Agricultural Risk Aversion Revisited: A Multicriteria Decision-Making Approach

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AGRICULTURAL RISK AVERSION REVISITED: A MULTICRITERIA DECISION-MAKING APPROACH

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Abstract

In modelling farm systems it is widely accepted that risk plays a central role. Furthermore, farmers' risk aversion determines their decisions in both the short and the long run. This paper presents a methodology based on multiple criteria mathematical programming to obtain relative and absolute risk aversion coefficients. We rely on multiattribute utility theory (MAUT) to elicit a separable additive multiattribute utility function and then estimate the risk aversion coefficients and apply this methodology to an irrigated area of Northern Spain. The results show a wide variety of attitudes to risk among farmers, who mainly exhibit decreasing absolute risk aversion (DARA) and constant relative risk aversion (CRRA).

Keywords: Risk analysis, Agriculture, Utility theory, Multiple criteria analysis.

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1. Introduction

Risk is present in all management decisions of agricultural systems, as a result of price, yield and resource uncertainty. If farmers were risk-neutral, it would be irrelevant to consider risk in their decision-making process, since their responses could be represented by the maximization of the expected profit. However, farmers' generalized risk aversion results in production decisions that conflict with those that would be regarded as optimal from a social point of view. This fact has brought agricultural economists to devote a great deal of attention to the stabilization features of agricultural policies aimed at reducing farming risk.

The degree of attention to the behaviour of agricultural producers under risk has recently been increased by the progressive liberalization of the world agricultural markets (Hope and Lingard, 1992; Berg, 1997; Oglethorpe, 1997), and the ever-increasing importance of environmental considerations (Lambert, 1990; Babcock, 1992; Parks, 1995; Babcock and Hennessy, 1996; Bontems and Thomas, 2000).

1.1. Expected utility theory and the measure of the risk aversion of producers

In the context of risk, expected utility theory (EUT), forgotten until Von Neuman and Morgenstern (1944), has been the basis for much decision-making theory. EUT assumes that the preferences of the decision maker comply with the axioms of ordering, continuity and independence[1], and that there is a utility function *U* that assigns a numerical value to each alternative[2]. In doing so, EUT allows the ranking of alternatives within the risk context.

The seminal works of Pratt (1964) and Arrow (1965) paid attention to one of the key elements of decision theory, i.e., the measure of risk aversion of the economic agents. These authors proposed two indicators that overcame the limitations in the use of a cardinal utility function to compare differences in risk attitudes. The first is the absolute risk aversion coefficient (r_a). Mathematically, this coefficient is calculated as follows:

$$r_a(X) = -\frac{U''(X)}{U'(X)} \tag{1}$$

This coefficient can be interpreted as the percentage change in marginal utility caused by each monetary unit of gain or loss (Raskin and Cochram, 1986). Thus, the coefficient r_a takes either positive or negative values for risk-loving or risk-averse economic agents respectively.

When the coefficient decreases as the monetary value increases we have decreasing absolute risk aversion (DARA). Alternatively, if the coefficient increases under the same set of circumstances we have increasing absolute risk aversion (IARA). Finally, if the coefficient does not change across the monetary level, the decision maker exhibits constant absolute risk aversion (CARA), which implies that the level of the argument of the utility function does not affect his or her decisions under uncertainty.

Since r_a is not a non-dimensional measure of risk aversion, its value is dependent on the currency in which the monetary units are expressed. To overcome the impossibility of comparing risk aversion among different economic agents we have devised a non-dimensional measure; the relative risk aversion coefficient (r_r):

$$r_r(X) = -X\,\frac{U''(X)}{U'(X)} \tag{2}$$

[1] These axioms have been under severe criticism in many applied studies. A revision can be found in Starmer (2000). However, EUT benefits from the credit of most agricultural economists (Schoemaker, 1982; Robison and Hanson, 1997).

[2] As most economic decisions are expressed in monetary terms, the utility function may have wealth as argument (U(W)), measuring the satisfaction from a given amount of money. However, it is also used the satisfaction from either a gain or a loss (U(X)) (Hardaker *et al*., 1997, p.94-95).

This second coefficient measures the percentage change of marginal utility in terms of the percentage change in the monetary variable; hence, r_r represent the elasticity of the marginal utility function, which ranges from 0.5 (slightly risk-averse) to 4 (extremely risk-averse)[3]. As with the absolute risk aversion coefficient, we can find decreasing, constant or increasing relative risk-aversion behaviour (DRRA, CRRA and IRRA, respectively).

All theoretical aspects of EUT related to agricultural economics have been discussed in classic works such as those of Dillon (1971), Anderson *et al*. (1977), Barry (1984), Robison and Barry (1987) and Hardaker *et al*. (1997).

1.2. Literature review

According to Young (1979), Lins *et al*. (1981) and Robison *et al*. (1984) there are three basic methods of measuring the attitudes to risk of agricultural producers:

- *Direct estimation of the utility function*. This method involves direct interaction with the decision maker, who expresses his or her preferences among various alternatives. Regression techniques then enable us to obtain their utility function. Examples can be found in Officer and Halter (1968), Francisco and Anderson (1972), Lin *et al*. (1974), Dillon and Scandizzo (1978), Halter and Mason (1978), Bond and Wonder (1980), Hamal and Anderson (1982), Sri-Ramaratmam *et al*. (1987) and Feinerman and Finkelshtain (1996).
- *Experimental methods*. This can be regarded as a variant of the previous method, in which real bets are used instead of hypothetical gains and losses. See for example Binswanger (1980 and 1981) and Binswanger and Sillers (1983).
- *Observed economic behaviour*. This method is based on the difference between the observed behaviour and that predicted by the empirical models. Furthermore, these models rely on either production theory under uncertainty (econometric models) or cropping pattern selection (mathematical programming). Wolgin (1975), Moscardi and Janvry (1977), Antle (1987 and 1989), Myers (1989), Chavas and Holt (1990 and 1996), Pope and Just (1991), Saha *et al*. (1994), Saha (1997) and Bar-Shira *et al*. (1997) present good examples of the first category, while for the latter we have Wiens (1976) and Brink and McCarl (1978).

All the above approaches have their drawbacks (see Young, 1979; Binswanger, 1980 and Lins *et al*., 1981), which are most important in the direct estimation method due to interviewer bias, the selection of probabilities, reluctance to play lottery games, lack of reality of the scenarios in place and/or insufficient experience on the part of the decision maker in the evaluation of hypothetical situations.

Even though these limitations can be reduced, to certain extent, by adopting the experimental method, this has often proved difficult to implement in practice, since the financial cost involved in a real situation with many producers is too high.

With respect to observed economic behaviour there are also some difficulties, such as the influence of other non-monetary objectives in the decision-making process (e.g. leisure, management complexity, etc.) and constraints (financial limitations, lack of technical information, etc.) that "contaminate" attitudes to risk. If this method is adopted, therefore, it would not be correct to explain any behaviour that differs from profit maximization purely in terms of risk aversion.

[3] Anderson and Dillon (1991) classify agricultural producers according the $r_r(W)$ coefficient. Although most authors consider value above 5-10 very unlikely (Kocherlakota, 1996), there are some studies reporting value up to 30 (Kandel and Stambaugh, 1991). According to them, these value can be reasonable when the alternatives in place represent a gain or loss of 1% of the total wealth.

In considering the econometric approach, the need for long time series and/or cross-sectional data on input use, production level and other relevant economic variables limits this alternative to specific groups of farmers for whom first-class data are available, a rather uncommon situation in agriculture.

In this paper we present a methodology based on mathematical programming that enables us to discriminate between the effect of the risk attitude of the producer on his or her decision-making and other criteria. This methodology, which resorts to the multiple criteria paradigm to estimate risk aversion coefficients, requires a minimum amount of data, making it a pragmatic approach to any real agricultural system in spite of limited availability of data.

The paper is organized as follows: Section 2 explains the methodology used to calculate farmers' risk aversion coefficients. Section 3 presents the area of study in which the methodology was applied, while the results are summarized in Section 4. We conclude the paper by drawing some important conclusions about the pragmatic advantages of this approach.

2. Theoretical framework

2.1. Decision theory and the analysis of risk attitudes

One of the basic principles of classical Economic Theory is that entrepreneurs behave as profit maximizers. Following this principle, modelling the decision-making of agricultural producers could be achieved by the maximization of single-objective models. Real-life observations refute this simplification.

Expected utility theory was a first step in the direction of broadening the profit maximizer assumption and including higher moments of the expected profit. However, EUT has been criticised for limiting its application to a single attribute: the pay-off (or wealth). Many authors have demonstrated the convenience of considering more than one attribute in the producer's utility function: e.g. Harman *et al*. (1972), Gasson (1973), Smith and Capstick (1976), Harper and Eastman (1980), Kliebenstein *et al*. (1980), Patrick and Blake (1980), Cary and Holmes (1982), Sumpsi *et al.* (1993 and 1997), Gómez-Limón and Berbel (1995), Berbel and Rodríguez (1998) and Amador *et al.* (1998). All these studies suggest that farmers' decision-making processes are driven by additional criteria to the expected profit (or higher moments), such as the maximization of leisure, the minimization of managerial problems, the minimization of working capital, etc.

Hence, the decision maker maximizes his or her expected utility following a function with profit (X) as one argument plus other attributes (Y_1, Y_2,…Y_n). The problem is thus reduced to the maximization of a multiattribute utility function (Robison, 1982):

$$\text{Max } E\ [U\ (X, Y_1,....Y_n)] \qquad (3)$$

If the Y_1,....Y_n attributes are not considered, the objective function becomes:

$$\text{Max } E\ [U\ (X, \text{å})] \qquad (4)$$

where the å term represents the error from omitting the other attributes. Hitherto, this has been the usual EUT approach to modelling the behaviour of economic agents under uncertainty. According to Robison (1982, p.374), predictions made by the single-attribute utility function cannot be accurate enough since there are other attributes involved in the decision-making process.

Having considered the above-mentioned findings, we have opted to model farmers' behaviour by means of multiattribute utility theory (MAUT), an approach, largely developed by Keeney and Raiffa (1976), that overcomes the limitations of the single-attribute utility function. The multiattribute approach attaches a cardinal value to each alternative, and considers the aggregated effect of all attributes. The difficulties arise in the first place from the mathematical form of each individual utility function and secondly from the aggregation of all values (Herath, 1981; Hardaker *et al*., 1997).

2.2. Multiple-criteria technique to calculate the risk aversion coefficients

- *Elicitation of the multiattribute utility function*

Although the conditions for the assumption of an additive utility function are somewhat restrictive[4], Edwards (1977), Farmer (1987) and Huirne and Hardaker (1998) have shown that the additive function yields extremely close approximations to the hypothetical true function even when these conditions are not satisfied[5].

The ranking of alternatives is obtained by adding the contributions of each attribute. Since attributes are measured in different units, normalisation is required to allow addition. The weighting of each attribute expresses its relative importance. In mathematical terms, the multiattribute utility function takes the following form:

$$U = \sum_{i=1}^{n} w_i u_i (r_k) \, , \qquad (5)$$

where U is the utility value of alternative k, w_i is the weight of attribute i and $u_i(r_k)$ is the value of attribute i for alternative k. Expression (5) in its simplest form becomes:

$$U = \sum_{i=1}^{n} w_i r_k \, , \qquad (6)$$

This formulation implies linear utility-indifferent curves (constant partial marginal utility), a rather strong assumption that can be regarded as a close enough approximation if the attributes vary within a narrow range (Edwards, 1977; Hardaker *et al*., 1997, p.165). There is some evidence for this hypothesis in agriculture. Thus, Huirne and Hardaker (1998) show how the slope of the single-attribute utility function has little impact on the ranking of alternatives. Likewise, Amador *et al*. (1997) analyse how linear and quasi-concave functions yield almost the same results. As a consequence, we assume this simplification in the elicitation of the additive utility function.

Following the methodology developed by Sumpsi *et al*. (1993 and 1997) with some modifications, we elicit the additive multiattribute utility function. The method may be summarised as follows:

1. Each attribute j is defined as a mathematical function of decision variables $\vec{X}$ (e.g. crop area); $f_j = f_j(\vec{X})$. These attributes are proposed *a priori* as the most relevant decision-making criteria that are utilised by farmers (usually profit, risk, etc.).

[4] If the attributes are mutually utility independent the utility function $U= U(x_1, x_2, ..., x_n)$ becomes $U= f\{u_1(x_1), u_2(x_2), ..., u_n(x_n)\}$ and takes either the additive form: $U(x_1, x_2, ..., x_n)= \sum w_i u_i(x_i)$, or multiplicative form: $U(x_1, x_2, ..., x_n)= \{\prod (K w_i u_i(x_i)+ 1)- 1\}/K$, where $0 \leq w_i \leq 1$ and $K= f(w_i)$. If the attributes are mutually utility independent and $\sum w_i= 1$, then $K= 0$, and the utility function is additive. If $\sum w_i \neq 1$, then $K \neq 0$, and the mathematical form is multiplicative (Keeney, 1974; Keeney and Raiffa, 1976; Fishburn, 1982).

[5] The approximation of the additive formulation to the real multiattribute function, supported by several empirical studies, is explained by some authors on the basis of psychological reasons (Dawes and Corrigan, 1974; Einhorn and Hogart, 1975; Dawes, 1979).

2. A pay-matrix is obtained optimising each objective. We also obtain an *m* by *n* variable-objective matrix, where *n* is the number of objectives and *m* the number of crops to be considered as alternatives. Each element of the matrix, $\boldsymbol{x_{ij}}$ represent the area of crop *i* when the objective *j* is optimized.
3. The following *m*+1 system of equations is solved:

$$\sum_{j=1}^{q} w_j x_{ij} = x_i \quad i = 1, 2, ..., q \quad \text{and} \quad \sum_{j=1}^{q} w_j = 1$$

   where $\boldsymbol{w_j}$ are the weights attached to each objective (the solution), $\boldsymbol{x_{ij}}$ are the elements of the decision variable-objective matrix and $\boldsymbol{x_i}$ the observed area of crop *i*.
4. Normally, there is not an exact solution to the above system, and it is therefore necessary to solve a problem by minimizing the sum of deviational variables that find the closest set of weights:

$$\text{Min } \sum_{i=1}^{q} n_i + p_i \quad \text{subject to:}$$

$$\sum_{j=1}^{q} w_j x_{ij} + n_i - p_i = x_i \quad i = 1, 2, ..., m \quad \text{and} \quad \sum_{j=1}^{q} w_j = 1$$

   where n_i and p_i are the negative and positive deviations respectively.
5. Dyer (1977) demonstrates that the weights obtained in the previous system are consistent with the following separable and additive utility function:

$$U = \sum_{j=1}^{n} \frac{w_j}{k_j} f_j(\vec{X}) \tag{7}$$

   where $\boldsymbol{k_j}$ is a normalising factor.

The additive utility function (7) can be alternatively expressed as:

$$U = \sum_{j=1}^{n} w_j \frac{f_j(\vec{X}) - f_{j*}}{f_j^{*} - f_{j*}} \tag{8}$$

Thus, the utility function (7) is normalized by the difference between the ideal (f_j^*) and the anti-ideal (f_{j*}) of the different objectives, and choosing the mathematical expression of the attributes as their utility function, f_j(X), minus the anti-ideal (f_{j*}).

This methodology differs from that of Sumpsi *et al*. (1993 and 1997) and Amador *et al*. (1998) in the goal-programming exercise employed to calculate the weights. The former authors use the pay-off matrix, based on objectives, instead of the decision variable-objective matrix. A similar approach can be found in Van Huylenbroeck *et al*. (2001).

Both approaches are the equivalent of regression analysis, where the weights are the coefficients to be estimated. In our approach, however, we improve the estimation by increasing the number of "observations", since, in most situations, the number of activities, *m*, exceeds the number of objectives, *n*.

Another advantage of this approach lies in the fact that we use observed dependent variables and it is not necessary to estimate unobserved values of the objective functions. Besides, normalization is not required in the minimization of the deviational variables, n_i and p_i, since all are measured in the same units (hectares).

The empirical results show that, in most cases, the method proposed in this paper outperforms the original one in terms of its ability to accurately reproduce the individual farmer's observed behaviour. Consequently, the modifications to the method proposed by Sumpsi *et al*. (1993 and 1997) result in an additive utility function that can be used as an instrument which is capable of reproducing the observed behaviour of the farmer.

- *Objectives in the multiattribute utility function*

The objectives included in the analysis were based on a survey of the study area, which revealed the objectives that farmers consider in their decision-making process to choose a crop plan. The objectives mentioned were:

- *Maximization of total gross margin* (TGM), as a proxy of profit in the short run. TGM is obtained from the average crop gross margins from a time series of seven years (1993/1994 to 1999/2000) -constant euros of 2000-.
- *Minimization of risk*, measured as the variance of the TGM (VAR). The risk is thus computed as $\vec{X}' \cdot$ [Cov]$\cdot$ $\vec{X}$, where [Cov] is the variance-covariance matrix of the crop gross margins during the 7-year period, and $\vec{X}$ is the crop decision vector.
- *Minimization of total labour input* (TL). This objective implies not only a reduction in the cost of this input but also an increase in leisure time and the reduction of managerial involvement (labour-intensive crops require more technical supervision).
- *Minimization of working capital* (K). This has the aim of reducing the level of indebtedness.

These objectives, which are selected *a priori* by farmers, are analysed in accordance with the methodology described above, making it possible to assess the importance of each objective in the decision making process.

- *Multiattribute utility function and Arrow-Pratt risk aversion coefficient*

Using expression (8) and the information on farmers' objectives obtained from the survey, we can build the additive utility function as follows:

$$U = w_1 \frac{TGM(\vec{X}) - TGM_*}{TGM^* - TGM_*} + w_2 \frac{VAR_* - VAR(\vec{X})}{VAR_* - VAR^*} + w_3 \frac{TL_* - TL(\vec{X})}{TL_* - TL^*} + w_4 \frac{K_* - K(\vec{X})}{K_* - K^*} \quad (9)$$

In order to reconcile the proposed methodology with the MAUT and EUT approach we need to establish the expected utility of the previous expression to be maximized by the decision maker. Since expression (9) does not have any random element and includes the first two moments of the total gross margin, its expected value and variance, we conclude that, within the context of MAUT, this expression is simultaneously both the decision-maker's multiattribute utility function and his/her expected utility.

To calculate the Arrow-Pratt risk aversion coefficients (r_a and r_r) from the former expression we need to divide it into three parts: the first part includes the first and second moment of the total gross margin, and the other two correspond to the two last elements. As we do so, we see the resemblance between the first part and the mean-variance analysis.

The Pareto optimum set of the EUT approach coincides with the E-V locus only under certain conditions of the decision-maker's utility function (quadratic) or the form of the distribution function of the variable that provides utility, in our case the TGM[6]. Both conditions are rarely observed in reality[7], yet a number of works justify the use of the E-V analysis. Thus, Tsiang (1972) supports it when the risk involved is small in comparison with the total wealth of the decision-maker. This condition applies to most farmers in Western countries that own their

[6] Meyer (1987) and Meyer and Rasche (1992) prove that a sufficient condition to find the optimum of the EUT within the E-V set relates to the difference of parameters of the random variables in location and scale. This condition, however, is not easy to implement in the continuous space (the cropping pattern) we move.

[7] As Pratt (1964) points out, a quadratic utility function implies an increasing marginal utility, hypothesis rejects by the observation of reality. Likewise, a normal distribution of the variable is not easily assumed. Yet, by the central limit theorem, when the number of variables, crop gross margins, is sufficiently high, the sum of them, the total gross margin, approximately follow a normal distribution, irrespectively of the distribution form of the initial variables.

land and machinery since the risk involved is much lower than his/her wealth. Likewise, Levy and Markowitz (1979) and Kroll *et al*. (1984) have demonstrated that the E-V analysis is a good approximation to reality even when these conditions are not met.

Thus, assuming that the expected utility of the TGM can be approximated by the Taylor series of the two first moments, mean and variance, the decision-maker's utility function can be expressed as follows:

$$E[U(TGM)] = E(TGM) - \frac{l}{2} s^{2}{}_{TGM} \tag{10}$$

where *ë* is the r_a coefficient (Pratt, 1964). Taking expected values we have:

$$E[U(TGM)] = TGM - \frac{r_a(TMG)}{2} VAR \tag{11}$$

Furthermore, linking Expressions (11) and (9), we can consider the first two elements of the latter as the first two moments of a Taylor series that approximates the utility function of TGM:

$$EU = \left\{ \frac{w_1}{k_1} \left[TGM(\vec{X}) - \frac{w_2 k_1}{w_1 k_2} VAR(\vec{X}) \right] - TGM_* + \frac{w_2 k_1}{w_1 k_2} VAR_* \right\} + \left\{ w_3 \frac{TL_* - TL(\vec{X})}{k_3} \right\} + \left\{ w_4 \frac{K_* - K(\vec{X})}{k_4} \right\} \tag{12}$$

where k_i is the difference between the ideal (f_j*) and the anti-ideal (f_{j*}).

From expression (12) we see that it is possible to obtain the risk aversion coefficients (r_a and r_r) by similarity with expression (11)[8]. We calculate the coefficients as follows:

$$r_a(TGM) = \frac{2w_2k_1}{w_1k_2} \quad \text{and} \quad r_r(TGM) = TGM_{observed} \frac{2w_2k_1}{w_1k_2} \tag{13}$$

- *Constraints in the models*

The constraints considered in the models utilised to obtain the pay-off and objective-activities matrix were:

- The sum of decision variables is equal to or lower than the farm size.
- European Common Agricultural Policy constraints (set-aside requirements and sugar-beet quotas).
- Rotational constraints as expressed by the farmers questioned in the survey.
- Market constraints that limit the amount of risky crops according to traditional practices.
- Water availability.

2.3. Relationship between the farmer's risk attitude and socio-economic variables

The mathematical programming method proposed in this paper allows the calculation of the risk aversion coefficients for a particular level of TGM. Thus, we cannot obtain the value of these coefficients for other levels of TGM than the observed ones since this would require the elicitation of the farmer's utility function. Indeed, expression (9) is only a local approximation to the real utility function. Therefore, this local measure of risk aversion cannot be used to infer IARA, CARA or DARA (or IRRA, CRRA or DRRA) behaviour. However, they do represent, for that level of TGM, the relative importance of risk in their decision-making process.

[8] The possibility of joining EUT and MCDM had been already pointed by Romero *et al*. (1988, p.275) in the context of compromise-risk programming (CRP).

Nevertheless, since it is important to determine how these risk coefficients change with the level of wealth in order to evaluate the impact of alternative agricultural policies, we can regress r_a and r_r on the level of TGM for all farmers. The regression models, $r_a = f(\text{TGM})$ and $r_r = f(\text{TGM})$, considered were: linear, exponential, reciprocal (X, Y and double), logarithmic, multiplicative, square root (X and Y), S-curve, logistic and log-probit; we then chose the model with the highest R^2. The slope indicates the aggregated farmers' attitude to risk: a statistically significant slope implies the rejection of CARA and CRRA, a negative slope would suggest DARA and DRRA, and finally, a positive slope IARA and IRRA.

Furthermore, it is interesting to relate the r_a and r_r coefficients to other socio-economic variables. We also resorted to multivariate regression analysis to estimate the relationship to the following variables:

- Farm size
- Percentage of land ownership
- Age
- Family size
- Percentage of income from farming
- Education (years of schooling).

3. Case study

The case study is a community of irrigators located in Northern Spain, *Los Canales del Bajo Carrión,* in the county of Palencia. This community has 6,554 irrigated hectares and 889 farmers. It has a typical continental climate, 700 m above sea level, with long, cold winters and hot, dry summers. Rain falls mostly in spring and autumn. During winter the main crops are wheat and barley, in the summer mainly maize, sugar beet and sunflower. During the summer it is necessary to irrigate to bring the crops to the harvestable stage.

The main irrigation systems are furrow for most crops and spraying for sugar beet. In decreasing order of importance, the average crop distribution is winter cereals, maize, alfalfa, sugar beet, and sunflower.

A survey of 52 farmers selected at random was used to gather the necessary data to build the models (crop area, costs, yields and constraints) and describe the socio-economic situation of the farmer. This source was complemented by official statistics on subsidies and prices.

4. Results

4.1. Estimation of the multiattribute utility functions

Utilising the methodology explained in Section 2, we were able to obtain the weighting (w_i) that each farmer attached to the optimization of each objective.

The results show that the maximization of total gross margin is the most important objective with an average weighted importance of 56.4%, followed by the minimization of risk with an average weighting of 31.8%. The objectives of the maximization of leisure time and the minimization of working capital, with relative weights of 9.2% and 2.5% respectively, seem to be less important. The following figure summarizes the cumulative distribution of the weighting of each objective.

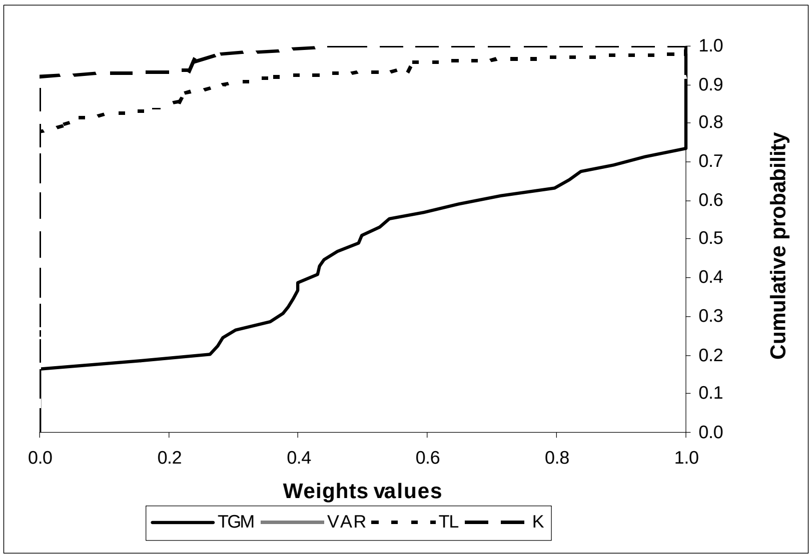

***Fig. 1**. Cumulative probability of the weighting of each objective.*

As we can see in Figure 1, 51% of farmers have the maximization of the total gross margin (w_1>0.5) as their first priority. The importance of this objective is complete (w_1=1) for 29% of the sample. In the case of minimization of risk, we observe how 35% of farmers give this a weight greater than 0.5, and that 10% consider it as their only objective (w_2=1). Finally, with respect to the other two objectives, only 8% of farmers consider the maximization of leisure time very important (w_3>0.5), while none of them regard the minimization of working capital as important.

In summary, the two most important objectives are the maximization of total gross margin and the minimization of risk. However it is important to include other objectives in the utility function in order to capture other behavioural attitudes that enable us to estimate more accurately the risk aversion coefficients.

4.2. Separate analysis of the risk aversion coefficients

The results obtained from Equations (13) are presented in Figures 2 and 3. As we can see, the r_a and r_r coefficients achieve relatively high values, with an average of 0.00010 (in 1/€) and 4.5, respectively.

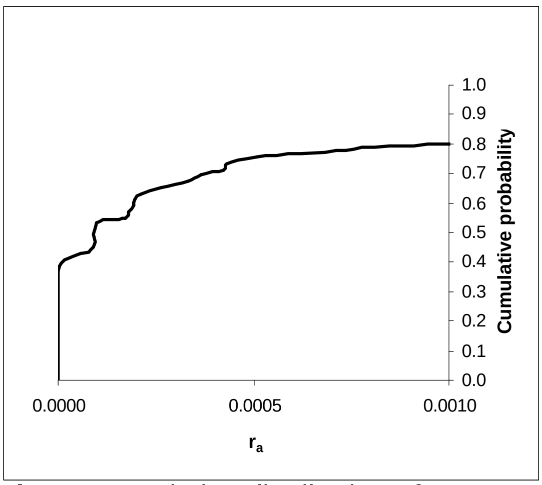

***Fig. 2**. Cumulative distribution of r_a.*

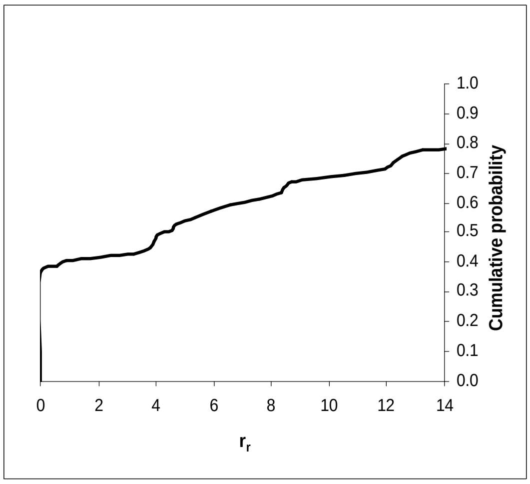

***Fig. 3**. Cumulative distribution of r_r.*

It is important to note the low significance of the mean value due to the wide range of results in the sample. Similar wide dispersal of values in agriculture has been pointed out by other authors, including Moscardi and Janvry (1977), Dillon and Scandizzo (1978), Binswanger (1980 and 1981), Sri-Ramaratman *et al*. (1987) and Antle (1987 and 1989).

Moreover, Figures 2 and 3 reveal that there is a high proportion of farmers (45%) for whom risk aversion is not a factor at all (r_a=r_r=0), that is, farmers whose behaviour is not explained by risk minimization (w_2=0), since they seek to maximize profits and leisure time and to minimize working capital. On the other hand, a number of farmers (41%) place a low weighting on the objective of profit maximization (w_1<0.2-0.3), with a rather conservative pattern of behaviour (r_r>6). This high risk-aversion value is due to the high weighting attached to risk minimization and/or the minimization of total labour and working capital.

We thus conclude that there are two distinctive groups of farmers who are divided by their attitudes toward risk rather than by their farm endowments. These results explain why different management decisions (i.e. crop plans) can be found within an area with homogeneous resources (climate, soil, etc.). As a result, a range of different responses can be expected for the same agricultural policy stimulus.

We also found a further group (20%) of farmers with extremely high risk aversion coefficients, who ignore the maximization of profit (w_1=0). These farmers own very large farms that provide them with risk-free income from the direct area payments. These farms are sown with crops that require low working capital and do not need a great deal of managerial involvement (high values of w_3 and w_4).

4.3. Analysis of the global structure of risk aversion

The regression analysis of the risk aversion coefficients on a proxy of wealth (TGM) revealed that, in the case of r_a, the best fit was obtained by the following logarithmic formulation:

$$r_a = 0.00401 - 0.00035 \cdot \ln(\text{TGM}) \quad (14)$$

(R^2= 0.34; slope significant at the 99% level)

According to this formulation, the farmers in this community exhibit decreasing absolute risk aversion (DARA), in line with most related studies, such as Wiens (1976), Binswanger (1980 and 1981), Lins *et al*. (1981), Hamal and Anderson (1982), Chavas and Holt (1990 and 1996), Saha *et al*. (1994), Feinerman and Finkelshtain (1996), Bar-Shira *et al*. (1997) and Saha (1997).

However, for the relative risk aversion coefficient it was not possible to find any clear relationship with the TGM (all models with R^2 lower than 0.20, and no statistically significant slopes). It follows, therefore, that we cannot either accept or reject IRRA (or DRRA) for this group of farmers. However, the scattergraph r_r-TGM suggests an almost horizontal relationship, that is, CRRA. This would support the results of other studies, e.g. Lins *et al*. (1981), Binswanger and Sillers (1983), Myers (1989) and Pope and Just (1991).

The previous results are limited to the aggregated behaviour of this group of farmers. Thus, it might well be possible to find individual farmers who differ significantly from the average. However, as we have pointed out, this method is intended to explain the aggregated behaviour.

4.4. The risk aversion coefficients and the socio-economic variables

The following table show the Pearson correlation coefficient of both risk aversion coefficients and the selected socio-economic variables:

***Table 1**. Pearson correlation coefficients of r_a and r_r and some socio-economic variables.*

	$\mathbf{r_a}$		$\mathbf{r_r}$	
	Pearson ρ	p-value (H_0: ρ = 0)	Pearson ρ	p-value (H_0: ρ = 0)
Total gross margin	-0.33	0.022	-0.09	0.551
Farm size	-0.26	0.072	0.01	0.954
Percentage of ownership	-0.22	0.125	-0.08	0.569
Farmer's age	0.30	0.036	0.17	0.255
Farmer's family size	0.12	0.410	0.15	0.309
Percentage of income from farming	-0.03	0.824	0.21	0.160
Farmer's education	-0.06	0.700	0.11	0.445

As we can see, significant correlations exist only between some of the socio-economic variables and the absolute risk aversion coefficient. The significant relationships were:

- Total gross margin. This result corresponds with the DARA assumption.
- Farm size. This correlation can be explained by the high correlation between TGM and farm size (ρ>0.90). Therefore, in the multivariate analysis, TGM and farm size will not be simultaneously included in the model to avoid multicolinearity problems.
- Farmer's age. The older the farmer the higher his/her risk aversion. This result is in line with other studies.

Other studies have found a positive correlation with the farmer's education and with the percentage of hired land (Moscardi and Janvry, 1977; Dillon and Scandizzo, 1978; Binswanger, 1980; Feinerman and Finkelshtain, 1996).

From this evidence, the attitude of farmers to risk seems to be the result of psychological rather than of socio-economic causes. A multidisciplinary approach would therefore be required to obtain more conclusive results.

In spite of the poor fit, we made a multivariate linear regression analysis of r_a on the TGM and the socio-economic variables (stepwise method), with the following estimates:

***Table 2**. Multivariate linear regression of r_a on TGM and farmer's age.*

Variable	Coefficient	Student's t	*p*-value
Intercept	-0.000147	-0.317	0.7529
Total gross margin	$-5.322 \cdot 10^{-9}$	-2.147	0.0372
Farmer's age	$1,955 \cdot 10^{-5}$	1.992	0.0524

5. Conclusions

The principal conclusions to be drawn from this study can be summarized as follows.

Regarding the methodology:

- Since farmers' decision-making processes simultaneously involve several different objectives, it is shown that the reduction of the problem to a utility function with a sole monetary attribute does not fully explain his/her behaviour. Our approach includes non-monetary objectives in a multi-criteria decision-making technique in order to overcome this limitation.

- The methodology employed allows the risk aversion coefficients to be calculated, unlike the econometric approach, using a minimum amount of data. This feature makes it particularly suitable for agricultural systems in view of the lack of data that is typical of this sector.

Regarding the results:

- It is interesting to note the wide range of weightings attached to the objectives. This results in a high variability of the risk-aversion coefficients. In this sense, we can divide the sample into two groups: those farmers whose risk-aversion coefficients are close to zero (r_a and $r_r \approx 0$), (about 45%); and those with an extremely high relative risk-aversion coefficient ($r_r > 6$), (about 41%).
- The high percentage of farmers with a high relative aversion to risk indicates that we cannot consider this as "paranoid" behaviour (Anderson and Dillon, 1992), and this term should perhaps be reserved for r_r values above 10.
- Average behaviour suggests DARA, and less clearly CRRA, for this group of farmers.
- The inclusion of socio-economic variables in the explanation of the risk aversion coefficients did not yield satisfactory results. Only the farmer's age is positively correlated with the r_a coefficient, suggesting that psychological variables may have a greater influence on a farmer's attitude to risk.

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