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AN APPROACH TO THE ECONOMETRIC ESTIMATION OF ATTITUDES TO RISK IN AGRICULTURE*

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A simple model is developed relating the debt and asset portfolio of the farm to the production decision, which leads to a small non-linear system of equations. The system is estimated with time-series cross-sectional data from Australian broadacre agriculture using non-linear three-stage least squares. This gives a new method of estimating risk aversion coefficients by using actual behaviour of farmers in a realistic economic environment, rather than games played in artificial situations. Australian farmers are found to be risk averse, and the partial coefficient of risk aversion decreases with wealth and increases with income. The results are consistent with the results of studies by Binswanger in India and elsewhere using a completely different method. This consistency suggests that the partial risk aversion coefficient is a relatively robust measure of attitudes to risk.

The behaviour of agricultural producers under risk has attracted a considerable degree of attention in the literature (see Newbery and Stiglitz 1981 for a comprehensive study). This is due to the uncertain nature of the enterprise, and the consequent focus of much of agricultural policy on risk reduction, including schemes for price stabilisation, insurance and underwriting. Developing appropriate methods for assessing attitudes to risk then becomes an important goal for research.

Several different methods have been used to derive estimates of risk attitudes. The oldest is the attitudinal method, in which individuals are asked how they would act in various hypothetical risky situations, usually games of chance. Recent examples of this method are Dillon and Scandizzo (1978), Bond and Wonder (1980), King and Robison (1981) and Wilson and Eidman (1983). Binswanger (1981) has taken this further in a series of experiments in India in which individuals were offered gambles involving realistically large sums of money. Binswanger's experiments have been replicated in a number of other countries (Binswanger and Sillers 1983). The major criticism of these methods is that they are artificial, even when real money is used, and that they may offer poor guidance as to likely behaviour in a normal economic environment.

* Peter Bardsley is now at the Department of Agricultural and Rural Affairs, East Melbourne. An earlier version of this paper was presented at the 30th Annual Conference of the Australian Agricultural Economics Society, Australian National University, Canberra, 3–5 February 1986. A reviewer has drawn to the authors' attention a paper by Antle (1987), which addresses a similar problem. Antle also estimates risk attitudes econometrically from actual farm data. The main differences in approach are that Antle looks at input decisions and derives information on the distribution of risk attitudes in the producer population, whereas the approach presented here concentrates on the whole farm portfolio, and we derive parametric estimates of the influence of wealth and income on attitudes to risk. The authors would like to thank reviewers for their helpful comments. Research on this project was supported by grants from the Wool Research Trust Fund and the Australian Meat and Live-stock Research and Development Corporation.

There have also been a number of econometric studies of portfolio behaviour and the demand for financial assets such as stocks and bonds (Lins, Gabriel and Sonka 1981; Brown and Gibbons 1985). These have the advantage of being more realistic, but they have failed to produce very detailed information. This paper contains a new approach which differs in providing explicit econometric estimates of risk aversion, and examines how risk attitudes are influenced by changes in wealth and income.

The structure of the paper is as follows. First, the concepts of risk and risk aversion are reviewed briefly and notation is defined for some standard measures of risk aversion. Then a model of production, consumption and financing in a risky environment is developed, allowing the measurement of risk attitudes to be based on the farmer's portfolio choice problem. This contrasts with the more limited input choice approach used by Antle (1987) and Just and Pope (1979). The optimising conditions of the model are then discussed. This model forms the basis for an econometric specification, taking the form of a non-linear system of equations, which is estimated using data from the Bureau of Agricultural Economics' Australian Agricultural and Grazing Industries Survey. The results are then discussed and related to earlier work.

Risk Aversion

In this paper, risk is identified with uncertainty about an event for which there is a subjective probability distribution. Income risk refers to unforeseen income fluctuations. It will be assumed that unforeseen changes are likely to dominate any foreseeable income variations in agriculture, so that, in practice, income risk will be identified with income variability.

Risk aversion is a general preference for a sure thing rather than a gamble with the same statistical expected value. Technically, risk aversion is related to the curvature of the utility of income function, with increased concavity of the utility function implying greater aversion to risk. It is widely believed (and available evidence provides support for the view, as in Binswanger 1981 and Antle 1987) that most individuals are averse to risk when they are faced with significant economic choices, although they may be risk preferring when it comes to recreational gambling. The results of the research reported here are consistent with this evidence, providing support for the hypothesis of widespread risk aversion.

It is important to recognise that risk behaviour depends not only on individual preferences but also on the economic environment in which the choice is made. If there is a complete set of risk markets available, even a strongly risk averse person may make choices which appear to be risk neutral. This is discussed, for example, by Binswanger and Sillers (1983). On the other hand, imperfect capital markets may lead to apparently risk averse behaviour by risk neutral individuals (Masson 1972). In practice, the economic environment will contain a range of imperfect risk and capital markets which will affect observed risk behaviour. Thus estimates of risk characteristics will be a function both of personal characteristics and of the environment. One of the weaknesses of attitudinal and experimental studies of risk behaviour is the ambiguity about the economic environment in which the choice is made. Econometric studies, such as the present one, measure apparent risk attitudes as they are expressed in the individual's normal environment. This is probably the most realistic approach and the one which is most relevant to policy.

The most widely used theory of choice in the face of risk is expected utility theory. According to this theory, individuals evaluate an uncertain wealth according to the rule:

$$(1) \qquad EU(W) = \int U(W)dF(W)$$

where U is the utility of wealth and $dF(W)$ is the probability distribution of W. Because this theory is cast in a timeless setting in which a single choice is made, rather than a sequence of choices, the distinction between wealth and income is blurred and the same equation is often used with income, x, in place of wealth. For a discussion of this issue, see Machina (1984).

In this framework, risk aversion is related to the curvature of the utility of wealth function, U (Pratt 1964; Arrow 1970). The most common measure is the absolute risk aversion coefficient:

$$(2) \qquad \alpha = -U''(W)/U'(W)$$

Because this measure varies with changes in the units of measurement, alternative scale-free measures have been developed. Two alternative measures are the partial risk aversion coefficient, which is defined in terms of income (that is, changes in wealth), x, about a given wealth level, W (see Menezes and Hanson 1970; Zeckhauser and Keeler 1970):

$$(3) \qquad \beta = -U''(W+x)x/U'(W)$$

and the relative risk aversion coefficient:

$$(4) \qquad r = -U''(W)W/U'(W)$$

These are all more or less equivalent formulations of the same concept, and it is easy to convert from one to the other. The absolute risk aversion coefficient is perhaps the more natural parameter for theoretical work, but Binswanger found that the partial risk aversion coefficient is the more stable parameter empirically. For this reason, the theory below is developed using absolute risk aversion, and is then reformulated in terms of partial risk aversion for estimation. The partial risk aversion coefficient measures the rate at which the utility of income decreases as income increases (conditional on a given level of wealth).

Since it is an elasticity, partial risk aversion, as measured by β, can readily be compared between different studies, and even between different cultures. Unfortunately, a number of earlier studies of risk attitudes used measures which are not so easily transferred or interpreted. The parameter β is an important one in predicting the response of agricultural producers to risk, and in evaluating price stabilisation schemes. Knowledge of β is the principal requirement for applying the methods developed by Newbery and Stiglitz (1981) to these problems. Newbery and Stiglitz suggested, as a rule of thumb, that β is constant and about equal to unity in magnitude.

It should be mentioned that expected utility theory is not the only available theory of behaviour under risk. Machina (1982) elegantly generalised expected utility theory to a much wider and arguably more plausible class of behaviour. In some ways, the theory described below fits more naturally into Machina's framework. However, for the sake of exposition, expected utility theory will be retained throughout this paper.

The Model

The model set out here is a unified model of the production, consumption and financing decisions made by farmers facing risk. The model is based on the conventional mean–variance approach, as discussed in Newbery and Stiglitz (1981, section 6.5). This approach is adopted here mainly for ease of exposition, although there is no reason why higher moments or other parameters of the distribution could not be used. It is in two parts, a production segment and a consumption segment, in which the farmer's preferences and technology are parameterised with a link through the financing decision. Farmers maximise expected utility, subject to a technical constraint on the profit–risk trade-off.

The production segment is a simplified representation of the production process. The inputs to the production process are capital, K, and other fixed factors, Z, which may include, for example, human capital. In the process of production, variable inputs such as labour may be purchased and used to produce physical output which can be sold. The final output of the production process is a stream of financial returns, which is expressed as a rate of return to capital, K. This output stream of profits is a random variable. It is assumed that this random variable is adequately described by its first two moments, π (the average profit rate), and v (the variance of the profit rate).

It is convenient to treat the production process as a 'black box' which takes K and Z as inputs and produces π (with variance v) as an output. For a given K and Z, a number of combinations of π and v may be possible according to the choice made by the operator. The set of all feasible output combinations defines a constraint set from which the operator must choose (see Figure 1). The boundary of the feasible set is called the risk efficiency frontier. If it is assumed that a higher profit is preferable to a lower one, other things being equal, then all individuals will choose to be on this frontier. The risk frontier defines the profit–risk trade-off available to the individual. The scale of production is determined by the choice of capital, K. Thus changes in K cause shifts in the risk efficiency frontier.

It is hypothesised that, as in Figure 1, the risk frontier will be upward sloping and convex. Higher profits may be earned by taking greater risks, but the returns to risk taking are diminishing.

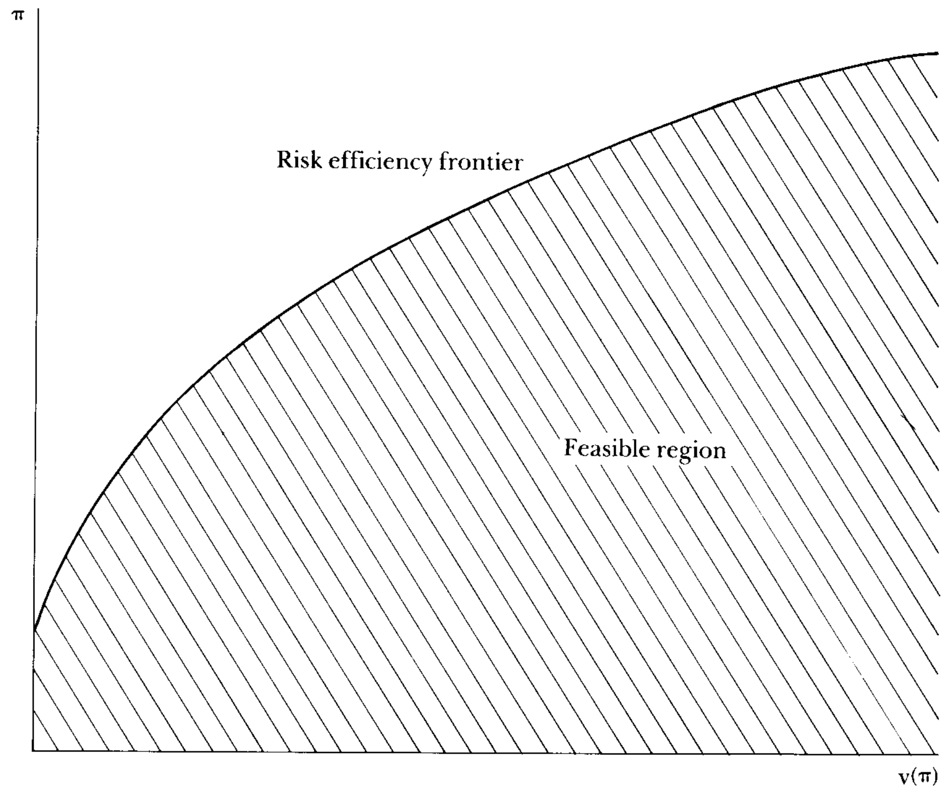

FIGURE 1—The Risk Efficiency Frontier.

The equation of the risk frontier will be written:

$$\pi = \pi(v, K, Z) \tag{5}$$

The hypotheses about π are that $\pi' > 0$, $\pi'' < 0$, where the prime denotes differentiation with respect to v.

The consumption segment is also highly simplified. The individual has wealth, W, and receives an income stream represented by x, which is a random variable with mean Y and variance V. Note that the upper case variables W, Y, and V are expressed as dollars, while π and v represent the characteristics of a rate of return (to capital). The owner's wealth is assumed to be invested entirely in the farm, so that wealth can be identified with the owner's equity. For convenience, the income stream is expressed as a rate of return on wealth. The mean rate of return on wealth is $\pi_0 = Y/W$, with variance $v_0 = V/W^2$. It is important to distinguish between π, the rate of return to the total capital in the business, and π_o which is the rate of return to the owner's equity, net of interest payments.

The choice among risky income streams is made according to the expected utility of income. From this the expected utility may be expressed in terms of the characteristics Y and V of the income stream:

$$\psi(Y, V) = \int U(x)dF(X) \tag{6}$$

In the usual way, it can be shown by a truncated Taylor expansion that, approximately,

$$\begin{aligned} \psi(Y, V) &= Y - \alpha/2V \\ &= W(\pi_0 - \alpha W v_0/2) \end{aligned} \tag{7}$$

where α is the coefficient of absolute risk aversion. This equation may easily be rewritten in terms of the partial risk aversion parameter, $\beta = Y\alpha$.

The preferences $\psi(Y, V)$ may be described by a set of indifference curves in (Y, V) space (see Figure 2). The slope of the indifference curves is simply $\alpha/2$. Note that α is not a constant, and may vary with income, so the indifference curves need not be straight lines. The hypotheses about preferences are that the indifference curves are upward sloping and convex, as shown in Figure 2. This implies that the individual is risk averse but that the value of successive amounts of risk reduction is diminishing. It is convenient to describe the sensitivity of β to variations in wealth and income in terms of elasticities. It can be shown that the last assumption can be written $\varepsilon_Y^\beta < 1$, where ε_Y^β is the elas-

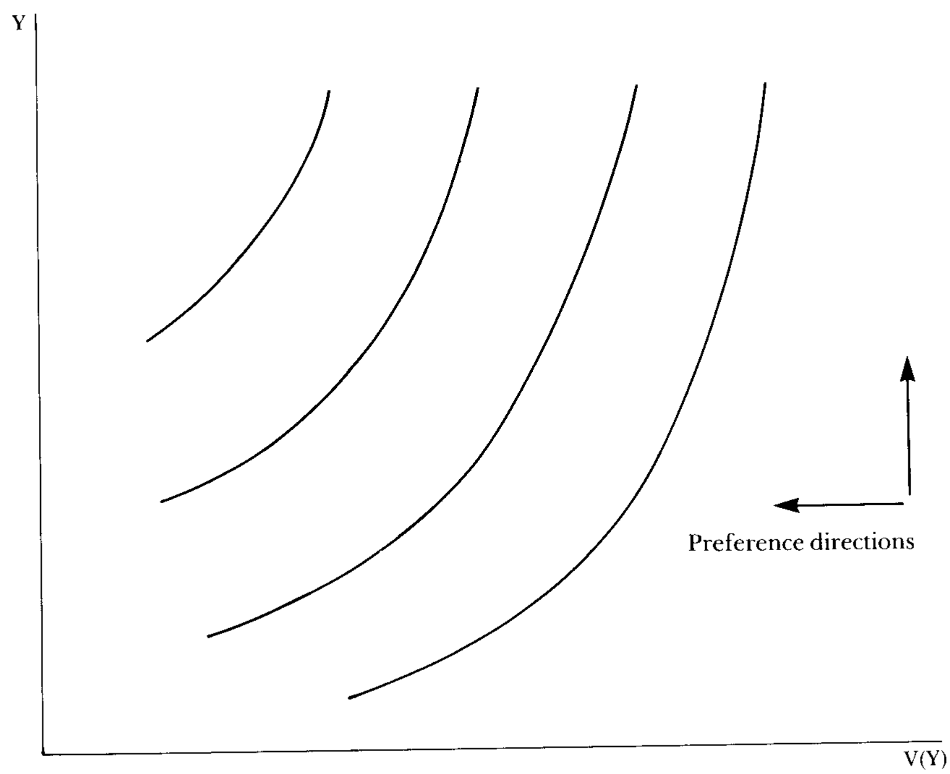

FIGURE 2—Indifference Curves of the Utility Function.

ticity of β with respect to Y. On the other hand, Binswanger (1981) found empirically that $\varepsilon_Y^\beta > 0$, so the full hypothesis is that $0 < \varepsilon_Y^\beta < 1$. In empirical work, Binswanger and others have found that the order of magnitude of β should be about unity (Newbery and Stiglitz 1981). The hypotheses about the model are summarised in Table 1.

Finally, the financing decision links the two segments of the model. The available capital, K, consists of the operator's wealth, W, plus debt, D, so that:

$$K = W + D = \lambda W \tag{8}$$

where λ is the leverage ratio, K/W. The link between the two halves of the model is given by:

$$\pi_0 = \lambda\pi + (1-\lambda)i \tag{9}$$

$$v_0 = \lambda^2 v \tag{10}$$

where i is the interest rate.

The Optimising Conditions

The model may be summarised as follows. The endogenous variables are π, v and λ. The exogenous variables are W and Z (which will be suppressed from the notation from now on). Since risk aversion may vary with wealth and income, α and β are functions of Y and W.

$$\text{Max } \psi(Y, V) = W\pi_0 - \alpha W^2 v_0/2 \tag{7a}$$

Subject to:

$$\pi = \pi(v, K) \tag{5a}$$

$$\pi_0 = \lambda\pi + (1-\lambda)i \tag{9}$$

$$v_0 = \lambda^2 v \tag{10}$$

It can be shown that the first-order conditions can be expressed as:

$$\pi = \pi(v, K) \tag{5a}$$

$$\pi' = (\alpha W\lambda)/(2 - W^2\lambda^2\alpha' v) \tag{11}$$

$$i = (1 + \varepsilon_K^\pi - 2\varepsilon_v^\pi) \tag{12}$$

where, as before, the prime denotes differentiation with respect to v, and ε_K^π and ε_v^π are elasticities of π with respect to K and v, respectively. Note that α' is the derivative of α with respect to Y.

Equation (5a) is simply the constraint. Equation (11) represents the optimal production decision. Equation (12) represents the optimal financial decision.

TABLE 1

Prior Hypotheses about Parameters

Parameter	Definition	Sign	Comment
P_1	Shift parameter	>0	Median real rate of return is positive
ε_v^{π}	Elasticity of π with respect to v	>0	The risk-return frontier slopes upward
γ	Elasticity of ε_v^{π} with respect to v	<0	The risk-return frontier is convex
CAP	Elasticity of π with respect to K	>0	Positive returns to size
CAP2	$\dfrac{d\,\mathrm{CAP}}{dK}$	<0	Diminishing returns to size
ρ	Box–Cox parameter	?	No prior hypothesis
β_0	Coefficient of partial risk aversion at (Y_m, W_m)	>0 (≈ 1)	Farmers expected to be risk averse, order of magnitude expected to be 1
ε_Y^{β}	Elasticity of β with respect to Y at (Y_m, W_m)	$0<\varepsilon_Y^{\beta}<1$	Indifference curves convex in (Y, V) space
ε_w^{β}	Elasticity of β with respect to W at (Y_m, W_m)	<0	Risk aversion diminishes with wealth

There is considerable evidence that credit may be subject to non-price rationing at the micro level. For a survey of the issue see Baltensperger (1978). For the purpose of this study, it was decided to avoid the complexities of a disequilibrium analysis by treating λ as exogenous and dropping equation (12) from the system because, over the period studied, interest rates were regulated and there is evidence that this led to credit rationing (Ockwell and Batterham 1980). In a credit rationing regime, λ will be supply determined and hence exogenous from the point of view of the farmer. Although a potential simultaneity problem arises if credit is not rationed, bias is likely to be minimal in the absence of a strong link between the financing and production decisions. Avenues for further research would be to investigate the relationship between these decisions and to provide a more detailed analysis of the impact of rationing on farmers.

Data

The data used in this analysis came from the Bureau of Agricultural Economics' annual Australian Agricultural Grazing Industries Survey. These data cover the five-year period 1977–78 to 1981–82, and the analysis was performed by zone (high rainfall, wheat-sheep and pastoral). The sample was restricted to those farms that had been observed at least four times, except for the high rainfall zone, in which, because of smaller population size, farms were included which had been observed three or more times.

The data consist of panel data, with a short time series of observations from each farm. From these an estimate of the mean profit rate and the variance of the profit rate can be produced for each farm. The data are then analysed using purely cross-sectional methods (see Meppem and Bardsley 1985). The profit measure used is the rate of return to capital and management, including imputed capital appreciation (Tucker 1981).

Functional Form

For the technical constraint, equation (5a), a flexible Box–Cox form was chosen which allows arbitrary slope and curvature at the median of the data without the global implausibilities of polynomial forms. This form was modified to allow for increasing returns to size as found by Quiggin and Vlastuin (1983), yielding the following form:

$$\pi/\pi_m = a_1 + a_2(K/K_m) + a_3(K/K_m)^2 + a_4(v/v_m) + a_5[(v/v_m)^\rho - 1]/\rho \tag{13}$$

where the subscript, m, denotes the median value of the variable. This form allows for variable returns to size and quite a flexible relationship between π and v, including for example a logarithmic form via the Box–Cox transformation if $\rho = 0$.

For ease of interpretation, the parameters a_1 to a_5 (which are simply coefficients without any sensible economic meaning) are rewritten as functions of the following parameters which are more easily interpreted:

- P_1 = the value of π/π_m at $v = v_m$, $K = K_m$; this is a shift parameter which moves the risk efficiency frontier in Figure 1 up or down;
- ε_v^π = the elasticity of π with respect to v at (π_m, v_m), thus measuring the slope of the risk efficiency frontier;
- γ = the curvature of the frontier (that is, the elasticity of ε_v^π with respect to v) at (π_m, v_m);
- CAP = the elasticity of π with respect to K at (π_m, v_m), thus measuring by how much the frontier shifts as K varies;
- CAP2 = a quadratic curvature term, which gives the effect on CAP as K changes; and
- ρ = the Box–Cox parameter which determines the flexible functional form of the frontier.

The details of the transformations relating these parameters to a_i are set out in the Appendix.

The equation representing the production decision, equation (11), is assumed to be of the following form:

$$v = (2 - \alpha\lambda W/\pi')/(w^2\lambda^2\alpha') \tag{14}$$

where π' is given by differentiating equation (13) and α is parameterised as follows:

$$\alpha = \beta/Y \tag{15}$$

$$Y = w\pi_0 = w[\lambda\pi + (1-\lambda)i] \tag{16}$$

$$\beta = \beta_0[1 + \varepsilon_Y^\beta(Y/Y_m - 1) + \varepsilon_w^\beta(W/W_m - 1)] \tag{17}$$

There are three parameters in equation (17):

β_0 = the coefficient of partial risk aversion at (Y_m, W_m);
ε_Y^β = the elasticity of β with respect to Y at (Y_m, W_m); and
ε_w^β = the elasticity of β with respect to W at (Y_m, W_m).

The parameters in the model, together with the maintained hypotheses on their signs, are summarised in Table 1.

The Error Specification

There are two sources of error which must be considered when attempting to estimate the system (13) and (14). The first is error in optimisation by the farmer, the second is measurement error. Since the available data consist of panel data with a short time period, the sampling error in the measurement of π and v for each farm is likely to be substantial. For the purpose of this preliminary study, it is assumed that this measurement error is dominant and any optimisation error is ignored or assumed to be negligible.

Measurement error is handled by scaling variables as follows. Consider an individual farm, and let π_t be the rate of profit in year t. Assume that π_t is independently normally distributed in each year, with mean π^* and variance v^*, and assume that there are T observations for this farm (T may vary from farm to farm). Let π, v be the usual unbiased estimates of π^* and v^*. Then π and v are independently distributed with variances v/T and $2v^2/(T-1)$, respectively (see Judge, Hill, Griffiths, Lutkepohl and Lee 1982).

This suggests that the transformations:

$$\sigma=\left(\frac{T-1}{2}\right)^{0\cdot 5}\log v \tag{18}$$

and

$$\tau=\pi\left(\frac{T}{v}\right)^{0\cdot 5} \tag{19}$$

might be useful to stabilise the variances. A normal probability plot confirmed the usefulness of these transformations, so the system was rewritten in these variables for the purpose of estimation. Details are given in the Appendix. Thus, according to the error specification for the system, the transformed variables, σ and τ, are independently normally distributed.

The Estimation Method

The estimator chosen was the non-linear three-stage least squares estimator (Amemiya 1977; Gallant 1977), as implemented in SAS ETS version 4, with the Gauss–Newton algorithm and the default convergence criterion. Regional dummies, exogenous variables and squares of exogenous variables were used as instruments, as recommended by Gallant (1977). The three-stage estimator was chosen because it is consistent and asymptotically efficient, and it is more robust to departures from normality than full information methods (Gallant 1977). It was found that the estimates were not sensitive to starting values.

Results

Results for the three zones are given in Tables 2 to 7. For comparison, both non-linear least squares (NOLS), and the preferred three-stage estimates (N3SLS) are presented. Asymptotic t-statistics are also presented for both sets of estimates, as are the median values around which they are performed.

The asymptotic t-statistics indicate that the parameters are estimated with a high degree of accuracy, and all of the prior hypotheses on the production technology and on risk preferences, as listed in Table 1, are supported.

The partial risk aversion coefficient, β, is positive in all zones although not significantly so in the pastoral zone. This may be because of the small sample size. The estimates of β indicate that producers are risk averse, rather than risk neutral or risk preferring. The estimates of risk aversion appear to be significantly higher in the wheat–sheep zone than elsewhere. This may be due to zonal differences in wealth and income, or locational self-selection by farm operators into diversified regions. Alternatively, it may simply be due to better sample coverage in the wheat–sheep zone.

The value of β is somewhat lower than was found by Binswanger (1981), and is less than the rule of thumb value of unity used by Newbery and Stiglitz (1981). Apart from the completely different methodology used, there are major differences in wealth between the two populations and the range of markets available for risk spreading is quite different.

Risk aversion is found to increase with income ($\varepsilon_Y^\beta > 0$) and to decrease with wealth ($\varepsilon_w^\beta < 0$). This is consistent with Binswanger's results, and with the hypotheses outlined above concerning Figure 2, implying that indifference curves are convex upward in mean–variance space.

The risk frontier slopes upward ($\varepsilon_v^\pi > 0$) and is convex ($\gamma < 0$). There is evidence of positive but decreasing returns to size (CAP>0, CAP2<0), as found elsewhere by Quiggin and Vlastuin (1983).

Conclusion

In this paper, a new method has been presented for estimating risk aversion parameters and attitudes to risk. It is based on comparing the farmer's financing decision with the production decision in a simple portfolio framework. It is based on observations of farmers' actual behaviour in a realistic economic environment, rather than on games played in artificial situations. It gives information not only on the degree of risk aversion and on how risk aversion varies with income and wealth, but also on the shape of the constraint which governs the trade-off between profit and risk.

This approach leads to a small non-linear system of equations which was estimated using non-linear three-stage least squares. All the parameters were estimated with high t-statistics, and the signs and magnitudes of the parameters were in accordance with prior hypotheses. It was found that, in the production system studied, it was possible to trade off profit and risk but that the opportunities to raise profit in this way were diminishing (the risk constraint is convex). It was

TABLE 2

Median Values: Pastoral Zone

Variable	πm	νm	λm	Ym	Km	Wm
Value	0·0369	0·0293	1·080	34563·6	839862	702129

TABLE 3

Estimates of Variables: Pastoral Zone[a]

Variable	NOLS	Asymptotic t-statistic	N3SLS	Asymptotic t-statistic
β_0	0·048	2·51	0·072	0·77
ε_w^β	−0·542	−24·00	−0·471	−6·01
ε_Y^β	0·125	3·39	0·194	1·20
ε_ν^π	0·254	4·81	0·44	1·40
γ	−0·308	−4·37	−0·038	−0·22
P_1	0·208	4·85	0·374	1·31
CAP	0·453	5·83	0·538	1·46
CAP2	−0·241	−5·52	−0·211	−1·09
ρ	0·291	1·05	2·58	0·83

[a] Elasticities are calculated at the median point described in Table 2. Three or more observations per farm (total observations = 53).

TABLE 4

Median Values: Wheat–Sheep Zone

Variable	πm	νm	λm	Ym	Km	Wm
Value	0·056	0·008	1·064	33084·8	582348	520420

found that the partial coefficient of risk aversion decreased with wealth and increased with income.

These conclusions are consistent with results obtained by Binswanger (1981) using an entirely different methodology. The coefficient of partial risk aversion estimated for Australian farmers was somewhat lower than the estimates reported by Binswanger for India, but this is not surprising given the differences in wealth, culture, and capital market access, and the completely different methods used. In fact, it is surprising that the estimates are of the same order of magnitude for such different groups.

The consistency of the results from this study with those of Binswanger suggests that the partial risk aversion coefficient is a robust

TABLE 5

Estimates of Variables: Wheat–Sheep Zone[a]

Variable	NOLS	Asymptotic t-statistic	N3SLS	Asymptotic t-statistic
β_0	1·937	4·97	0·696	3·63
ε_w^β	−0·512	−45·60	−0·642	−23·71
ε_Y^β	0·114	9·46	0·182	5·75
ε_v^π	0·811	9·72	0·507	5·97
γ	−0·300	−18·32	−0·498	−9·83
P_1	0·868	9·23	0·940	5·48
CAP	0·778	9·16	0·100	0·77
CAP2	−0·165	−5·30	−0·069	−2·59
ρ	0·763	13·45	0·485	5·34

[a] Elasticities are calculated at the median point described in Table 4. Four or more observations per farm (total observations = 156).

TABLE 6

Median Values: High Rainfall Zone

Variable	π_m	v_m	λ_m	Y_m	K_m	W_m
Value	0·0301	0·011	1·053	15930·5	496589	456310

TABLE 7

Estimates of Variables: High Rainfall Zone[a]

Variable	NOLS	Asymptotic t-statistic	N3SLS	Asymptotic t-statistic
β_0	0·191	4·77	0·099	4·00
ε_w^β	−0·434	−34·60	−0·312	−11·22
ε_Y^β	0·163	8·16	0·129	5·09
ε_v^π	0·522	9·41	0·349	6·30
γ	−0·072	−3·90	−0·187	−7·39
P_1	0·634	9·09	0·692	6·30
CAP	0·912	8·73	0·480	5·40
CAP2	−0·119	−7·32	−0·043	−3·02
ρ	1·851	7·02	0·337	5·77

[a] Elasticities are calculated at the median point described in Table 6. Four or more observations per farm (total observations = 204).

measure of attitudes to risk. This lends confidence to the use of this measure in the development of agricultural policy, such as the work of Newbery and Stiglitz (1981) on price stabilisation.

There are several areas where further research would be of value. The current study uses only variance as a risk indicator. It would be straightforward, and very informative, to include the effect of skewness and higher moments of the profit distribution. Another useful development would be to look in more detail at the borrowing constraint, which has here been treated as exogenous (at the cost of some potential simultaneous equation bias). Finally, it would be interesting to see the study replicated using data from another country.

APPENDIX

Transformation of the Estimated Equations

Equations (13) and (14) are transformed as follows for the purpose of estimation, using the normalising transformations (18) and (19) and the definitions (15) and (16). All symbols are as defined in the main text.

$$\sigma = \left(\frac{T-1}{2}\right)^{0\cdot 5} \log v$$

$$\tau = \pi(T/v)^{0\cdot 5}$$

$$\begin{aligned}\pi/\pi_m = {} & P_1 + \mathrm{CAP}[(K/K_m) - 1] + \mathrm{CAP2}[(K/K_m)^2 - 2(K/K_m)] \\ & + [\gamma\varepsilon/(\rho-1)][(v/v_m)\rho - 1]/\rho + [1 - \gamma/(\rho-1)]\,\varepsilon_v^\pi[(v/v_m) - 1]\end{aligned}$$

where:

$$\pi' = (\pi_m/v_m)\,\varepsilon_v^\pi\{1 + \gamma[(v/v_m)^{\rho-1} - 1]/(\rho-1)\}$$

$$Y = \pi\lambda W + (1-\lambda)iW$$

$$\beta = \beta_0 \varepsilon_Y^\beta Y_m$$

$$\alpha = \beta/Y$$

$$\alpha' = \beta'/Y - \beta/Y^2$$

$$v = (2 - \alpha W\lambda/\pi')/(W^2\lambda^2\alpha')$$

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