THE AUSTRALIAN JOURNAL OF AGRICULTURAL ECONOMICS

VOL. 28 APRIL 1984 NO. 1

# THE ECONOMICS OF INSURING CROPS AGAINST DROUGHT

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**The necessary conditions for the existence of a financially viable crop insurance scheme against drought are examined. A supply and demand model for crop insurance is developed which identifies the parameters that are critical to the efficiency of such a scheme. The values of these parameters are estimated by using data from the Australian wheat industry. It is found that crop insurance against drought would appear to be unattractive from an efficiency point of view.**

Production and price variability are well recognised as being characteristic features of Australian agriculture. For some agricultural commodities, futures markets offer a relatively efficient means of hedging against price fluctuations. In addition, for some commodities in Australia, most notably wheat, a degree of price stability is assured by various schemes which underwrite price. Production or yield variability is more difficult to hedge against, however, especially if production loss is due to natural disasters such as drought, flood, fire or disease. Government disaster relief measures give some protection, but the efficiency of these has been questioned (see Freebairn 1978).

One common technique for risk mitigation is insurance. In an insurance scheme the total risk is reduced by pooling the risk over a large number of individuals. The success of household fire insurance or motor vehicle insurance prompts the question of whether insurance would be a feasible and efficient means of protecting farmers from unforeseen production loss (see, for example, Quiggin and Anderson 1979). Various crop insurance schemes operate throughout the world, but all schemes of which the authors are aware are characterised by some element of government subsidy, coverage of a very limited range of risks, or coverage of a small number of crops. For example, crop insurance schemes in the United States, Canada, Sweden and South Africa are all government subsidised.

In this paper, some of the conditions which are necessary for the existence of a financially viable insurance scheme are examined in order to develop a demand and supply model for crop insurance. The scheme modelled differs from conventional crop insurance schemes in that it is based on meteorological observations rather than changes in yields, which allows a considerable reduction in information costs (on the desirability of 'weather crop insurance', see Halcrow 1978). Since one of the major risks to Australian broadacre crops is that of reduced yields due to drought, this is the hazard considered in this analysis. The principles involved, however, are general and can be applied to other hazards.

### *Risk, Liquidity and Insurance*

A crucial difference between a typical insurance scheme such as household fire insurance and crop insurance is that household fire is a rare event, whereas widespread drought is a relatively common one. The householder who insures against fire will, in probability, never make a claim against the policy. Consequently, the total sum paid over a lifetime is much less than the value of the house. On the other hand, most agricultural areas in Australia experience drought as an integral part of the farming environment (Reynolds, Watson and Collins 1983). Since a claim based on drought is almost certain to be made in time against any crop insurance policy, the premiums paid out over the good years must be at least sufficient to cover the losses claimed in the bad years. For example, if drought occurs once every five years and in the drought year a payment of $20 000 is made by the insurer, then the annual premium paid in the four good years must be at least $5000. This assumes that no interest is earned by the insurance pool, but the conclusion is similar under more realistic assumptions.

Thus, crop insurance can be regarded to some extent as a way of saving to cover an anticipated future loss. One of the costs of buying insurance is that the asset accumulated is relatively illiquid, compared with other forms of saving. An insurance policy is of no benefit in meeting uninsured losses, which might, for example, be caused by ill health or machinery breakdown. A producer may be reluctant to lock up substantial savings in the relatively illiquid form of insurance unless there are substantial gains to be had through increased efficiency in risk bearing.

In order to better understand these efficiency gains it is useful to look more closely at the nature of risk (which is used here synonymously with uncertainty). An individual who is faced with an uncertain loss faces two types of costs. One is the cost of the loss itself, which will be called the actuarial cost since this is the component of cost used in actuarial calculations. The other is the cost the individual incurs because the event is unpredictable. This may be termed the cost of risk bearing (for a more general analysis of risk and insurance, see Arrow 1970).

The cost of risk bearing depends upon the degree of uncertainty, which may, for convenience, be measured by the variance of the individual's cash flow or income. It also depends upon the individual's aversion to risk and financial capacity to absorb income fluctuations. This capacity will be referred to in the general sense as liquidity. Liquidity is taken here to include a credit rating or borrowing capacity as well as the holding of assets (see Barry and Baker 1971 on the costs of maintaining a good credit rating).

Similarly, the premium charged for an insurance policy can be broken down into three components. The first of these is the actuarial cost, which is equal to the actual claims, smoothed through time, that the insurer expects to pay out. In practice it is estimated by a statistical analysis of past losses. The second component is the cost of risk bearing, which is the cost to the insurer of maintaining sufficient liquidity to meet any claims promptly. The final component consists of administrative and operating costs.

It should be emphasised that insurance does not in any way reduce the actuarial cost of the premium. Of course in any one year, those who make a claim on their policy are subsidised by those who do not. But, if the insurance scheme is actuarially fair, then in the long run everything averages out and the actuarial cost to any individual is the same as it was before the insurance scheme was introduced. It is well known that in practice there are a number of anomalies which may lead to net cross-subsidisation of the careless by the careful, of the dishonest by the honest and so on. These anomalies under the generic names of 'moral hazard' and 'adverse selection' may lead to market failure, with socially undesirable outcomes. These phenomena, generally caused by unequal distribution of information, have been much studied (see Pauly 1974; Prescott and Townsend 1984). It has been claimed (Ahsan, Ali and Kurian 1982) that market failure due to such information defects may be responsible for the observed lack of privately operated crop insurance schemes. While information defects may be important, the authors believe that, with regard to crop insurance against the hazard of drought in Australian conditions, the difficulties are of a more fundamental nature.

To appreciate this point it is necessary to consider the main source of gains under a conventional insurance scheme. It has been noted that there are no gains to be had in insurance from the actuarial point of view. Where the gains may lie is in the area of risk bearing. If $N$ identical individuals facing similar, but independent, risks form themselves into an insurance pool, then the cost of uncertainty, as measured by the variance, is reduced by a factor of $1/N$. This is a simple consequence of the properties of independent random variables. If $N$ is large, then the cost of uncertainty may be virtually eliminated and the gains may be substantial. This is the situation with the classical types of insurance such as household fire insurance, where the risk faced by any one individual is essentially independent. However, if the risks are correlated, the gains from risk sharing are reduced or, in the case of perfect correlation, eliminated entirely. There remains, however, one possible source of advantage. If the insurer, because of diversification or better access to capital markets, is able to bear risk at a lower cost (is less risk averse) than the insured, there may still be some gains to be had.

To summarise, for an insurance scheme to be financially viable, a number of conditions must be met.

(a) To guarantee adequate participation in such a scheme, the benefits to the insured must be of sufficient magnitude relative to the benefits from alternative investments and the liquidity costs must not be too great.
(b) The number of individuals in the insurance pool must be large in order to maximise risk spreading.
(c) The risks faced by individuals should be independent. If the risks are correlated, this has the effect of reducing the effective size of the insurance pool.
(d) The risks faced by each individual must be known by both parties and should not be open to manipulation by the insured. This reduces the problems of moral hazard and adverse selection.

(e) The administrative costs must be low. In particular, the costs of gathering the information necessary for loss assessment and to avoid moral hazard and adverse selection problems should be low.

In addition to these conditions, it is desirable that the insurance policy does not alter the producer's incentives for efficient production. This is closely related to the issue of moral hazard. Whether a given insurance scheme is viable or not depends upon the balance of these various factors. In the next section, a mathematical model which helps to throw some empirical light on this balance is developed.

## *A Supply and Demand Model for Crop Insurance Against Drought*

### *Assumptions*

In order to set up a model, a number of simplifying assumptions are made. The effect of relaxing these assumptions is examined later. The first assumption is that there is full information to all parties and that the probabilities of loss are known exactly. This means that there are no difficulties of the moral hazard and adverse selection types. This assumption is made for two reasons. First, it enables attention to be focused on the liquidity choice and risk correlation aspects of insurance, which can be seen more clearly in a simplified setting. Second, it enables an assessment of the proposal that drought insurance schemes for broadacre crops which provide full information at low cost can be designed (see Halcrow 1978).

The type of scheme proposed is this. The population of crop growers falls into regional groupings, such as shires, which are reasonably homogeneous in meteorological and production conditions. An insurance contract is essentially a bet between the insurer and insured. If instead of betting on the future conditions experienced on their properties, producers were to bet on the future average conditions in their shires (such as whether or not the shire is drought-declared), then there may be little loss from the point of view of risk reduction but a great saving in information costs. Good actuarial data are available, costly loss assessment is avoided, and an individual producer cannot easily manipulate the insured event. There is no loss in generality in considering such a scheme because if each 'shire' is comprised of a single producer then this is the same as a conventional insurance scheme.

Thus, the population will be assumed to fall into $N$ shires, each containing $m$ identical producers. The total number of producers is then

$$n = mN \tag{1}$$

For the moment, it is assumed that the attitude to risk and cost of risk bearing are the same for all individuals and are the same for the insurer as for the insured. This assumption is appropriate for a co-operative scheme, where the insured and the insurer are identical. Later, this assumption is relaxed and risk associated with a public versus a private insurer is examined (for further discussion, see Arrow and Lind 1970). Individuals are assumed to protect themselves from uncertainty by holding a stock, $K$, of liquid assets to draw on in lean years to stabilise their income or cash flow from unforeseen and unplanned fluctuations.

The cost of maintaining this liquidity is $rK$, $r$ being the difference between short-term and long-term interest rates. This strategy does not completely eliminate risk. There is a level of residual risk which may be interpreted as the probability of a fluctuation which completely exhausts the reserve $K$. This will be interpreted as insolvency, an event with a very high cost. This is of course an oversimplification. However, it is adequate for the purposes of the model.

Since insurance makes no difference to the actuarial cost of risk bearing, actuarial cost plays no part in the model, and is set equal to zero throughout this section. One way of formalising this is to suppose that each insurance contract is in two parts. The first consists of an actuarially fair bet with the insurer, that is, one which on average leads to a zero transfer of funds but which transfers risk from the insured to the insurer. The second part is a fee paid to the insurer to compensate for this risk and for any other costs of providing the service. It is this fee that is regarded as the cost of insurance in this section. Finally, it is assumed that the insurer makes zero profit, either because of competition or because the insurer is the government.

*Notation*

The producer's income stream from the farm business (net of any insurance premiums or receipts) is a random variable, $X$, with variance $V(X) = \sigma^2$. The return from one unit of insurance taken out is also a random variable, $Y$. Since it has been assumed that the insurance policy takes the form of an actuarially fair bet, it follows that $E(Y) = 0$. The variance of $Y$ depends entirely on the units chosen for insurance. It is convenient to choose the size of one unit of insurance such that $V(Y) = \sigma^2$. Let the correlation of the random variables $X$ and $Y$ be $-\delta$. The negative sign is convenient for ease of interpretation. For convenience, $X$ and $Y$ may be assumed to be normally distributed.

The parameter $\delta$ will be referred to as the correlation between the producer's risk (the negative of the income fluctuation) and the return from the insurance policy. With respect to liquidity, as discussed previously, what matters is not absolute liquidity, in the sense of the ability to meet at low cost any unexpected demand for funds but rather the ability to meet demands of the type to be expected in a given line of business and environment. The parameter $\delta$ captures precisely the liquidity properties, in this restricted sense, of the insurance policy. If $\delta = 1$, then the returns from the policy come just when they are needed, exactly matching fluctuations in income. If $\delta = 0$, then the timing of the insurance returns is completely unrelated to the need for them. If $\delta$ is negative, then the insurance actually destabilises the income stream. We will assume that $\delta > 0$.

Generally, $\delta$ could be expected to be strictly less than 1 for the following reasons:

(a) Variation in output is not the only source of a producer's income variability.

(b) The insurance policy may not exactly match the producer's production risk. For example, if the policy is on rainfall, then rainfall may be an imperfect proxy for soil moisture, and furthermore there is no protection from unrelated risks such as disease or machinery breakdown. If the policy is based on regional rainfall, then $\delta$ will be lower still because of local climatic variations.

(c) The insurance policy would be discrete in operation and the timing of payments would not exactly match the losses.

(d) Any deductible or co-insurance arrangements would further lower $\delta$.

If $\alpha$ is the residual risk of insolvency (held constant throughout the model), and $f_X$ is the density function of the random variable $X$, then the stock, $K$, of liquid assets which must be held is determined by the equation

$$(2) \qquad \alpha = \int_{-\infty}^{E(X)-K} f_X(x)dx$$

(see Figure 1).

It is convenient to write $K = t\sigma$, where $\sigma$ is the standard deviation of $X$; $t$ is then a parameter which summarises the level of residual risk borne by the producer. For example, if $X$ is normally distributed and $t = 1.65$, then the producer has a 5 per cent probability of insolvency in any year, and he needs to hold a stock $K = 1.65\ \sigma$ of liquid assets. If $t = 2.33$, then the probability is 1 per cent, and $K = 2.33\ \sigma$. If $r$ is the cost of holding one unit of liquid assets, then the cost of maintaining a residual risk level $\alpha$ is

$$(3) \qquad C_o = r\sigma t$$

This is the cost to the producer of maintaining risk level $\alpha$ without using insurance and may be used as a baseline when considering the cost of strategies that include insurance.

Let $\theta$ be the amount of insurance purchased. It is shown in the model below that $0 \leq \theta \leq 1$. If $\delta = 1$, then $\theta$ can be interpreted as the proportion of the risk insured. For convenience, even when $\delta \neq 1$, $\theta$ will continue to be referred to as the proportion of the risk insured. Let $P$ be the price of one unit of insurance. As already mentioned, $P$ includes the cost of risk bearing and administrative costs, but not any actuarial cost.

Just as it was convenient to normalise the units in which insurance was measured so that $V(Y) = V(X) = \sigma^2$, it is convenient to normalise the price of insurance by dividing by the baseline cost $C_o$. Thus let $p = P/C_o$. As already mentioned, the population insured consists of $n$ individuals who fall into $N$ homogeneous groups (shires) each consisting of $M = n/N$ individuals.

The insurance scheme is built around bets on an event in each shire, for example rainfall. Let $\tau$ be the intraclass correlation of these events. $\tau$ is a measure of the spatial correlation of the insurer's risk. If $\tau$ is close to 1, then very little risk sharing is possible, while if $\tau$ is close to zero then the risk reduction may be considerable. $\tau$ will be referred to as the correlation of risk between shires. It will be assumed that the insurer makes no profit, but incurs administrative costs of $\gamma C_o$ per individual insured.

*Demand for insurance*

The producer chooses a portfolio consisting of a stock, $K$, of liquid assets and $\theta$ units of insurance. The producer then chooses the most efficient (least cost) portfolio consistent with the constraint that his or her residual risk of insolvency is $\alpha$.

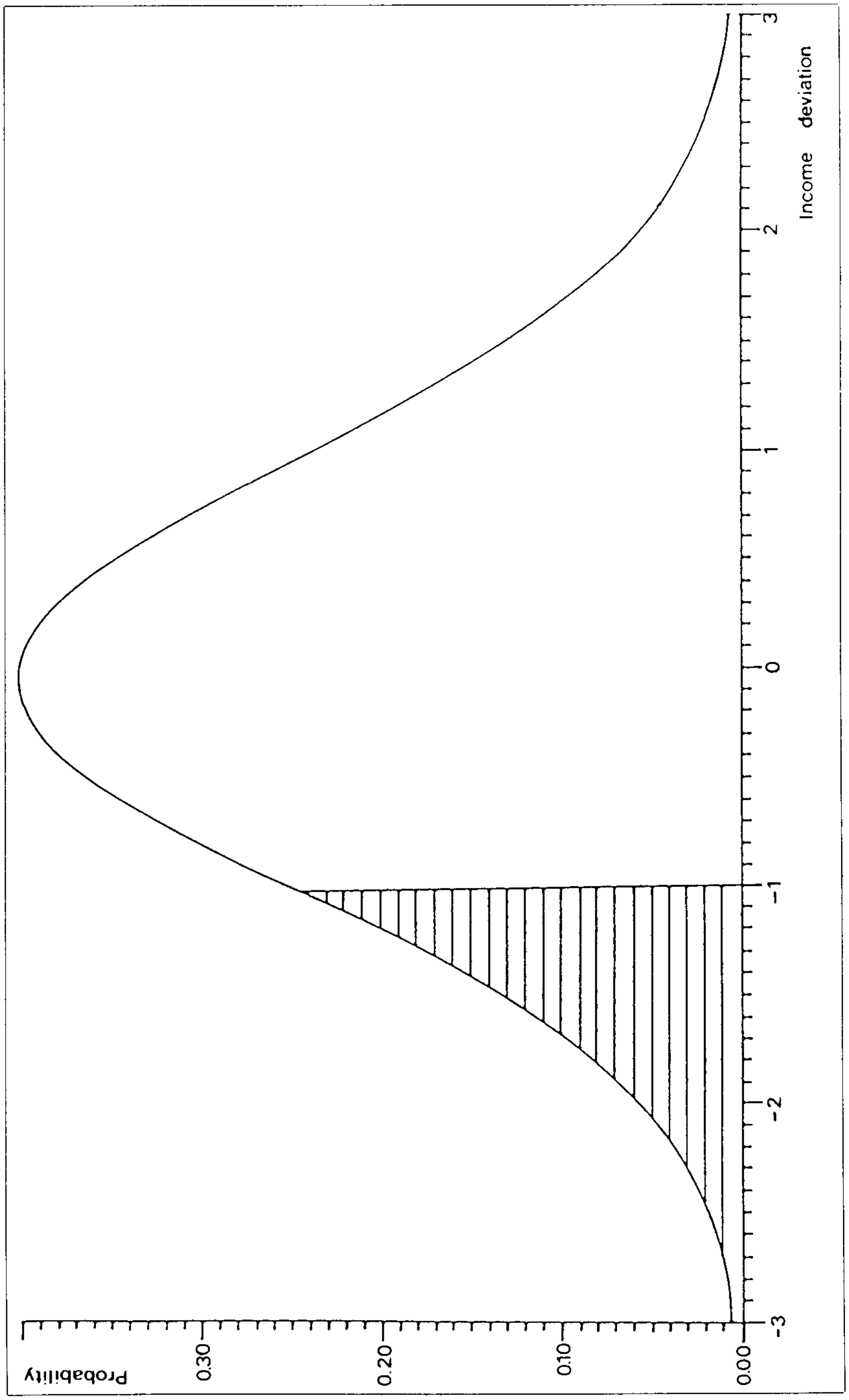


FIGURE 1 — Residual Risk of Insolvency.

The producer's total income is a random variable $X+\theta Y-rk-P\theta$, with variance $V=\sigma^2(1-2\delta\theta+\theta^2)$. To achieve a residual risk $\alpha$ the producer must hold a stock $K=tV^{0.5}=t\sigma(1-2\delta\theta+\theta^2)^{0.5}$, where $t$ is the parameter appropriate to risk level $\alpha$. Thus the constraint can be written

(4) $$K^2=t^2\sigma^2(1-2\delta\theta+\theta^2)$$

The cost of the portfolio is

(5) $$\begin{aligned} C&=rK+P\theta \\ &=rK+p\theta C_o \end{aligned}$$

Thus the problem is to minimise (5) subject to the constraint (4). Lagrangian minimisation gives

(6) $$\begin{aligned} \theta&=\delta-p\lambda \\ K&=\lambda C_o/r \end{aligned}$$

where $\lambda=[(1-\delta^2)/(1-p^2)]^{0.5}$ is a Lagrange multiplier (the positive square root is appropriate since $K\geq 0$).

A representative set of demand curves is shown in Figure 2. It can be seen that even if the price, $p$, is zero, less than 100 per cent insurance will generally be held; there is a critical price, $p=\delta$, above which no insurance will be taken out; as $\delta\rightarrow 0$ the insurance taken out tends to zero; and as $\delta\rightarrow 1$ the curve becomes more and more convex.

*Supply of insurance*

If $Y_i$ is the insurance claim to be paid out to an individual in shire $i$, then the insurer's total liability is

(7) $$Y=\sum_{i=1}^{N} mY_i$$

which has variance

(8) $$V=N[1+(N-1)\tau]m^2\sigma^2\theta^2$$

where $\tau$ is the intraclass correlation of the $Y_i$.

If it is assumed that the insurer has the same attitude to risks and cost of risk bearing as the insured (that is, the scheme is one of risk sharing rather than risk transfer), then the insurer will hold a pool of liquid assets.

(9) $$\begin{aligned} K&=tV^{0.5}=t\{N[1+(N-1)\tau]m^2\sigma^2\theta^2\}^{0.5} \\ &=n\sigma t\theta\{[1+(N-1)\tau]/N\}^{0.5} \end{aligned}$$

If the cost of holding the assets is $rK$, if the insurer faces administrative costs of $\gamma C_o$ for each insured individual, and if the premium, $P$, is set so that the insurer makes zero profit, then

(10) $$Pn\theta=n\theta C_o\{[1+(N-1)\tau]/N\}^{0.5}+n\gamma C_o$$

(11) $$p=\gamma/\theta+\{[1+(N-1)\tau]/N\}^{0.5}$$

If $N$ is reasonably large, then the supply equation simplifies to

(12) $$p=\gamma/\theta+\tau^{0.5}$$

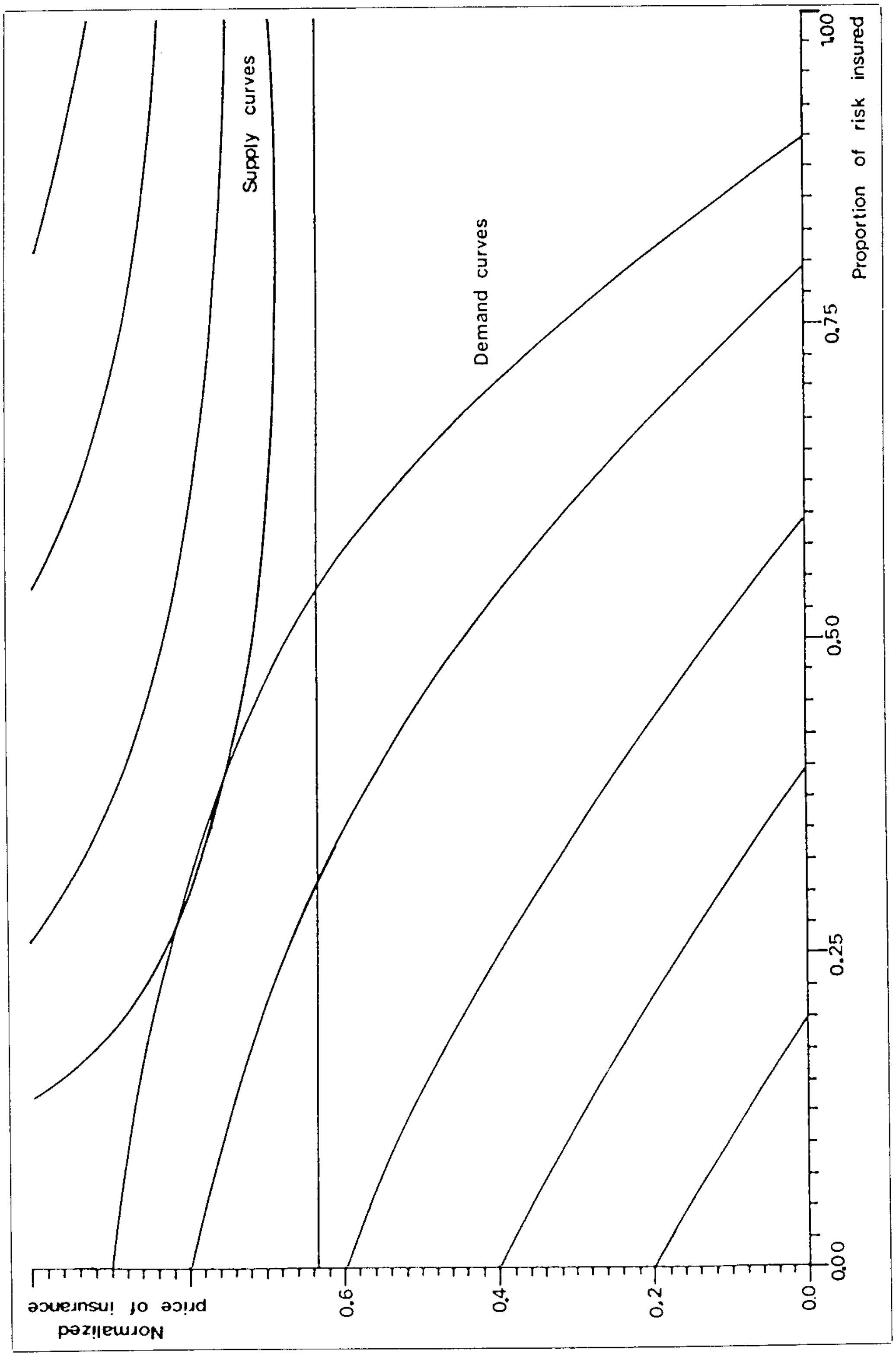


FIGURE 2 – Demand for and Supply of Insurance.

If $\gamma = 0$, then the supply curve is horizontal. If $\gamma$ is positive, then the supply curve is downward sloping because of economies of scale and the fixed costs are spread over a larger amount of business. A set of supply curves is shown in Figure 2.

*Equilibrium of supply and demand*

Assuming that $N$ is reasonably large (say $N > 20$ and $\tau > 0.5$ or $N > 100$ and $\tau > 0.2$), the complete model can be summarised in three equations:

(13) $$\theta = \delta - p\lambda \qquad \text{(Demand)}$$

(14) $$p = \gamma/\theta + \tau^{0.5} \qquad \text{(Supply)}$$

(15) $$\lambda = [(1 - \delta^2)/(1 - p^2)]^{0.5}$$

where $p$ is the price of insurance and $\theta$ is the proportion of the risk insured. Since the supply curve slopes downward, it can intersect the demand curve twice. Only the lower intersection is stable (see Figure 2).

The equilibrium is determined by the values of three parameters:

$\delta$— the correlation between the producer's income stream and the return from the insurance policy;

$\tau$— the correlation of the insurer's risk between shires; and

$\gamma$— the administrative and information costs.

It is noteworthy that $N$, the size of the insurance pool, drops out of the equations unless the correlation, $\tau$, is very small.

Since it has been assumed that the insurer's profit is zero, all the gains from introducing insurance accrue to the producer in the form of a decrease in the cost of reducing his risk. This saving, which may be labelled the 'efficiency gain', is

(16) $$\begin{aligned} C_o - C &= C_o - rK - p\theta C_o \\ &= C_o - \lambda C_o - p\theta C_o \\ &= (1 - \lambda - p\theta)C_o \end{aligned}$$

Thus the percentage gain is

(17) $$(C_o - C)/C_o = 1 - \lambda - p\theta$$

This is tabulated for a range of correlations in Table 1.

The assumption that both parties choose the same level of $\alpha$ greatly simplifies the analysis. However, in so doing it ignores the possibility that there are gains to be had by transferring risk from individuals with a high cost of risk bearing to individuals with a lower cost of risk bearing. Thus conclusions drawn from the model must be tempered by considering whether the insurer is likely to be more or less risk averse than the insured. This is an issue taken up later.

## *A Case Study of the Australian Wheat Industry*

On the basis of the model developed above, it is apparent that the viability of any crop insurance scheme depends critically upon the values of the three parameters, $\delta$, $\tau$ and $\gamma$. Only if $\tau$ is small, and $\delta$ reasonably large is insurance likely to be attractive, and then its feasibility will depend on $\gamma$, the cost of risk appraisal, loss assessment and administration.

TABLE 1

*Percentage Efficiency Gain from Insurance Assuming that Administrative Costs are Zero*

| Correlation of insurer's risk ($\tau$) | Correlation between payout and drought loss ($\delta$) | | | | |
|---|---|---|---|---|---|
| | 0.2 | 0.4 | 0.6 | 0.8 | 0.9 |
| 0.8 | 0 | 0 | 0 | 0 | 0 |
| 0.6 | 0 | 0 | 0 | 0 | 2 |
| 0.4 | 0 | 0 | 0 | 2 | 9 |
| 0.2 | 0 | 0 | 1 | 10 | 20 |
| 0.1 | 0 | 0 | 5 | 17 | 30 |

Data which the Bureau of Agricultural Economics had available on wheat yield and production variability, covering 48 shires in the New South Wales wheat belt over the period 1945-69, were analysed in order to assess the likely size of the parameter $\tau$. The data from each shire were detrended to remove any spurious correlation with time, since only unpredictable movements are significant and the intraclass correlation, $\tau$, was calculated. For these shires over this period, the value of $\tau$ was 0.5 (for wheat production) and 0.7 (for wheat yield). Naturally $\tau$ would be lower for the whole Australian industry than for the New South Wales industry. An approximation was calculated using state yield and production histories. This indicated that the value of $\tau$ was about 0.3 (for wheat production) and about 0.4 (for wheat yield) across Australia.

In the absence of the necessary time-series/cross-sectional micro data, it is difficult to make an accurate estimate of the parameter $\delta$. As an approximation, the correlation of aggregate net farm income with yield and production series was calculated. The analysis indicated that $\delta$ was about 0.65 for both yield and production.

From Tables 1 and 2 it can be seen that for any plausible value of $\gamma$ which would be faced by a private firm, a commercial crop insurance scheme based on guaranteed yield or production would not be viable. This would presumably apply also to insurance based on a rainfall event.

TABLE 2

*Proportion of Risk Insured, Assuming that Administrative Costs are Zero*

| Correlation of insurer's risk ($\tau$) | Correlation between payout and drought loss ($\delta$) | | | | | |
|---|---|---|---|---|---|---|
| | 0.2 | 0.4 | 0.6 | 0.7 | 0.8 | 0.9 |
| 0.8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| 0.6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.36 |
| 0.5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.43 |
| 0.4 | 0.00 | 0.00 | 0.00 | 0.10 | 0.31 | 0.54 |
| 0.3 | 0.00 | 0.00 | 0.00 | 0.23 | 0.40 | 0.63 |
| 0.2 | 0.00 | 0.00 | 0.20 | 0.33 | 0.50 | 0.68 |
| 0.1 | 0.00 | 0.09 | 0.33 | 0.48 | 0.60 | 0.75 |

The assumptions of the model are now relaxed to investigate whether the lower aversion to risk and the lower cost of liquidity for a government-backed insurer are sufficient to alter the conclusions. The supply and demand model can be modified as follows to explore this issue. Using the previous notation, let $\alpha_o$ be the residual risk of insolvency that the producer is prepared to carry, and let $\alpha_1$ be the residual risk borne by the insurer. Let $t_o$ and $t_1$ be the corresponding risk parameters. Let $r_o$ be the cost faced by the producer of maintaining a given level of liquidity, and let $r_1$ be the cost faced by the insurer in maintaining the same level of liquidity. Let $C_o = r_o t_o \sigma$. Then the demand equation (13) is unchanged, while the supply equation (14) should be replaced by

$$p = (r_1/r_o)(t_1/t_o)(\gamma/\theta + \tau^{0.5}) \tag{18}$$

The effect of different levels of risk aversion is explored in Table 3. It can be seen, for example, that if the insurer is willing to bear eight times the risk level that the insured bears, then it could be expected that about 30 per cent of the risk would be insured and that the resulting efficiency gain would amount to a reduction of about 4 per cent in the cost to the producer of risk protection. This assumes that administrative costs are held at zero. If the administrative cost rises to 2 per cent, then the insurance sold covers 25 per cent of the risk, and the efficiency gain falls to about 2 per cent. If administrative costs rise to 5 per cent, then no insurance is taken out.

The effect of different costs of holding liquid assets is set out in Table 4. For example, if this cost is 50 per cent higher for the producer than for the insurer, then one would expect to see 30 per cent of the risk covered

TABLE 3

*Effect of Different Levels of Risk Aversion on the Insurance Equilibrium for the Australian Wheat Industry*[a]

| Relative risk levels[b] $\alpha_1/\alpha_0$ | Administrative costs ($\gamma$) | | | | |
|---|---|---|---|---|---|
| | zero | 2 per cent | 5 per cent | 10 per cent | 20 per cent |
| 1 | 0.03 (0.0) | 0 | 0 | 0 | 0 |
| 2 | 17.2 (1.1) | 0 | 0 | 0 | 0 |
| 4 | 25.0 (2.5) | 0 | 0 | 0 | 0 |
| 8 | 30.1 (3.8) | 24.6 (2.3) | 0 | 0 | 0 |
| 16 | 33.7 (4.9) | 29.7 (3.7) | 0 | 0 | 0 |
| 32 | 36.1 (5.9) | 32.9 (4.7) | 25.4 (2.3) | 0 | 0 |

[a] The proportion of risk insured and the percentage efficiency gain (in brackets) are given for a range of administrative costs and a range of relative risk levels.
[b] $\alpha_0$ is fixed at 0.05 in this table.

TABLE 4

*Effect of Differential Costs of Borrowing on the Insurance Equilibrium for the Australian Wheat Industry*[a]

| Relative cost of credit $r_0/r_1$ | Administrative costs ($\gamma$) | | | | |
|---|---|---|---|---|---|
| | 0 | 2 per cent | 5 per cent | 10 per cent | 20 per cent |
| 1 | 0.03<br>(0.0) | 0 | 0 | 0 | 0 |
| 1.1 | 0.11<br>(0.4) | 0 | 0 | 0 | 0 |
| 1.5 | 0.30<br>(3.6) | 0.24<br>(2.1) | 0 | 0 | 0 |
| 2.0 | 0.40<br>(7.3) | 0.37<br>(6.3) | 0.33<br>(4.5) | 0 | 0 |
| 3.0 | 0.49<br>(12.0) | 0.47<br>(11.3) | 0.46<br>(10.2) | 0.42<br>(8.3) | 0 |

[a] The proportion of risk insured and the percentage efficiency gain (in brackets) are given for a range of administrative costs and a range of relative costs of credit.

with a gain of about 4 per cent. If administrative costs rise to 2 per cent, then 24 per cent of the risk is covered with a gain of about 2 per cent. If the administrative costs rise to 5 per cent, then no insurance is taken out.

In both cases it can be seen that while there are some gains to be had in the absence of administrative costs, they are quickly reduced if the administrative costs are allowed to rise. The analysis suggests that crop insurance against drought for the Australian wheat industry may be unattractive from an efficiency point of view. The funds locked up in the insurance pool may be put to better use if they remained in the hands of the farmers.

## *Conclusion*

In this paper the role of insurance in the financial strategy of farmers engaged in risky production has been examined. The relative efficiency of insurance as opposed to other financial measures for managing risk was assessed through a simple mathematical model of insurance supply and demand. It was found that the usefulness of insurance depends on the spatial correlation of the risk, on the correlation of the producer's total risk with the returns from the insurance policy, and on the administrative costs.

Thus the role to be played by insurance reduces to the empirical question of estimating these parameters. One would expect the conclusions to vary from industry to industry and from country to country. After an analysis of the findings from a case study of the Australian wheat industry it is concluded that insurance can make only a minor contribution to risk management in that industry. It also explains why successful unsubsidised private insurance schemes are not to be expected for the Australian wheat industry.

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