachter, B. (1986), 'Unbiased Estimation of the Black/Scholes Formula', *Journal of Financial Economics* 15, 341–57.

Dickey, D. A. and Fuller, W. A. (1981), 'Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root', *Econometrica* 49, 1057–72.

Dixit, A. (1989), 'Entry and Exit Decisions Under Uncertainty', *Journal of Political Economy* 97, 620–39.

Fackler, P. L. (1987), 'An Analysis of Alternative Market and Governmental Risk Transference Mechanisms', paper presented at Conference on Stabilization Issues in Agriculture Policy, Raleigh NC, May.

Gardner, B. L. (1977), 'Commodity Options for Agriculture', *American Journal of Agricultural Economics* 59, 986–92.

—— (1988), 'Current Farm Programs and How They Relate to Futures and Options', in *Options, Futures, and Agricultural Commodity Programs Symposium Proceedings*, Economics Research Service, USDA, Washington DC, 1–11.

Hinchy, M. (1987), 'Evaluating the Producer Benefits from Underwriting', paper presented at the 31st Annual Conference of the Australian Agricultural Economics Society, Adelaide.

Industries Assistance Commission (1983), *Assistance to Australian Agriculture*, AGPS, Canberra.

—— (1987), *Assistance to Agricultural and Manufacturing Industries*, AGPS, Canberra.

—— (1987*a*), *Annual Report 1986–87*, AGPS, Canberra.

—— (1988), *The Wheat Industry*, Report No. 411, AGPS, Canberra.

Jarrow, R. A. and Rudd, A. (1983), *Option Pricing*, Irwin, Homewood, Ill.

Longworth, J. W. and Knopke, P. (1982), 'Australian Wheat Policy 1948–79: A Welfare Evaluation', *American Journal of Agricultural Economics* 64, 642–54.

Marcus, A. J. and Modest, D. M. (1986), 'The Valuation of a Random Number of Put Options: An Application to Agricultural Price Supports', *Journal of Financial and Quantitative Analysis* 21, 73–86.

Petzel, T. E. (1984), 'Alternatives for Managing Agricultural Price Risk: Futures, Options, and Government Programs', *AEI Occasional Paper*, American Enterprise Institute for Public Policy Research, Washington DC.

Reserve Bank of Australia (1990), *Statistical Bulletin*, various issues.

Shastri, K. and Tandon, K. (1986), 'Valuation of Foreign Currency Options: Some Empirical Tests', *Journal of Financial and Quantitative Analysis* 21, 145–60.