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A NOTE ON THE VIABILITY OF RAINFALL INSURANCE

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Although policy measures aimed at mitigating the uncertainty facing farmers have generally been focused on price uncertainty, the main problem for many industries, notably the wheat industry, is yield uncertainty (Piggott 1978). For this reason, several writers have discussed the possibility of insurance against unpredictable events such as drought as a means of reducing uncertainty (Industries Assistance Commission 1978; Quiggin and Anderson 1979; Freebairn 1982). Two main points have emerged from this discussion. First, because of the high correlation among risks, pooling of the sort which makes, say, motor vehicle insurance attractive, will not be very effective. This explains the failure of rainfall insurance schemes to emerge spontaneously as a result of mutual arrangements between farmers. Second, such schemes can be viable only if they are backed by a large pool of assets such as that held by governments or large (perhaps multinational) insurance organisations.

A recent paper by Bardsley, Abey and Davenport (1984) provides a formal model in which the economics of rainfall insurance can be analysed. Bardsley et al. first analyse the economics of a scheme based solely on pooling of risks among wheat growers. As would be expected from the discussion above, they find that such a scheme would not be viable even in the absence of administrative costs. The high correlation among risks forces the insurer to charge a substantial risk premium which in turn makes insurance purchases unattractive.

Bardsley et al. then go on to consider the prospects for a government-backed insurer whom they characterise as having 'lower aversion to risk and lower costs of liquidity' (p. 12). They claim 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' (p. 13). Thus, it is concluded that crop insurance is 'unattractive from an efficiency point of view' and 'can make only a minor contribution to risk management' (p. 13) in the Australian wheat industry.

In this note, it is argued that while the analytical framework developed by Bardsley et al. (1984) is very useful, their argument contains important errors. In particular, their conclusion as to the unattractiveness of rainfall insurance cannot be upheld on a correct analysis. Indeed, their analytical framework, modified to eliminate these errors, indicates that rainfall insurance could yield significant gains.

There are two main problems with the analysis offered by Bardsley et al. (1984). First, they do not take adequate account of the way in which possession of a pool of assets uncorrelated with wheat industry risks affects the position of an insurer (government-backed or private).

Second, their treatment of administrative costs is both misleading and incorrect. The combined impact of these errors is substantial, as will be shown below.

Risk Pooling

In their analysis of a government-backed scheme, Bardsley et al. (1984) assume that the insurer in this case would have lower risk aversion than the insured, but no analytical basis is given for this. As a result, it is impossible to say what form this lower risk aversion should take. The range of relative risk levels of 1 to 32 shown in Table 3 of Bardsley et al. (1984) are merely guesses. No argument is given to show that the appropriate relative risk levels might not be of the order of hundreds or thousands.

Fortunately, standard portfolio theory may be used to derive the correct basis for lower risk aversion of the insurer. The basis is the existence of a portfolio of risky assets uncorrelated with that under consideration. Such a portfolio may be possessed either by the government or by a large private insurance company. Hildreth (1974) analyses the risk effects of adding a new risky asset to such a portfolio. A particularly important result is that, if the new asset is uncorrelated with the existing portfolio, then for 'small' amounts of the new asset, the holder of the portfolio is effectively risk neutral. This is intuitively reasonable. A large insurance operation with assets of billions of dollars is not going to require a risk premium for a scheme with a maximum payout of, say, \$1m. The analysis offered by Bardsley et al. (1984), in which the possession of a pool of risky assets is modelled in terms of a fixed coefficient of relative risk aversion, does not capture this aspect of the problem. In particular, it leads to unduly negative conclusions about the prospects for 'small' schemes involving insurance of only part of the crop.

There is, however, no great difficulty in incorporating a pre-existing portfolio into the model directly. The notation of Bardsley et al. (1984) will be used with additions where necessary. Thus:

- δ is the correlation between producers' risk and the return from the insurance policy;
- τ is the correlation among risks for wheat growers;
- t is a residual risk parameter;
- θ is the proportion of risk insured;
- σ is the variance of the returns from wheat growing (and, by choice of units, from a unit of insurance);
- C_0 is the cost of self-insurance;
- p is the price of insurance, normalised by C_0;
- $\lambda = [(1-\delta^2)/(1-p^2)]$ is a Lagrange multiplier;
- β is the ratio between the variance of the pre-existing portfolio and the variance of the insurance pool (for $\theta = 1$)
- N is the number of shires; and
- n is the number of individuals.

The only one of these parameters not included in the Bardsley et al. analysis is β, the ratio between the variance of the pre-existing portfolio and that of the insurance pool. The larger is β, the less risk averse is the insurer with respect to the insurance option. This may be formalised by showing how β affects the variance (and the standard deviation) of the insurer's total portfolio. Assuming N is reasonably large, the total variance of the insurer's portfolio is given by the following modified form of Bardsley et al. equation (8):

$$(1) \quad V = n^2\tau\sigma^2\theta^2 + \beta\tau n^2\sigma^2$$

Before undertaking rainfall insurance, a pool of reserve assets of:

$$(2) \quad K_0 = tn\sigma(\beta\tau)^{0.5}$$

is required in order to achieve the residual risk of insolvency associated with the parameter t. (This is a modified form of Bardsley et al. equation 9.) When rainfall insurance is added, the required pool rises to:

$$(3) \quad K = tV^{0.5} = tn\sigma[\tau(\theta^2 + \beta)]^{0.5}$$

so that:

$$(4) \quad K - K_0 = tn\sigma\tau^{0.5}[(\theta^2 + \beta)^{0.5} - \beta^{0.5}]$$

Working through the remainder of the analysis as in Bardsley et al., and excluding administrative costs for the moment, yields:

$$(5) \quad p = \tau^{0.5}[(\theta^2 + \beta)^{0.5} - \beta^{0.5}]/\theta$$

as the price for actuarially fair insurance.

It may be noted that this is the same as Bardsley et al. equation (12) provided $\beta = 0$ and there are no administrative costs. Since the demand for insurance is not changed, it is once again possible to use Bardsley et al. equation (6) to determine the proportion θ of the crop which will be insured. That is,

$$(6) \quad \theta = \delta - p\lambda$$

Although, because p now depends on λ, this equation is not in closed form, it may be solved fairly easily using standard computational methods. The approach used was the 'brute force' method of searching all possible values of θ between 0 and 1 (with a grid interval of 0.01) to find the unique solution to equations (4) and (5). Table 1 shows solution values for a range of values of δ and β on the assumption that, as estimated by Bardsley et al., $\tau = 0.4$. Percentage efficiency gains, relative to the cost of self-insurance, are shown in parentheses.

Two main features of this table are noteworthy. First, the optimal level of insurance is always non-zero. This reflects the fact that, for sufficiently small values of θ, an insurer with a pre-existing pool of assets is effectively risk neutral. Second, even a fairly small value of β leads to significant gains relative to the case where $\beta = 0$. This latter point must be stated with caution, however. The Australian wheat industry is very large and its revenue is quite variable. Thus even the smallest values of β cited here correspond to quite large portfolios.

Administrative Costs

The second major problem with the analysis of Bardsley et al. (1984) relates to the treatment of administrative costs. It is common practice to

TABLE 1

Proportion of Risk Insured when Insurer Has Outside Pool of Assets[a]

Relative size of outside pool (β)	Correlation between payout and drought loss (δ)				
	0.2	0.4	0.6	0.7	0.9
0.05	0.09 (0.2)	0.19 (1.4)	0.25 (2.6)	0.42 (6.9)	0.68 (20.0)
0.1	0.11 (0.3)	0.22 (2.1)	0.37 (5.6)	0.46 (8.9)	0.71 (23.0)
0.2	0.12 (0.7)	0.25 (3.0)	0.41 (7.4)	0.50 (11.4)	0.74 (26.9)
0.5	0.14 (1.0)	0.29 (4.0)	0.46 (9.9)	0.55 (14.9)	0.78 (32.7)
1.0	0.16 (1.1)	0.32 (4.7)	0.49 (11.9)	0.58 (17.7)	0.81 (37.1)
2.0	0.17 (1.3)	0.34 (5.6)	0.52 (13.6)	0.61 (20.0)	0.83 (41.5)

[a] Figures in parentheses are the percentage cost reduction, relative to self-insurance.

report the administrative costs of an insurance scheme as a percentage of premium income or of payouts. For example, it was recently reported that the administrative costs for Medicare were of the order of 5 per cent of payouts (*The Age*, 22 January 1985). Bardsley et al. measure administrative costs as a percentage, but not of premiums or payouts. Rather the denominator is nC_0, the cost of risk management in the absence of insurance. As well as being misleading to the casual reader, this definition involves significant analytical difficulties. First, as in the case of the relative risk aversion ratios, there is no obvious basis for judging what levels of administrative costs are 'reasonable'. If costs were measured relative to premiums, the range used by Bardsley et al., from 2 per cent to 10 per cent, would be quite reasonable on the basis of the experience of other insurance schemes. But, as it is, no argument is given to justify the choice of parameters. Second, and more importantly, C_0, and thus the level of administrative costs, are independent of the amount of insurance actually taken out. Once again, this leads to a strong bias in the analysis against schemes involving partial insurance.

It may be argued that the costs of insuring a given individual are in fact largely independent of the amount of insurance taken out. However, if this is the case, then it would be highly irrational for the insurer to adopt the pricing policy assumed by Bardsley et al. (1984) in which all units of insurance are priced equally. Rather, the rational insurer would give substantial bulk discounts, or, more simply, set a minimum purchase requirement. The result would be that some farmers would not insure at all, while others (those with high levels of risk aversion, high costs of liquidity or high values of δ) would take out an amount greater than or equal to this minimum requirement. Provided the minimum was chosen appropriately, administrative costs would be roughly proportional to premiums (or, equivalently, to payouts).

TABLE 2

Proportion of Risk Insured with Administrative Costs Included[a]

Relative size of outside pool (β)	Administrative costs as percentage of premiums (γ)		
	2	5	10
0.05	0.35 (4.9)	0.32 (4.2)	0.28 (2.4)
0.1	0.39 (6.6)	0.36 (5.7)	0.32 (3.7)
0.2	0.43 (8.6)	0.40 (7.0)	0.36 (5.1)
0.5	0.48 (11.0)	0.45 (9.9)	0.41 (7.1)
1.0	0.52 (13.3)	0.49 (11.5)	0.44 (8.7)
2.0	0.54 (15.4)	0.51 (13.0)	0.46 (10.1)

[a] Figures in parentheses are the percentage cost reduction, relative to self-insurance.

In order to make the measure of administrative costs meaningful, it is necessary to estimate $nC_0 = rn\sigma t$. Suppose r, the cost of liquidity, is 10 per cent, and $n\sigma\tau^{0.5}$, the standard deviation of total wheat revenue, is \$800m. Then, using the Bardsley et al. (1984) estimates of $t = 2.33$ and $\tau = 0.4$, $nC_0 = \$291$m. Thus, the implied levels of administrative costs for figures of 2, 5 and 10 per cent are \$5.8m, \$14.5m and \$29.1m, respectively. It must be emphasised once again that these very large figures are independent of θ, the amount of insurance taken out.

By considering a specific form for the insurance policy, and fixing a value for θ, it is possible to express the Bardsley et al. (1984) administrative costs as a proportion of premiums. Suppose the policy is one which pays out in a 'ten-year' drought, and there are no insurer's profits. Then the standard deviation of the returns from the policy will be three times the premium. If $\theta = 0.25$, then σ will be twelve times the premium, and $C_0 = r\sigma t$ will be 2.75 times the premium. Thus, administrative costs of 10 per cent, on the Bardsley et al. definition, will correspond to 27.5 per cent of premiums. Obviously, this bias is larger for small values of θ, and *vice versa*. However, the effect is always to give higher costs as long as $\theta < 0.7$, a figure which is hardly ever exceeded in any of the tables.

Using the same example, it is possible to recalculate the estimates given above, including administrative costs expressed as a fixed proportion of premiums. The level of administrative costs is given by $\gamma/3rt$ where γ is the level of costs as a percentage of premiums. The results are given in Table 2, on the assumption that $\delta = 0.65$. Once again, the level of insurance and the net gains are significantly higher than those estimated by Bardsley et al. (1984).

Rainfall Insurance in Practice

The analysis above suggests that the pessimistic conclusions reached by Bardsley et al. (1984) are not justified. However, this immediately raises the Chicago-style question: if rainfall insurance is efficient, why does it not already exist? The analysis already undertaken provides a partial answer. Most insurance schemes have grown out of simple pooling of risks on a small scale. Clearly, rainfall insurance cannot arise in this way, but must be offered by an organisation with a large pre-existing pool of assets and experience in risk management. There are not many such organisations in Australia.

Second, it seems likely that existing drought relief policies act to reduce the viability of rainfall insurance. This reflects both their general tendency to discourage preventative measures and the fact that they compete for public resources which could be devoted to designing and setting up an insurance scheme.

Third, as the debate over the issue has shown, the difficulties involved in designing a scheme which will avoid problems of moral hazard and adverse selection while maintaining low administrative costs and good risk reduction are very complex. Given the public-good properties of information, it is unlikely that private firms will provide the necessary effort.

One crucial consideration in design is the need to maximise δ, the correlation between the payouts from the insurance policy and the actual requirements of policy holders. In this respect, the Australian wheat industry is relatively well placed because of the dominance of a single risk, namely drought. However, δ could be significantly increased if the policy was extended to cover price fluctuations so that revenue, rather than output, was the target variable. This would clearly be difficult, since the design would have to avoid problems of adverse selection. Moreover, the existence of publicly funded underwriting for wheat prices could create problems for private insurers. It would be desirable to integrate any publicly operated insurance scheme with existing price policies.

On a less ambitious scale, it is likely that risk reduction would be improved if payouts were not normally distributed (as Bardsley et al. (1984) implicitly assume) but were strongly skewed, as in the sample scheme described above. In addition, crop growth models could be used to select a better indicator of the favourability of climatic conditions than annual rainfall.

Finally, it may be noted that the difficulty of explaining the concepts and details of a rainfall insurance scheme to farmers may be considerable. However, there are advantages to a gradual adoption of insurance. In particular, the required pool of outside assets could be built up gradually through measures such as reinsurance, which could be difficult if the entire wheat crop were to be insured at a stroke. It should be noted that the gains from insuring even 10 per cent of the crop could be considerable in absolute terms, especially if this comprises farmers with the highest costs of self-insurance.

Concluding Comments

The analysis given in this note suggests that, contrary to the conclusions of Bardsley et al. (1984), rainfall insurance backed by a large pool of uncorrelated assets could yield significant gains by reducing the costs of risk management. However, this is likely to be effective only if government policies such as drought relief policies are designed to encourage, rather than discourage, precautionary measures such as insurance. There is also a need for more research into the most desirable design for an insurance scheme.

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