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Non-parametric estimation of decision makers' risk aversion

Gudbrand Lien*

Norwegian Agricultural Economics Research Institute, P.O. Box 8024 Dep., N-0030 Oslo, Norway

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Abstract

A new non-parametric method to estimate a decision maker's coefficient of absolute risk aversion from observed economic behaviour is explained. The method uses the expected value–variance (*E–V*) framework and quadratic programming. An empirical illustration is given using Norwegian farm-level data.

JEL classification: Q12; D81

Keywords: Risk analysis; Risk aversion; Quadratic programming; Norwegian agriculture

1. Introduction

In much risk-related work, it is necessary to have some measure of the decision maker's attitude to risk. Risk attitude may be measured by either the coefficient of absolute or the coefficient of relative risk aversion. This paper describes a non-parametric method to estimate the coefficient of absolute risk aversion from observed economic behaviour.

A survey of different approaches to specifying decision maker's risk attitudes is given in Robison et al. (1984). The following approaches have been utilised to assess risk attitudes: (1) direct elicitation of utility functions (see Anderson et al., 1977; Hardaker et al., 1997 for details; an example on a new empirical study within this approach is presented by Abadi Ghadim and Pannell, 2000); (2) experimental procedures in which individuals are presented with hypothetical questionnaires regarding risky alternatives with or without real payments (e.g. Dillon and Scandizzo, 1978; Binswanger, 1980); and (3) inference from observation of economic behaviour. In this paper, I focus on approach (3): inference from observation of economic behaviour, based on an assumed relationship between the actual behaviour of a decision maker and the behaviour predicted from empirically specified models. Empirical inference of risk attitudes from observed economic behaviour can be divided into non-parametric (mathematical programming) and parametric (econometric) approaches. The pioneering work with econometric applications was that of Moscardi and de Janvry (1977). Antle (1987) estimated producer risk attitudes by applying econometric techniques to cross-sectional data from individual farms. Bar-Shira et al. (1997) used an econometric approach to examine the effect of wealth changes on the measure of absolute, relative, and partial risk aversion.[1] Compared with the programming approach, the econometric approach has the

* Tel.: +47-2236-7250; fax: +47-2236-7299.
E-mail address: gudbrand.lien@nilf.no (G. Lien).

[1] The econometric approach to inference of risk attitudes is related to stochastic specification and estimation of the production function. Asche and Tveterås (1999) model the production risk with a two-step procedure, where they estimate the mean and risk function separately.

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advantage of straightforward hypotheses testing. On the other hand, non-parametric methods offer greater flexibility in modelling the farm situation.

Applications with mathematical programming have usually been used in an expected value–variance (E–V) framework.[2] Simmons and Pomareda (1975) used linear programming in an E–V framework to compute optimal input choices at different levels of risk aversion. Each solution (in hectare (ha)) was compared with actual choices to determine the level of risk aversion that gave the solution most closely corresponding to actual choice. Brink and McCarl (1978) and Hazell et al. (1983) derived farmers' coefficient of risk aversion as that value of estimated coefficient which minimised the difference between the farmer's actual behaviour and the results of a linear programming model. The difference was measured in terms of summed total absolute deviation of areas for all crops. The approach of Wiens (1976) was to match the primal quadratic risk programming (QRP) solution with the actual land patterns and the dual solution (shadow prices) with the market prices of the farm resources, and from these results derive the decision maker's coefficient of risk aversion.

The E–V framework and QRP are also used in this paper but in a different way. The approach is as follows. First, formulate the QRP model to represent the farm's resource base, activities, expected activity net revenues per unit level, fixed costs, variance and covariance of expected net revenues to reflect the decision maker's beliefs and circumstances as closely as possible. Second, for an observed farm plan presumed to reflect a farmer's risk-averse behaviour, calculate expected net farm income and variance. Third, solve the QRP problem setting expected net farm income equal to the farm's observed net farm income and minimise variance. Forth, solve the QRP problem again with variance set equal to the farm's actual variance and find maximal expected net farm income. Fifth, having ascertained two points on the efficient frontier, the gradient of the line in E–V space between these two solutions is used to approximate the coefficient of absolute risk aversion. To my knowledge, no one has used this approach before.

This paper is structured as follows: Section 2 describes the model; an application of the model is presented in Section 3; Section 4 contains some concluding comments.

2. The model

Given (approximately) normally distributed total net revenue[3] and assuming that the decision maker's utility function is represented by a negative exponential utility function, we maximise the decision maker's expected utility with the following E–V formulation (Freund, 1956):

$$\max U = E - \tfrac{1}{2}r_{\mathrm{a}}V = cx - f - \tfrac{1}{2}r_{\mathrm{a}}x'Qx \tag{1}$$

subject to

$$Ax \leq b, \quad x \geq 0$$

where U is expected utility, $E = cx - f$ is expected net farm income, 'c' a $1 \times n$ vector of expected activity net revenues per unit level, r_{a} the absolute risk aversion coefficient, 'x' an $n \times 1$ vector of activity levels, 'Q' a $n \times n$ variance–covariance matrix. So, $V = x'Qx$ is the variance of expected net farm income, f the fixed costs, 'A' an $m \times n$ matrix of technical coefficients, and 'b' an $m \times 1$ vector of resource stocks.

Solving this problem for various values of r_{a} gives points exhibiting minimum variance for a given expected net farm income, and/or maximum expected net farm income for a given variance of income. The frontier ACB in Fig. 1 is the E–V efficient set.

Consider a decision maker with indifference curve U, which is linear in the E–V space given normally distributed total net revenue (Freund, 1956). Assuming the decision maker's absolute risk aversion coefficient is r_{a}, his or her indifference lines are given by Eq. (1) for various values of U. As illustrated in Fig. 1, the tangent between the decision maker's indifference line, U_2, and the efficient frontier is at point C which

[2] The study of Amador et al. (1998) is somewhat related to the mathematical programming approach used to estimate decision maker's risk attitudes. Amador et al. (1998) use goal programming to elicit farmers' multi-criteria utility function.

[3] Since total net revenue is the sum of several random variables, appeal to the Central Limit Theorem suggest approximate normality (Anderson et al., 1977, 193 pp.; Hardaker et al., 1997, 187 pp.).

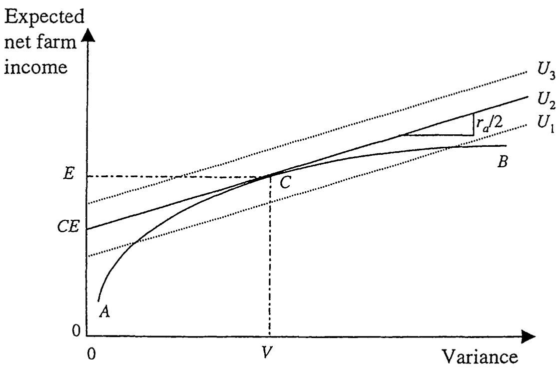

Fig. 1. Optimal portfolio choice illustrated in E–V space.

corresponds to the optimal production mix with expected net farm income E and variance of expected net farm income V. Since point CE has zero variance, it is called the certainty equivalent (CE) to the risky expected net farm income E. The indifference line's slope coefficient is $r_a/2$ and the decision maker's coefficient of absolute risk aversion to this constructed problem is r_a.

Freund's E–V formulation may also be formulated as (Hardaker et al., 1997)

$$\max E = cx - f \tag{2}$$

subject to

$$x'Qx = V, \quad V \text{ varied}$$

$$Ax \leq b, \quad x \geq 0$$

Likewise, Markowitz (1952) original formulation of the E–V problem set up to minimise variance subject to a given level of expected net income is formulated as

$$\min V = x'Qx \tag{3}$$

subject to

$$cx - f = E, \quad E \text{ varied}$$

$$Ax \leq b, \quad x \geq 0$$

with the same notation as in Eq. (1). Freund and Markowitz's formulations yield identical efficient frontiers. The differences between the formulations are the way the frontier is derived. In Eq. (1), r_a is parameterised, in Eq. (2), V is parameterised and in Eq. (3), E is parameterised.

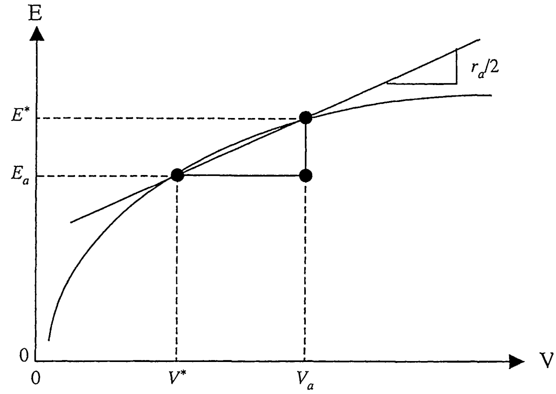

Fig. 2. Approximation of a decision maker's coefficient of absolute risk aversion.

The framework described above is used to estimate a decision maker's coefficient of absolute risk aversion, as illustrated in Fig. 2. Formulate the QRP model to represent the farm's resource base, activities, expected activity net revenue per unit level (in this paper, expected gross margin (GM) per unit level is used), fixed costs, variance and covariance of expected GMs which are assumed to reflect the farmer's beliefs and circumstances. Further, for a current farm situation (the farm we want to analyse) calculate from observed economic behaviour net farm income E_a (a for actual) and variance V_a. Then, using Markowitz's formulation, solve the QRP problem setting expected net farm income E to E_a and minimise variance V at $V_{\min} = V^*$. Next, using Freund's formulation (Eq. (2)) solve again with V set to V_a to find $E_{\max} = E^*$. We have then two points on the efficient frontier, (E_a, V^*) and (E^*, V_a). The gradient of the line in E–V space between these two solutions is used to approximate the coefficient of absolute risk aversion

$$r_a = \frac{2(E^* - E_a)}{V_a - V^*} \tag{4}$$

The point (E_a, V_a) is inefficient, since the farmer can increase the expected net farm income to E^* and still have the same variance V_a, or the farmer can have the same expected net farm income E_a with lower variance V^*. The farmer can get these efficient portfolios if she or he choose the optimal combination of activities.[4]

In the model, it is also possible to get a solution where the actual farm plan (E_a, V_a) is north-west of the frontier. One reason for this is a mis-specified variance–covariance matrix, Q, for the analysed farm, e.g. that the analysed farm has a smaller variances for some activities and/or different covariances between activities than assumed in the QRP model. Alternatively, the vector of net revenue per unit level, c, may be mis-specified. A third possible reason is that the constraints, A, are less restrictive than assumed in the specified QRP model. For all these cases, Eq. (4) is assumed still to be valid to approximate the coefficient of absolute risk aversion.

One thing, which is important to consider, is which r_a we are estimating. In the model outlined in this section, the payoffs are expressed in terms of annual income. Following Hardaker (2000), we have to distinguish whether transitory income or permanent income is the argument of the utility function. Permanent income is where the uncertainty is about the long-run level of income. Transitory income is where the income in some future year, say next year, is uncertain. The approximate relationship between coefficient of absolute and relative risk aversion with respect to both permanent and transitory income is given by Hardaker (2000).

3. Application

In this section, as an example of its application, the approach outlined above is used to estimate the coefficient of absolute risk aversion for some case-study farmers in Norway. Two methods to compare the estimated coefficient of absolute risk aversion between farms are also illustrated.

[4] The efficient and inefficient portfolios are somewhat related to technical efficiency in the efficiency and productivity literature. Technical efficiency reflects the ability of a firm to obtain maximum output from a given set of inputs (Coelli et al., 1998). The vertical difference between E^* and E_a in Fig. 2 can be interpreted as an output-oriented measure of 'technical efficiency', and reflects the farm's ability to select proportions of activities which give maximal expected net farm income for given variance.

3.1. The farm system and data

Ideally, in constructing a QRP model, the variance–covariance matrix should be formed for each individual farmer. In practise, the required historical data may not be available from the analysed farm. In particular, of course, there will be no data for activities not previously included on that farm that are nevertheless of interest for the programming analysis. Therefore, calculation of a variance–covariance matrix that reflects GM interaction between activities for a particular farm normally requires data for combinations of activities from many similar farms over several years.

In this analysis, the data used came from the Farm Business Survey (driftsgranskingsdata), collected by the Norwegian Agricultural Economics Research Institute. Information used relates to unbalanced panel data consisting of a total of 2136 observations from the Norwegian lowlands [5] over the 6-year period (1993–1998) (NILF, 1994–1999a). The number of observations on each activity varied from 1472 for barley to 70 for vegetables. The lowlands of Norway were used since within this area, production possibilities are rather homogeneous. The growth season is about 180 days from April/May to September/October. Subsidies and production regulation are important factors influencing farmers' choice of mix of farm activities. Apart from production regulations, farmers in the Norwegian lowlands region can choose between many activities: cereals, potatoes, oilseed, grass-seed, vegetables, and pig, dairy, beef and sheep farming chiefly.

The model used in this analysis finds the optimal farm plan given a planning horizon of 1 year. At the beginning of the season, the farmer chooses a cropping and stocking pattern conditional on his or her expectation of output at the end of the season. In principle, the expected GM vector and variance–covariance matrix should be represented by the farmer's subjective beliefs about returns from the production. Obtaining such data is generally very demanding and difficult if not infeasible. Thus, the historical mean GM vector and variance–covariance matrix were assumed to represent farmers' beliefs.

[5] The Norwegian Farm Business Survey (NILF, 1994–1999a) sample is subdivided into lowlands and other parts. Parts of Eastern Norway, parts of Trøndelag and Jæren are categorised as lowlands. The production basis is substantially better in lowland regions than elsewhere.

Expected net farm income, E, on a specific farm in a specific year is given by

$$E = \sum_q \left(c_q x_q + \sum_p \mathrm{sub}_{qp} x_{qp} \right) - f \qquad (5)$$

where E is expected net farm income including subsidies, c_q the expected GM for enterprise q (without subsidies), sub_{qp} the subsidy for enterprise q at activity level p, and f the fixed costs. The subsidies are not proportional to production area/herd size but are partially differentiated according to headage and area-size. The variance including subsidies is calculated in the model depending on activity levels, rather than a simple historical trace of subsidy payments. The average subsidy level for the periods 1993–1998 is used and assumed to reflect as closely as possible farmers' expectation for the range of years for which the actual farm plan is applied. One part of the subsidy scheme in dairy production (driftstilskudd i melkeproduksjonen) is product-specific. This product-specific support is included in the historical GM for dairy cows and then incorporated into the variance–covariance matrix.

Annual per ha GMs are developed for activities over a 6-year period (1993–1998) in the following manner. First, nominal gross returns are developed from the Farm Business Survey (NILF, 1994–1999a). Second, the individual activity nominal gross returns are converted to a real 1998 Norwegian kroner (NOK) basis using the consumer price index (CPI). Third, the individual activity GMs are developed by subtracting 1998 budgeted variable cost (NILF, 1994–1999b) from real 1998 NOK gross returns. Budgeted variable costs are used, since the survey only has aggregated variable costs, not specific costs for each activity. These measures from the unbalanced panel data are used to calculate the variance–covariance matrix for GM used in the QRP model. Budgeted variable costs can remove some of the real variation in GM per unit. It is therefore important to realise that this approach can underestimate the variation in activity GMs.

Although almost all activities in the analysis have administered prices, the GM per unit for each activity within a farm may vary greatly from year to year. This variability is caused by factors such as weather, plant and animal diseases, which induce yield and product quality variation. In other words, activity expected GMs are uncertain, and this is accounted for in the variance–covariance matrix. The following model was used to measure variation within farms between years and calculate the GM variance–covariance and correlation matrix within farms

$$c_{qit} = \alpha_{qi} + \beta T + w, \qquad w \approx N(0, \sigma^2) \qquad (6)$$

$$s_q^2 = \frac{\sum_{i=1}^{n} \sum_{t=c_i}^{d_i} (c_{qit} - \hat{c}_{qit})^2}{N - n - 1} \qquad (7)$$

$$Q(q, p) = \frac{\sum_{i=1}^{n} \sum_{t=c_i}^{d_i} (c_{qit} - \hat{c}_{qit})(c_{pit} - \hat{c}_{pit})}{N - n - 1} \qquad (8)$$

$$\rho_{qp} = \frac{Q(q, p)}{s_q s_p} \qquad (9)$$

where c_{qit} is activity q's GM per unit on farm i in year t, α_{qi} the regression constant for activity q on farm i, T the time ($T = 1, \ldots, 6$), β the systematic change in income over the period (this component adjusts for an equal trend on all farms, caused by technological change among other things), w a random error, $\hat{c}_{qit}$ the activity q's predicted regression value for mean GM per unit on farm i in year t, N the total number of observations on all farms in the sample, n the number of farms in the sample, c_i the first year with observation on farm i, d_i the last year with observation on farm i, s_q^2 the activity q's variance of GM per unit, $Q(q,p)$ and ρ_{qp} are covariance and correlation between activity q and p, respectively. Degrees of freedom are $(N-n-1)$ in Eqs. (7) and (8), where n is lost degrees of freedom caused by calculation of average for each farm and 1 is lost degrees of freedom caused of the estimation of the time trend.

The data in the Farm Business Survey of Norway lowlands for the period 1993–1998 restrict the analysis to include only the following activities in calculation of the variance–covariance matrix in the model: barley, oats, wheat, potatoes, oilseed, carrots, grass-seed and dairy cows. Activity average GMs, standard deviations (S.D.s) and coefficients of variations (CVs) are given in Table 1. The correlation matrix of activity GMs is shown in Table 2. Note the low correlation between some of the activities, which implies opportunities for income stabilisation through diversification.

3.2. Results

Historical average net farm income in NOK, E_a, and variance, V_a, was calculated for nine farms from the

Table 1
Activity mean gross margins (GMs) per unit exclusive of subsidies in Norwegian kroner (NOK), average standard deviation (S.D.) within farms, and coefficient of variation (CV) for the Norwegian lowlands 1993–1998

Activity	Unit	Mean GM	S.D.	CV
Barley	ha	5499	1947	0.35
Oats	ha	5127	2295	0.45
Wheat	ha	8781	3389	0.39
Potatoes	ha	20401	11375	0.56
Oilseed	ha	5816	2049	0.35
Carrot	ha	49990	26791	0.54
Grass-seed	ha	10226	5242	0.51
Dairy	No	14743	2295	0.16

Farm Business Survey of Norwegian lowlands for the period 1993–1998. In addition, the same calculations were made for the average of a subsample of 28 farms. This subsample was also divided into two subsamples with above or below average wealth levels. [6]

A common variance–covariance matrix, Q, was used for all farms, cf. Section 3.1. As far as possible farm-specific GMs were used in the QRP model. One problem is data for each activity on each farm. For activities without farm-specific data, the mean c from Table 1 was used.

The case farms used in the model have the following constraints: (1) actual farm area of arable land; (2) with respect to rotational considerations, no more than two-thirds of the area of agricultural land on the actual holding can be cereals, no more than one-quarter of the area can be potatoes, and a maximum of one-sixth of the area can be carrots; (3) because of contract constraints on grass-seed production, the area of this crop is restricted to 3 ha for farms without grass-seed production in the period 1993–1998. On farms with grass-seed in the same period, the average of actual grass-seed area in this period is used; (4) the farm's milk quota is set to the average actual milk production on the farm in the period 1993–1998. Farms without milk production in the period 1993–1998 are assumed to have zero milk quotas; (5) farms without carrots in the analysed period do not have carrots as a possible activity in the QRP model. These restrictions are used since carrot production requires special soil that not all farms have; (6) one constraint on labour family availability in each of the 4-year period: spring (April–May), summer (June–July), autumn (August–October), and winter (November–March). Average registered hours of family labour available in the period 1993–1998 are distributed as one-sixth of the hours in the spring and summer seasons, one-quarter of the hours in the autumn season and three-seventh of the hours in the winter season. Technical input–output coefficients for seasonal labour requirements are assumed fixed and are based on data from NILF (1994–1999b); (7) hired labour use is restricted to the actual average registered hired labour for the period 1993–1998; (8) subsidies constraints are set according to the average subsidies prevailing for the years 1993–1998 (NILF, 1994–1999b); (9) actual fixed cost for the case farms are used in the model.

Solutions from Freund's E–V formulation (Eq. (2)) and Markowitz's E–V formulation (Eq. (3)) were used in Eq. (4) to estimate the coefficient of absolute risk aversion, r_a (Table 3). Observe that observed expected net farm income, E_a, and estimated optimal net farm income, E^*, are rather close each other, which may indicate a quite valid model.

In the single-year farm plan used in this model, income can be considered as transitory income, and the absolute risk aversion coefficient estimated is with respect to transitory income, c_t (Hardaker, 2000). For the individual case farms, the results show the estimated coefficient of absolute risk aversion with respect to transitory income, $r_a(c_t)$, vary from 0.00000006 to 0.0000202. The estimated $r_a(c_t)$ values vary considerably from farm to farm. The results show that the estimated $r_a(c_t)$ for the subsample existing of 28 farmers was 0.0000014. The subsample with 13 farmers in the 'wealthy' group had an absolute risk aversion of 0.00000053, which is lower than for the subsample existing of 15 farmers in the 'non-wealthy' group of 0.00000248. That the absolute risk aversion is a decreasing function of wealth is in accordance with Arrow (1970) expectation.

[6] Occasionally, (not for the results presented here) when I tried to estimate the coefficient of absolute risk aversion, I found no feasible solution. The apparent reason for the infeasible solutions was either that the technical input–output constraints, A, and/or the expected activity GMs per unit level, c, and/or the variance–covariance matrix, Q, was mis-specified and not representative for the analysed farm. For these reasons, the QRP problem may sometimes be infeasible when expected net farm income is set to E_a and variance, V, is minimised or variance is set to V_a and E is maximised.

Table 2
Correlation matrix of expected activity gross margins within farms for the Norwegian lowlands 1993–1998

Activity	Barley	Oats	Wheat	Potatoes	Oilseed	Carrots	Grass-seed	Dairy
Barley	1.00							
Oats	0.38	1.00						
Wheat	0.28	0.47	1.00					
Potatoes	−0.17	0.07	−0.23	1.00				
Oilseed	0.28	0.40	0.22	0.09	1.00			
Carrots	0.17	0.34	0.21	−0.05	0.03	1.00		
Grass-seed	0.05	0.16	−0.01	−0.23	0.62	−0.28	1.00	
Dairy	−0.07	0.04	0.03	0.06	0.55	0.46	−0.43	1.00

For case farmers 4 and 8, the actual farm plan (E_a, V_a) is to the north-west of the frontier. The reason may be that these farmers have smaller variance for some activities, and/or different covariance between activities than assumed in the QRP model, and/or that the constraints are less restrictive than assumed in the QRP model.

It is not straightforward to compare $r_a(c_t)$ between case farmers in Table 3. Among many possibilities, I used some approximate quantitative indication of whether risk aversion matters. The method used is to calculate the proportional risk premium (PRP) representing the proportion of the expected payoff of a risky prospect that the farmers would be willing to pay to trade away all the risk for a sure thing, proposed by Hardaker (2000). Following Freund (1956), if the net revenue for each activity is normally distributed and assuming a negative exponential utility function, we have the following relationship: $U = \mathrm{CE} = E - 0.5r_a(c_t)V$, cf. Eq. (1). The risk premium (RP) is given by $\mathrm{RP} = E - \mathrm{CE} = 0.5r_a(c_t)V$. The PRP is defined as $\mathrm{PRP} = \mathrm{RP}/E$ so that here

$$\mathrm{PRP} = 0.5r_a(c_t)\frac{V_a}{E_a} \tag{10}$$

The more risk averse the farmer is, the higher will the PRP be. In Table 4, we observe that case farmer 2 is willing to pay a rather large proportion of the expected net farm income of the risky prospect for the sure thing. Case farmer 3 is willing to pay almost none of the expected net farm income for the sure thing. Also note that the 'non-wealthy' group has a larger PRP than the 'wealthy' group.

An alternative way to compare estimated absolute risk aversion, $r_a(c_t)$ values between case farms is to calculate the corresponding coefficient of relative risk aversion, $r_r(W)$, with respect to wealth, W. The approximate relationship between these two measures of

Table 3
Approximated coefficient of absolute risk aversion, $r_a(c_t)$, for case farmers and subsamples, Norway lowlands 1993–1998

Case farmer	E_a	V_a	E^*	V^*	$r_a(c_t)$
1	357974	33401217600	387493	8674138549	0.00000060
2	26933	946362169	46482	462899657	0.00002022
3	224919	7905213933	225323	4503820138	0.00000006
4	237693	8705266936	236368	8993218790	0.00000230
5	267012	18215011369	321153	11115334991	0.00000381
6	92600	3379110851	126987	480662822	0.00000593
7	249988	14615731592	257543	5917899470	0.00000043
8	303147	4495367256	186836	10471231970	0.00000973
9	233304	13498257124	233251	13517354484	0.00000140
Subsample	284950	22631591844	341005	3109608536	0.00000144
Wealthy	367533	28337682244	381667	14901283442	0.00000053
Non-wealthy	231510	11842880625	280282	1993850986	0.00000248

Table 4
Approximated proportional risk premium (PRP) and coefficient of relative risk aversion with respect to wealth, $r_r(W)$, for case farmers and subsamples, Norway lowlands 1993–1998

Case farmer	PRP	Wealth (in NOK)	$r_r(W)$
1	0.028	2937787	1.75
2	0.355	433484	8.76
3	0.001	1296224	0.08
4	0.042	2534455	5.83
5	0.130	717518	2.74
6	0.108	455811	2.70
7	0.013	1505067	0.65
8	0.072	1109625	10.80
9	0.040	2583345	3.61
Subsample	0.057	1540770	2.21
Wealthy	0.020	2753189	1.45
Non-wealthy	0.063	756263	1.87

risk aversion is shown by Hardaker (2000) as

$$r_r(W) = r_a(c_t)W \quad (11)$$

The relationship in Eq. (11) requires a rational farmer, i.e. asset integration where a farmer shows consistent risk attitude to risky prospects whether they are presented in terms of wealth, income or losses and gains. Anderson and Dillon (1992) have proposed a rough and ready classification of degrees of risk aversion, based on the relative risk aversion with respect of wealth, $r_r(W)$, in the range 0.5 (hardly risk averse at all) to about 4 (very risk averse). The results in Table 4 display $r_r(W)$ mostly within this range. That case farmers 2, 4 and 8 show a large $r_r(W)$ may be caused by failure of asset integration, i.e. these farmers may be more risk averse when they contemplate transitory income than they would be if the same risky prospects were presented to them in terms of wealth.

Note also that $r_r(W)$ decreases with increasing wealth. This result is not in accordance with Arrow (1970), who argued on theoretical and empirical grounds that $r_r(W)$ would generally be an increasing function of W. However, Hamal and Anderson (1982) found that in extremely resource-poor farming situations, relative risk aversion could reach values as extreme as four or more, contrary to what Arrow had hypothesised. Binswanger (1980) found that wealth appeared to have little influence on risk-taking behaviour.

Saha et al. (1994, 175 pp.) present an overview of the principal findings of earlier studies. But it is important to remember that the coefficient of absolute risk aversion, r_a, is not constant for change in currency units. That makes it meaningless to compare coefficients of absolute risk aversion in different countries with different units (Hardaker, 2000).

4. Concluding comments

The main advantage with the approach outlined in this paper is simplicity. If you have a farm or a group of farms with data on activity GMs and fixed costs over some years, the method can easily be implemented in a standard software program that solves non-linear programming problems. If the coefficient of relative risk aversion is needed it is, following Hardaker (2000), possible to derive the approximate relationship between the coefficients of absolute and relative risk aversion.

Some basic weaknesses with this approach to approximating a farmer's risk aversion have to be mentioned. First, estimation of the risk aversion parameter will pick up errors in model specification and data, and it is difficult to know how serious these errors might be (Hazell et al., 1983). Good model specification is essential to get worth trusting estimates of the absolute risk aversion coefficient. One approach that may reduce possibilities for actual farm plans above the frontier is to estimate and use pooled variance–covariance matrix for different groups of, e.g. type of farming or farm size in the programming model.

Second, a feature of this approach is that the risk parameter estimates are conditional (Saha et al., 1994). That is, the coefficient of absolute risk aversion is estimated conditional upon a specific risk preference structure implied by the assumed negative exponential utility function form. The negative exponential utility function imposes constant absolute risk aversion, usually not regarded as a desirable property.

Third, this approach requires that the farmer's utility function is quadratic or that the distributions of total net revenue is normal if the set of solutions are to be equivalent to maximising expected utility (Freund, 1956). Hardaker et al. (1997, 187 pp.) write 'The distribution of total net revenue varies from case to case and may not be normal ... (but), at least for a mixed farming system, appeal to the Central Limit Theorem suggests that the distributions of total net revenue may be approximately normal'.

Fourth, this model does not account for farmers' responses to non-business risk (not explicitly considered in the model). Introduction or modification of business risk in the production process may affect the farmers' decisions about leverage and financial risk-taking (Gabriel and Baker, 1980).

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