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Farm decision making under risk and uncertainty

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Abstract

The aim of this paper was to review relevant portions of the risk literature, to relate them to observed behaviour in farm decision-making, and to propose relevant topics for applied agricultural risk research. The concept of decision making under risk and uncertainty was discussed by reviewing the theory of Subjective Expected Utility and its limitations. Subjective Expected Utility theory is the major framework for thinking systematically through complex issues of decision. Limitations of Subjective Expected Utility theory were that its application to unique decisions is doubtful, that it does not contribute to difficulties in determining the available decision alternatives, and that it is cast in a timeless setting, making the theoretic framework to a very limited extent helpful to solve real world decision problems. Most empirical studies indicated that farmers are risk neutral to slightly risk averse. But it was doubtful whether decision makers could be classified according to their risk preferences. A presented overview of applied risk responses revealed much attention for diversification of the enterprise and of production practices, maintaining reserves, and farm expansion. Research reports on observed problems in farm decision making behaviour were lacking. Proposed topics for agricultural risk research included the assessment of the need for a strategic change, the creation of databases to determine both the (co)variances of input and output prices, the effectiveness of various kinds of decision support for different decision problems, and methods for applied scenario analysis to deal with long-run risk.

Key words: decision making, risk, uncertainty, utility, scenario

Introduction

General introduction

For many strategic decisions concerning firm viability and personal well-being there is a good deal of uncertainty. Accounting for risk can also be important in day-to-day farm management decisions, where the accumulated effect of the choices may have a significant impact on overall business performance. For all these decisions, therefore, risk may be judged to be very significant.

Diversification is commonly advanced as a method of reducing risk. Perhaps one of the more effective means of reducing uncertainty is to monitor the operation and to adjust plans in response to changing production and price conditions. Several strategies can be listed which tend to shift some of the risk to another individual or firm. Total premium for insurance of various kinds – fire, wind, all-risk herd insurance, life and health – for a typical Dutch full time livestock farmer (40 years of age, married, and with two children of 13 and 16 years) varies from NGL 14.000 to NGL 18.000, which equals approximately 20 to 25% of Dutch average family farm income (P.A.M. Bens, personal communication).

During the last decades, quantifying and managing risk in agriculture has been a topic of continuing interest to agricultural economists, especially in the United States and Australia. The contributions made by agricultural economists to firm level risk research were summarized by Anderson *et al.* (1977), Barry (1984) and Robison & Barry (1986).

In general, a decision involves four steps (Simon, 1960): (1) Perception of decision need or opportunity; (2) Formulation of alternative courses of action; (3) Evaluation of the alternatives; and (4) Choice of one or more alternatives. Analysis of the decision problem or opportunity implies analyzing both the relative firm position and the firm environment. This phase guides the direction for specifying relevant decision alternatives. According to Shackle (1961), decisions aim at the experiences most preferred, using the freedom of imagination only constrained by judgement of what is possible. People face decision problems when they have alternatives in choosing, each with significant consequences, and when they are unsure about which particular choice is best.

When uncertainty exists about the consequences of a particular choice because of stochastic states of nature, the decision problem is said to be risky. External changes in technology, markets and legislation as well as internal changes in production contribute to the risky environment for farmers. Farmers still farm because many risky situations are also potentially profitable. Typically, farmers have some information on the possible outcomes and some feeling for those that are more likely to occur. Appropriate decisions must consider the possible outcomes and the individual's attitude towards bearing risk.

Knight (1921) divided decision-making situations into risk and uncertainty. He defined the risk situation as one in which the decision maker knows both the alternative outcomes and the probability associated with each outcome. Under uncertainty, the decision maker does not know the probability of alternative outcomes. Furthermore, he may or may not know the different outcomes that can occur. This distinction between risk and uncertainty is relevant for the knowledge of the probability of an event has a certain value.

According to Von Winterfeldt & Edwards (1986), most difficulties in decision making become apparent with the identification and recognition of the available alternatives, the determination of relevant attributes, and the collecting of relevant information. A non-trivial difficulty, however, is enclosed in the compounding of events. If A is unlikely, and if B is likely when A occurs, what is the likelihood of B? Probabilities are used in deriving such implications, but it is by no means evident that this is correct in such a circumstance.

The purpose of this paper is to review relevant portions of the risk literature, relate them to observed issues in farm decision-making and to promote discussion of ways that we can aid decision makers to apply what has been learned. The discussion focuses on these topics as they relate to agricultural producing units. Observed issues in real world farmer decision-making under risk and uncertainty are discussed. Furthermore, the theory of Subjective Expected Utility and methods to measure risk preferences are outlined. After discussing the role of risk responses in farm management, an approach for scenario analysis is proposed. Finally, suggestions are made for future applied agricultural risk research.

Observed behaviour in individual farm decision-making

The long term viability of the farm depends on the rendability of farming and the relative position of the own farm in terms of farm size, family expenditures, productivity, costs due to legislation, debt structure, and financial reserves. The relative position of the farm is influenced by personal and business goals and objectives, the farm-family relationship, and farm management strategies. It is not possible to achieve these goals by merely implementing some standard strategy. Each farm requires specific measures depending on farm equipment, farm structure, management abilities and ambitions of the farmer.

To gain insight into the practical aspects of farmer decision-making under risk and uncertainty, issues in farmer decision-making, as they were observed by experienced extension officers, were discussed in several meetings with experts of the Dutch National Extension Service for Agriculture. In these meetings, attention was paid to both issues leading either to succes or to failure. The Dutch National Extension Service for Agriculture employs more than 500 full time extension officers working for the Dutch farming community. Therefore, the mentioned issues may be regarded as an important part of real world agricultural decision-making.

For individual farmers trying to achieve economic goals, it was concluded that important issues in farmer decision-making are (1) frequent monitoring and systematic working; (2) fooling yourself; (3) the formulation of a sufficient number of alternatives; (4) the judgement of emerging opportunities; (5) jumping in; and (6) estimating both investment cost and productivity level for alternative investment plans.

A regular and systematic approach is beneficial for the whole farm business, as long as it is goal-oriënted. Frequent monitoring of farm performance using Management Information Systems (MIS) allows for timely recognition of a possible need for adjustment. Labour organisation but also the implementation of planned business expansions can be seriously affected by lack of a systematic approach. Often, a farmer with a systematic labour organization can even handle a larger farm easier than his non-systematic colleague with a smaller farm. This decreases labour costs per unit of production due to both scale effect and more efficient working methods. Moreover, the systematic farmer often realizes a better farm productivity.

Often individuals, for whatever reason, do not asses their situation properly. If a farmer with an above average farm productivity level still has a high debt level, after 10 years of above average farm productivity, he is fooling himself when not putting effort in how to decrease costs and/or family expenditures. Those farmers are often aware of the debt level, but are more interested in discussing their productivity level, which is high indeed, than in the financial performance of the farm.

Many farmers do not spend the mental effort to formulate alternative plans, or have lack of confidence in whether they themselves can overview the whole 'decision space'. They often decide on a single plan, and only ask advice on how to implement it.

Correct judgement of emerging opportunities enables timely adoption of those technologies that are indeed profitable. Farmers who ten years ago correctly assessed the consequences of increasing Dutch legislation on the disposal of by-products from the human food processing industry realized that by-products could replace a large portion of compound feed together with considerable savings in feed costs. Ten years later the number of Dutch pig farmers adopting this technology, and thus the demand for by-products, has become so high that margins, which were very high initially, have eroded to almost zero, leaving the profit only for those farmers who invested in the technology in a timely manner. Some farmers decide without having judged their situation and the associated possible alternatives in a correct manner. In the late 1980's more than 200 Dutch sow farmers adopted a new technology, Electronic Sow Feeding (ESF), which had its origin from the dairy industry. Within five years, less than 20 sow farmers in the Netherlands had an ESF system on their farm. Many of these 200 farmers underestimated the required change in management associated with the new technology.

Some farmers jump into a new opportunity too quickly, and that time after time. They decide too hastily without really considering the consequences of the opportunity. This is often the case for opportunities that do not require a loan, and thus more intensive screening of the consequences of choosing for that specific opportunity. Process automization and hiring another farm are typical examples of such opportunities.

Farmers often do not take unforeseen expenditures sufficiently into account. Differences between ex ante and ex post calculations of the required amount of money for a planned investment are often due to too low ex ante calculations of up to 10%, only partly caused by rising prices. Farmers also have difficulties in estimating farm productivity levels for alternative investment plans. They are able to indicate the direction, but able not to give quantitative indications. This is especially important when assessing the financial feasability of such plans.

Subjective Expected Utility

The major theory of decision making under risk is the theory of Subjective Expected Utility. According to this theory, the decision maker's expected utility depends on the individual's utility function and the dispersion of the outcome. The expected utility of a risky prospect to the individual is given by $Eu(y) = \int u(y)dF(y)$, where u is the utility of money y and dF(y) is the probability distribution of wealth (y) (Schoemaker, 1982). Exchanging a risky prospect between two decision makers can create utility because of the difference in wealth between them. However, besides wealth, utility is also influenced by the well being of the individual. Aspects like the wish to be independent and farm labour circumstances, like health, safety and stress, can therefore influence utility.

Von Neumann & Morgenstern (1944) proved that if an individual's behaviour conformed to certain axioms, his preferences for two or more outcomes of a risky prospect could be determined. These axioms were: ordering of choices, transitivity, substitution of choices (independence axiom), and certainty equivalent of choices. If the axioms hold, the theorem follows that an optimal risky choice is based on the maximization of expected utility. The set of axioms is summarized as follows:

1. Ordering of choices: For any two actions, A1 and A2, the decision maker either prefers A1 to A2, prefers A2 to A1, or is indifferent.
2. Transivity among choices: If A1 is preferred to A2, and A2 is preferred to A3, then A1 must be preferred to A3.
3. Substitution among choices: If A1 is preferred to A2, and A3 is some other choice, then a risky choice PA1 + (1–P)A3 is preferred to another risky choice PA2 + (1–P)A3, where P is the probability of occurence.
4. Certainty equivalent among choices: If A1 is preferred to A2, and A2 is preferred to A3, then some probability P exists that the decision maker is indifferent to having A2 for certain or receiving A1 with probability P and A3 with probability (1–P). Thus A2 is the certainty equivalent of PA1 + (1–P)A3.

Risk is incorporated into the Subjective Expected Utility theory by assigning probability distributions to relevant variables. The Subjective Expected Utility theory requires estimates of probability distributions of the outcome of risky prospects. The decision maker may use historical data, expert advice and other data in forming personal probabilities. According to Carter & Dean (1960), the use of empirical data for encoding risk requires careful examination of the length of the historical period from which data should be used, the source of the data, and the method for processing the data.

Personal probabilities directly elicited from the decision makers express the individuals' degree of believing in an event. Spetzler & Stael von Holstein (1975) referred to the process of extracting and quantifying individual judgment about uncertain quantities as probability encoding. Hogarth (1975) concluded that people, as selective, step-wise information processing individuals with limited capacity, are ill-equipped for assessing subjective probability distributions. According to March & Shapiro (1987), managers are quite insensitive to estimates of the probabilities of possible outcomes. The question is when the use of probabilities is legitimate? Shackle distinguished unique decisions on the one hand and recurring decisions on the other. Its application to unique decisions is doubtful.

In the Subjective Expected Utility theory, risk preferences are related to the curvature of the utility of money function u (Pratt, 1964; Arrow, 1971). Common measures of risk preferences are the absolute risk aversion coefficient $\alpha = -u''(y)/u'(y)$ and the relative risk aversion coefficient $r = y(-u''(y)/u'(y))$. Thus, $\alpha = r / y$, with α

and r being coefficients when they are calculated for a particular X. They can also be functions, however, to describe the individual's risk preference over a range of y. Risk aversion coefficients are derived from a Taylor series expansion, and thus are local measures of risk aversion.

With outcomes measured in dollars, an absolute risk aversion coefficient of, for example 0.00125 indicates that near the outcome level at which α was elicited, the decision maker's marginal utility drops at a rate of 0.125 % per dollar change in income. Because α varies with changes in the units of measurement, a scale-free measure like the relative risk aversion coefficient can be useful. The value for r may be two or three if the decision maker is considered fairly risk averse, and four if he is extremely risk averse. Values as small as 0.5 may be assumed if an individual is regarded as hardly being concerned about risk.

The mathematical representation of utility is related to the actual decision makers' risk preference. According to Zuhair *et al.* (1992), decision makers may be classified as risk averse, risk neutral or risk preferring, depending on the type of utility function chosen by the researcher. If the second derivative of the quadratic utility function is less than zero it implies risk-averse behaviour. If it is positive it implies risk-preferring behaviour over the entire range of income. The second derivative of the negative exponential utility function is less than zero, thus implying constant risk aversion over all income levels (Pratt, 1964). This is one of its major limitations (Zuhair *et al.*, 1992). Kimball (1990) reported on the analogy between risk aversion and the sensitivity of optimal choices to risk. He showed the usefulness of the third derivative of the utility function, which sign governed the presence or absence of a precautionary saving motive just as the sign of the second derivative governed the presence or absence of risk aversion. The question is, however, whether it is possible to classify decision makers. Are the risk aversion coefficients constant over a wide range of possibilities? When buying a lottery ticket, do I have the same risk aversion if the price is 1 $ or 10000 $ (whatever the size of the lottery outcome)? Moreover, Subjective Expected Utility theory is cast in a timeless setting in which a single choice is made, rather than a sequence of choices. This makes the distinction between final wealth and annual income vague (Machina, 1984). Furthermore, it can take time to decide, and yet sometimes a decision has to be taken at very short time.

The length of the personal time horizon is also an important aspect of farm management. The number of years ahead over which the decision maker evaluates the consequences of alternative actions may influence the choice of the preferred decision alternative.

Maximizing final wealth implicitly assumes additive utility, and the decision maker to be indifferent to the temporal rate of wealth accumulation as long as the overall level is the same (Jeffrey & Eidman, 1991). However, people change when they grow older. Their perception on what is and what is not important changes, and thus their utility function. Their financial situation changes, and thus their ability to bear risk. Utility depends not only on the individual, but also from the utility of others, and thus on changes in the social and economic environment.

Schoemaker (1982) reviewed evidence concerning the Subjective Expected Utility theory. Those who applied the theory find the real world so complex that the theoretic framework rarely offers much help. The Subjective Expected Utility theory fails as a descriptive model because people do not structure problems as holistically and comprehensively as the theory suggests, and they do not process information, especially probabilistic, according to the Subjective Expected Utility theory. Moreover, Subjective Expected Utility theory as an 'as if' model poorly predicts choice behaviour in laboratory situations.

Simon stated 'The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required' (1957). In Simon's concept of bounded rationality, people do not choose the best of all possible alternatives. Instead they seek a satisfactory alternative, they satisfice instead of optimize. Theories of bounded rationality can be generated by relaxing one or more of the assumptions of the Subjective Expected Utility theory. Instead of assuming a fixed set of alternatives among which the decison-maker chooses, we may postulate a process of generating alternatives. Instead of assuming known probability distributions of outcomes, we may introduce estimating procedures for them, or we may look for strategies for dealing with uncertainty that do not assume knowledge of probabilities. Instead of assuming the maximization of strategy, we may postulate a satisfying strategy.

Heuristics can be a relative efficient way to solve decision problems. However, they can also lead to errors. Tversky & Kahneman (1974) considered three heuristics of thinking under uncertainty which can lead to systematic and predictable errors in probabilistic judgments: representativeness, availability and anchoring. Representativeness refers to the resemblance between an event and its population. Availability is the ease with which relevant information comes to mind, for example, recent dry years. Anchoring implies an available relevant value, which is the starting point for additional probability judgments. Although these three heuristics lead to systematic errors, they are usually effective.

Kahneman & Tversky (1979) presented an alternative for the Subjective Expected Utility theory, called the Prospect Theory. In this theory, value is assigned to gains and losses rather than to final assets, and outcomes are weighted according to their probability. The Prospect Theory is able to take anchoring into account. From the descriptive perspective, therefore, it is an improved version of the Subjective Expected Utility model.

Examined deviations from the Subjective Expected Utility theory are also caused by the way in which the research is conducted: the cognitive costs of being rational are not taken into account, decision experiments are conducted with decision problems as discrete events without giving any feedback, and the way in which the decision problem is structured is seldom explicitly checked (Jungerman, 1983). It is indeed costly to go through all phases of a decision. Cost of experienced support in preparing a budget plan for one or more investment alternatives often already exceed 5% of the annual family income. Moreover, farmers rarely face dichotomous choices, like to invest now or never, but they rather choose among a series of options to either invest now or postpone the decision.

Subjective Expected Utility theory still remains the major framework for thinking systematically through complex issues of risky decision making. This is supported by the fact that farmers are clearly sensitive to both the probabilities of events and the outcome contingent on these events, especially for recurring decisions. Where Subjective Expected Utility theory differs from observed decision-making behaviour is in how outcomes and probabilities are evaluated and combined in assessing the relative attraction of different alternatives. Application of Subjective Expected Utility theory, that is cast in a timeless setting, to unique decisions is doubtful. Utility functions of people change when they grow older, as does their ability to bear risk. Furthermore, Subjective Expected Utility theory does not contribute to difficulties in decision making related to the determination of the available alternatives. In conclusion, the major theoretic framework for decision making under risk and uncertainty is rarely helpful to solve real world decision problems, making the best not good enough.

Risk preferences

A decision maker can be considered to be more risk averse than another at all values of y if, and only if, for every risk, his risk or insurance premium is higher than that of the other decision maker (Pratt, 1964). The risk premium is equal to the amount he is willing to pay for insurance against risk. Therefore, adequate rankings of individuals according to their attitude toward risk can only be made if their risk aversion – over their entire utility function – is known.

Risk attitudes are logically related to the financial ability of the individual to accept a small gain or loss. The influence of the risk preference of a decision maker on the choice of preferred action depends on the shape of the distribution function of possible outcomes for alternative actions.

Several field studies were carried out to measure farmers' attitudes toward risk. Risk attitudes have been determined by various techniques: (1) direct elicitation of utility functions; (2) the experimental approach; and (3) partial ordering of risky alternatives.

Direct elicitation of utility functions involves direct questioning the decision makers to specify their risk attitudes (Bond & Wonder, 1980). Early attempts to measure risk attitudes were based on utility functions derived from certainty equivalents of hypothetical lotteries (Officer & Halter, 1968). According to Anderson *et al.* (1977), the simplest method is based on considering an Equally Likely risky prospect and finding its Certainty Equivalent. In using the so-called ELCE-method, utility points are established continuously until sufficient Certainty Equivalents are elicited specifying the utility function.

Because of the lack of realism in the game setting, possible interviewer bias, and the lack of time for respondents to study the hypothetical choices, direct elicitation of utility functions was criticized (Binswanger, 1980; Robison *et al.*, 1984). In a study of risk attitudes of rural households in India, Binswanger (1980) used an experimental approach, involving lotteries with real money payoffs. Dillon & Scandizzo (1978) used mind experiments involving choice between risky and sure farm alternatives.

A partial ordering of risky alternatives, given certain assumptions concerning either peoples' preferences or the distribution of risky outcomes, is provided by efficiency criteria. Efficiency criteria consider the trade-off between the expected outcome and its dispersion. Consideration of the dispersion reduces the ability to select a preferred action, but may reduce the number of actions a decision-maker must compare in making a choice. The interval approach was developed by King & Robison (1981a, 1981b) and is a preference measurement technique designed to be used in conjunction with Stochastic Dominance With Respect to a Function, developed by Meyer (1977). This approach assumes that, over small interval ranges, an average risk aversion measure is a good measure of the Arrow-Pratt function of absolute risk aversion. Stochastic dominance relates shape features of u to distribution function comparisons. The procedure requires the decision maker to choose between pairs of probability density functions of monetary outcomes. It calculates the boundary levels of absolute risk aversion that would make the decision maker indifferent to the two distributions. The method requires the finding of a utility function u(y) which satifies $r1(y) \leq -u''(y)/u'(y) \leq r2(y)$ and minimizes $\int_{-\infty}^{\infty} [G(y)-F(y)]u'(y)dy$. The latter equation equals the difference between the expected utilities of outcome distributions F(y) and G(y). If for given bounds of r(y), the minimum of this difference is greater than zero, then F(y) is preferred to G(y). If the difference equals zero, indifference occurs.

Dillon & Scandizo (1978) concluded that most farmers are risk averse, and that income level, and maybe also socio-economic variables influence risk attitude. Using simple statistical tests, Pope & Just (1991) found strong evidence congruent with constant relative risk aversion, and against constant absolute risk aversion and constant partial relative risk aversion. Evidence for diminishing absolute risk aversion by individuals is provided by Hildreth & Knowles (1982). Young's (1979) survey of risk studies of Australian and American farmers revealed that approximately 50% of the sampled individuals showed risk-preferring attitudes over at least some ranges. Wilson & Eidman (1983) found that 69% of a sample of Minnesota swine producers had almost risk neutral risk-aversion coefficients ranging from –0.0002 to 0.0003 .

In general, most empirical results indicate that farmers are risk neutral to slightly risk averse with respect to mean annual income. However, from the fact that changes in the context or framing of a problem may lead to different preferences, the question arises in which context the 'true' risk attitude is measured. If it can be measured at all. Risk preferences appear only partly to be a stable feature of an individual decision maker. Huirne *et al.* (1996) concluded that eliciting utility functions from farmers is at best a very risky business. They found that a significant proportion of farmer respondents revealed a preference for risk and they also showed that elicited risk attitudes are very unstable. This has lead Hardaker (1996) to the conclusion that we must either infer risk preferences from observed behaviour, make an informed guess, or fall back on efficiency analysis. But then, what does one do with a large and efficient set?

A problem also exists in the definitions of wealth or income. Even within countries, there are no universally accepted data definitions and calculation rules for computing income figures. Differences in measured risk attitudes may be explained as much by differences in farmers' understanding of the meaning of income as by the methods employed. It is, therefore, doubtful whether decision makers can be classified according to their risk preferences.

Risk reponses

A number of strategies can be listed that may reduce uncertainty. The selection of certain production systems may have less variability than others. Diversification is commonly advanced as a method of reducing risk. Two ways of diversification are adding resources and diversifying with existing resources. It is important to notice that the variance of returns for two enterprises is the sum of the variances of each enterprise plus the covariance of the two. Thus variance can be reduced by increasing resources and adding enterprises that have either less variance per money unit of return or a negative correlation with the included enterprises.

Many empirical studies on methods for managing risk were mentioned by Barry (1984) and Eidman (1989). Available evidence indicates that farmers use a combination of methods to manage risk on their individual farms. According to Patrick *et al.* (1985) and Wilson & Luginsland (1988), obtaining information, pacing investments, diversification, production practices, maintaining eligibility for government programs, forward contracting, spreading sales, insurance, and maintaining financial, feed and credit reserves are relevant management responses to variability. In addition to individual risk responses, the role of public policy must be recognized, both in the need for risk management and in the opportunities available to respond to uncertainty.

In Table 1, an overview of empirical research on farm risk management is presented. Major topics of interest were the diversification of the enterprise (Boehlje *et al.*, 1991; Jeffrey, 1988; Johnson & Boehlje,1983; Johnson & Rausser, 1977; Rawlins & Bernardo, 1989; Turvey & Driver, 1987; Young & Barry, 1987), the diversification of production practices (Berbel, 1989; Hatch *et al.*, 1989; Rawlins & Bernardo, 1989; Vandeveer *et al.*, 1989; Williams *et al.*, 1990; Van Zijl & Groenewald, 1986), and marketing strategies (Smidts, 1990).

Diversification may reduce risk if the farmer includes a sufficient number of activities. Constraints for this way of eliminating risk at the individual farm level include the objectives of the farm, management skills, compatibility of activities with the resources available, and economies of scale.

Farm size as a risk response was studied by Held & Helmers (1980), Jeffrey (1988) and Johnson & Boehlje (1983). According to Held & Helmers (1980), expansion by purchase may be advantageous. However, a higher rate of business failure may occur. Increasing the herd size in conjunction with the elimination of some or all crop enterprises was preferred to more traditional expansion strategies (Jeffrey, 1988) .

Tauer (1985), Williams *et al.* (1990), and Young & Barry (1987) presented research examples of maintaining reserves, either feed or financial reserves as risk responses. Carrying reserves is, like diversification, a method for limiting the impact of unfavourable events on the firm, but the reserves cannot affect the events themselves. (Fleisher, 1990). Potentially profitable situations are not used.

Alocilja & Ritchie (1990), Bosch & Eidman (1987), and Vantassel (1987) studied specific production practices as possible risk responses. Specific production practices as a risk method are more likely to affect the occurrence of an event.

The use of information supports farmer's decision making with respect to defining and estimating the expected outcomes of these decisions and, therefore, directly influences the selection of risk methods. Bosch & Eidman (1987) presented empirical evidence that additional information has diminishing marginal results for a given level of risk aversion, and that the value of information increases with the level of risk aversion. Byerlee & Anderson (1982) estimated the value of a rainfall predictor to Australian sheep farmers. The risk averse decision makers attached more value to the information than the risk prone ones did, but, among risk averse decision makers, the value of information declined slightly with the degree of risk aversion, as a result of the higher preposterior variance associated with the use of information. Thus, the decision to acquire new information is in itself often a risky one.

Many efforts with respect to modelling decision making under risk were directed toward single-period, single attribute models. The attribute is net income which is risky. Most of the literature examined did not take the consequences of a sequence of events into account, nor the existence of conflicting goals. A few studies incorporated sequences of events, but did not allow the decision maker to re-evaluate the decision strategy (Kaiser & Apland, 1987). The existence of conflicting goals in farm decision making was explicitly recognized in studies by Berbel (1989) and Patrick (1979).

The fields of interest were those that relate to practical farm management issues. But no attention was paid to the process of determining alternative courses of action. Reports on the use on information were rare, and reports on descriptive research toward decision errors were lacking. Although practical difficulties in obtaining data may occur, it should be possible to gather information about the decision making process on farms that do not succeed to survive. Simulation, stochastic dominance, MOTAD, mean-variance analysis, and quadratic programming are used research methods. More attention was paid to the validity of the research method applied than to the relevance of the decision problem. To the best of our knowledge one has to conclude that research was more method-oriented than issue-oriented.

Uncertainty

Successful farms, those that continue to produce profitably, survive. A farm can change its operations to respond to changes in the external environment. Identifying changes in the environment is part of the decision making process. The farm environment incorporates the decisions from buyers of farm products and suppliers of farm inputs and of colleague farmers. The available decision alternatives are not the same for all farmers, because both the farmer and his relative firm position differ. This makes that not all farmers choose for the single 'best' alternative. Furthermore, the decision is often not whether to invest, but when to invest. Computer based farm accounting systems and herd management information systems (MIS) are introduced in the early and late 1980's respectively, enabling the individual farmer to use recent and accurate information on actual results in analyzing farm performance. Because more and more farmers started to use these systems, the farm environment against

Table 1. Overview of empirical research on farm-level risk responses.

Study	Field of interest	Research method	Classification of risk response
Alocilja & Ritchie (1990)	Adoption of high-yielding technologies	Simulation, Pareto optimization	Specific production practice
Bailey & Richardson (1985)	Marketing strategies for grain sale considering hedging and cash sales	Simulation, Stochastic Dominance	Market information, hedging
Berbel (1989)	Cropping pattern, farm size	Optimization	Production practice diversification
Boehlje *et al.* (1991)	Farm and non-farm diversification	Calculation of several portfolios	Enterprise diversification
Bosch & Eidman (1987)	Value of soil, water and weather information to irrigators	Simulation, Stochastic Dominance	Specific production practice
Byerlee & Anderson (1982)	Value of rainfall predictor to Australian sheep producers	Calculation of Quadratic Utility Function	Feed reserves
Dayton & Baldwin (1989)	Marketing alternatives for grain farmers	Simulation	Government programs, hedging, forward contracting
Hatch *et al.* (1989)	Risk-income trade-offs associated with buying, selling, and producing at alternative catfish growth stages	Safety-First Stochastic Dynamic Programming	Production practices diversification
Held & Helmers (1980)	Purchasing and/or renting land	Simulation	Purchasing and/or renting land
Jeffrey (1988)	Farm expansion, changes in crop mix, specialization in dairy	Simulation, Stochastic dominance	Enterprise diversififcation, farm size
Johnson & Boehlje (1983)	Firm expansion, portfolio activities, storage and hedging options	Mean-Variance analysis (Quadratic Programming)	Enterprise diversification, storage and hedging, firm expansion
Johnson & Rausser (1977)	Land purchase, diversification, insurance	Simulation	Enterprise diversification, insurance Government programs, hedging, forward contracting
Kaiser & Apland (1987)	Participation in farm commodity programs relative to other risk strategies	MOTAD (*) (Discrete Stochastic Sequential Programming)	Government programs
Karp & Pope (1984)	Rangeland management as a control problem, choice of treatment and stocking rate	Stochastic Dynamic Programming	Control of stocking rate and treatment of rangeland
Patrick (1979)	Purchasing and/or leasing land with different loan repayments	Simulation	Debt management
Plain (1982)	Production and marketing flexibility	Simulation (deterministic)	Hedging, spreading sales, flexibility
Rawlins & Bernardo (1989)	Forage diversification, herd size	MOTAD	Enterprise diversification Production practices diversification
Reidy (1988)	Evaluation of tillage/grass vs. tillage	Simulation	Enterprise selection

Smidts (1990)	Marketing strategies of potato producers	Utility Function based on linair regression	Spreading sales, forward contracting
Tauer (1985)	Life insurance vs. installment payments for farm purchase	Stochastic dominance	Financial reserves
Turvey & Driver (1987)	Diversification	Capital Asset Pricing Model	Enterprise diversification
Vandeveer *et al.* (1989)	Irrigating as a risk management strategy	Safety-first Target MOTAD	Production practices diversification
Vantassel (1987)	Grazing strategies, mesquite controlling	Simulation, Stochastic Dominance	Specific production practices
Williams *et al.* (1990)	Two tillage systems, five crop rotations	Stochastic Dominance	Production practices diversification, feed reserves, Government programs
Young & Barry (1987)	Financial assets as a risk response	Mean-Variance analysis	Enterprise diversification, financial reserves
Van Zijl & Groenewald (1986)	Maize cultivar strategies	Simulation, Stochastic Dominance MOTAD	Production practices diversification

(*) MOTAD = Mean of total absolute deviations which the individual farmer operates changed. In 1992, ten years after the introduction of MIS, sow farming data on 75% of all Dutch sows were stored in MIS. With farmers as price takers, this implies that the consumer instead of the farmer will benefit from the long term economic gains of using the MIS. Farmers did not face a dichotomous choice, whether to invest in MIS, but when to invest in MIS. Probably, the early adapters of MIS on sow farms are the only farmers who gained, whereas the late adapters had to adapt in order to limit their loss. Timing of investments is an important risk response.

The external environment of the farm has several dimensions, five of which are major ones: natural, technological, social, economic, and political factors.

A major uncertainty factor of the natural environment for crop farmers is the weather. Present day indoor livestock farming means the use of process automation to regulate environmental control decisions. Therefore, weather is not an important source of uncertainty for farmers in Western Europe, as it used to be. Of course, in the long run global warming may also affect farming. With increasing concentration of farm production in local regions, epidemic diseases receive increasing attention. The individual farm with another farm nearby that suffers from an epidemical disease, faces a sudden increasing risk. The risky farm environment can also differ between EU member states. Farmers in countries that heavily depend on exports are more vulnerable to temporary trade barriers as a consequence of epidemic diseases than their colleague farmers in importing countries.

Technological advance continues to create new breakthroughs in technology. In the 1960s and 1970s, technological innovations were directed towards the reduction of labour, making increases in farm size possible. One of the recent advances in the field of biotechnology is the production of the growth hormone porcine somatotropin (PST) and bovine somatotropin (bST). Saha *et al.* (1994) showed that the decision of Texas dairy producers whether to adopt bST is determined solely by the producer's perception of bST-induced yield and adoption costs. Risk attitude had no influence on the adoption decision.

An important aspect of the social environment of farming in Western Europe is the ongoing process of urbanization, leading to changing consumer attitudes with respect to production methods, and thus influencing the methods farm operators may use. This influence occurs through social pressure and through changes in laws and regulations affecting pig farming.

Because agricultural markets do not reflect the social costs of production, farming in the European Community has evolved to a state where it is often in conflict with the environment. Governments are developing environmental policies that try to take into account environmental costs and benefits as well as income consequences. It is difficult to determine the social cost and benefits of agricultural products. The goals of environmental policy are aimed at the adoption of environmentally friendlier production technology, and have had a more or less floating character over time. This creates an important source of uncertainty for the individual farmer. Some public policy measures, such as subsidies and price guarantees, are directly aimed at providing stability. However, more changes to encourage the use of more environmentally friendly technology are probably forthcoming.

The economic environment of EU farming can be described as a market which is strongly influenced by the EU price and market policy. An important development, as a corollary of the halt to the growth of the EU budget expenses, is the change in agricultural price and market policy towards reduction of price support for agricultural products like milk, sugar, and grain. Although agricultural product prices may vary, most farmers have an idea whether prices are high or low. They know that with certain price levels more farmers are beginning to either leave or expand the business, and thus leading toward a new market situation. The better farmers can determine structural changes in the relevant farm environment, the better they can anticipate to changing conditions in a timely manner.

The relevant farm environment does not only have implications for decision-making. Besides being a decision maker, the farmer is also a worker. There are health risks associated with farming that underscore the serious nature of the labour endured by farmers. In addition to the injuries and illnesses sustained by farm workers, broader public health issues have also come to attention in the form of the spread of pesticide and chemical residues from the farm land into the groundwater, air and soil. A pattern of disease and injury linked to farming as an occupation has been identified (May, 1990). Tractor incidents are the leading cause of fatal injuries. Machinery, animals and trucks are the leading causes of non-fatal injuries.

Long-term uncertainty

Available methods to quantify risk are better suited to estimate short-run than long-run risk. Perhaps the best way to characterize the long-run uncertainty is to develop a set of scenarios that encaptures the range in the uncertainty apparent in the firm's external environment. The strategic management literature recommends the use of scenario analysis to evaluate the desirability of alternative strategies.

A scenario is a set of statements about a possible future state of the environment and of the events and other changes that will lead to the future state. Multiple scenarios or alternative futures emerge as internally consistent views of the future industry structure under one set of assumptions (Willis, 1987). A problem is that scenarios need to consider the full range of environmental factors. The large number of factors makes the number of potential scenarios very large, whereas there is a need to develop a small number of good scenarios (Beck, 1982).

Porter (1985) suggested to examine each element of industry structure and classify them under one of the three categories: constant, predetermined and uncertain. Constant elements of industry structure are those aspects of structure that are very unlikely to change. Predetermined elements of structure are areas where structure will change, but the change is largely predictable. Constant and predetermined structural variables are part of each scenario, while uncertain structural variables actually determine the different scenarios (Porter, 1985).

Technological advance and the existence of a market mechanism are said to be constant elements of the agricultural industry structure. The floating character of environmental legislation is assumed to be an uncertain variable, as well as inflation and relative input prices. In the Western world, inflation levels vary from time to time as a consequence of structural changes in the economy. The impact pattern of inflation is highly unpredictable. Changes in labour costs are a consequence of changes in wealth. For the farmer this implies both higher labour costs and higher levels of family living expenditure. Changes in investment costs reflect changes in building costs. Finally, changes in environmental costs depend on national and international legislation to protect the environment.

Willis (1987) suggested evaluating scenarios on their responsiveness, comprehensiveness, documentation and plausibility. Scenarios should be responsive to the need of evaluating alternative strategies. They should be comprehensive enough to develop the time line of events which lead to the future situation described. The time line of events must begin with the present situation. The shift toward the future situation must therefore have a gradual character, unless abrupt changes are expected. Finally plausibility refers to the need for the scenario to be internally consistent.

To enable controllability of scenario analysis a time horizon of, say, not longer than 5 years should be applied. Longer time horizons make ex post evaluations practically impossible. Moreover, why looking 10–15 years ahead, when it apparently is so difficult to construct plausible scenarios with a time horizon of 5 years? The argument that it takes several years before the full impact of alternative strategic decisions comes into effect seems not strong enough to support the use of scenario analysis with very long time horizons.

A proposed approach for scenario analysis is:
(1) Classify farms according to relevant characteristics
(2) Specify a reference scenario, based on an extrapolation of structural historical developments
(3) Determine the decision alternatives for both the individual and all colleague farms
(4) Specify one or two alternative scenarios for uncertain structural variables of interest
(5) Asses how each group of farmers reacts within the scenarios
(6) Quantify the aggregate effect of expected farmers reactions within the scenarios for variables of interest
(7) Quantify the expected results for the individual farm within the scenarios for each alternative strategy
(8) Choice of preferred strategy

Elements of risk and uncertainty are most apparent in specifying the scenario (step 2 and 4), in assessing expected results for the individual farm and how colleague farmers react within the scenarios (step 5 and 7), and in the choice of preferred strategy (step 8).

To enable the construction of scenarios that describe the relevant farm environment, farms have to be classified in groups according to relevant characteristics, like firm size, geographic location, type of operation. Depending on the purpose of the scenario analysis, suppliers of farm inputs, or consumers of farm products can also be part of the analysis, and need to be classified.

Constructing a reference scenario based on an extrapolation of structural developments of the last few years ensures that historical developments are analyzed at least. It is a good starting point, because it requires only one assumption, that the near future will be like the near past. When analysing historical developments, attention must be paid to the possible presence of changes in structural developments within the time period analysed.

The decision alternatives that are relevant within the scenario need to be defined. Depending on the scenario alternatives like firm expansion, firm location, specialization, and leaving the business must be specified. The next step involves specifying the uncertain structural variables of interest which determine the alternative scenarios. For example, a highly leveraged farmer evaluating a new investment plan can gain important insight into the stability of alternative strategies when studying alternative scenarios with high interest rates and or inflation.

A prerequisite for internally consistent scenarios is insight into the aggregate effects of the expected reactions of individual colleague farmers. The reaction of each group of farmers must be assessed within the scenarios. Than, it is possible to quantify the aggregate effect of farmers reactions within the scenarios for variables of interest. Quantifying the expected results for the own individual farm within scenarios for alternative strategies is necessary to be able to determine the expected relative firm position. What remains is choosing the preferred strategy.

Although the problem of choice remains when different strategies are optimal under different external conditions, scenario analysis helps the farmer to learn the relevance of what he knows and does not know, thereby improving his ability to judge changes in the farm environment, so that he is better able to react to both emerging opportunities and threats in a timely manner.

On a practical note, it must be mentioned that the computational burden can increase very quickly within scenario analysis. A limited number of assumptions that have to be made seems to keep the exercise workable. Five decision alternatives, fifteen groups of farmers and three scenarios make already up for 225 assumptions on how farmers react within a specific scenario. The development of computer based Decision Support Systems (DSS) can provide users with the necessary computational support in applying scenario analysis.

Decision support systems (DSS) can also be a useful tool to improve management skills (Sprague and Carlson, 1982), but results supporting their merits are usually lacking (Adelman, 1991). Huirne (1990) reported a field test with a DSS with two extension officers and on ten farms, which resulted in a full test agreement between the system and human experts of about 60%. In only 4% of the cases, system and experts fully disagreed. No report was given on who was right in case of a disagreement.

For most farmers, the required effort in learning to use a DSS for not so frequent decisions will be too high. Available DSS will be more used by expert advisors than by farmers.

Changing farm environments require a significant level of support to keep DSS operational. The question is whether DSS-user organisations can succeed in maintaining DSS for actual problems. The economic lifetime of a DSS is short, due to both rapid changes in information technology and newly emerging farm decision problems. The costs of developing and maintaining DSS are not only high, it also takes a too long period before the DSS is developed and in operational use. Thus the development of DSS has therefore the potential of becoming a major and risky undertaking. Part of the risk, however, can be shifted to other firms by using commercially available software (spreadsheets, DBMS).

For expert organizations there are also significant potential advantages of using DSS, like stimulating a uniform approach to decision problems. Moreover, DSS can be beneficial for less experienced advisors within the expert organization.

Discussion

For given clear personal and business goals as well as for recurring decisions, Subjective Expected Utility theory with its probability calculus mechanism can be of help in making decisions. For well formalized decision problems, that have to be taken frequently, it is possible that people can learn to improve their estimations. But, application of the theory to unique decisions is doubtful. Most times there also is no single operational variable representing wealth. The decision maker faces the problem of trading off the achievement of one objective for the other. Moreover, expected utility of a probability distibution of wealth is calculated for a certain time horizon. The more distant the future time horizon under consideration, the more vague the alternative futures are. The shorter the time horizon, the more consequences of alternative decisions are neglected. Finally, Subjective Expected Utility theory does not contribute to difficulties in determining available decision alternatives, making the theory to a verly limited extent helpful to solve real world decision problems.

The relevance of knowing risk preferences depends on whether different risk preferences lead to a different choice of decision alternative, and on its impact on utility. It is doubtful that decision makers can be classified according to their risk preferences. Risk preferences only partly are a stable feature of an individual decision maker. Measuring farmers' risk preferences does not appear to be a very promising activity for researchers.

The effectiveness of risk management depends to a great extent on the personal qualifications of the farmer. Especially external orientation and the use of information sources by farmers have a close relation to the survival of the farm business. Adaption of new technologies induce a change in both the farm environment against which the individual farmer operates and the attractiveness of alternative strategies. Farmers often do not face a dichotomous choice, whether to invest, but when to invest. Timing of investments is an important risk response. Therefore, information is essential. But, the required effort to collect sufficient information can be considerable. More focus by agricultural economists on information as a risk response may contribute to improve farm decision making under risk and uncertainty.

To the best of our knowledge, disappointing few observed problems in farm decision making under risk and uncertainty were tackled in the applied agricultural risk research. Research on risk responses was directed at diversification of the enterprise and of production practices, maintaining reserves, and farm expansion. Decision analysis under uncertainty was based on rational models of decision making that require estimation of risk and the use of risk preferences. To address practical issues like formulating alternative plans, estimating both investment cost and productivity level for alternative investment plans, and timing of investments, more research effort should be made to support farmers in what they are doing before telling them what they should be doing.

A method for applied scenario analysis to deal with long-run risk is introduced in this manuscript. Other proposed topics for applied agricultural risk research include: (1) assessment of the need for a strategic change, (2) the creation of databases to determine the (co)variances of input and output prices, and (3) the effectiveness of various kinds of decision support for different decision problems.

Many farmers underestimate the impact of structural changes in the farm environment on the long-term relative position of the firm. The medium long-term viability of the farm may appear to be satisfactory. But when structural changes in a farm sector increase, the risk that the adaptation of the own farm to these changes is too late becomes significant. Research on the relation between the actual firm position and the long-term viability of the firm can improve farmers'assessment of the need for a strategic change.

The creation of databases to determine the (co)variances of input and output prices provides farmers with the necessary information to make correct assumptions required for calculating expected results of alternative plans. The risk of underestimating investment costs decreases. Also, the long-term relation between input and output prices of agricultural products must be taken into account when judging the attractiveness of alternative strategies. Not so much the level of either input or output prices, but the relation between input and output prices is important in determining the attractiveness of alternative plans.

The effectiveness of various kinds of decision support depends on the type of decision problem. Farmers lacking a systematic approach in labour organization may effectively be supported by providing check lists, without further guidance. In other cases, where farmers have problems in judging both emerging opportunities and/or threats, regular guidance may be required. An important question is when to hire advice and to what extent.

Rapidly changing environments ask for a decision framework that takes into account price and production variability, as well as uncertainty due to changes in the social and/or political environment. Scenario analysis can be used as a way to deal with uncertainty. Appropriate guidelines in developing multiple scenarios, if any, are rare. The proposed approach for scenario analysis is not only aimed at identifying the major factors behind the changing farm environment, but must also wean decision makers from their dependence on single-line forecasts.

The computational burden for scenario analysis is great enough that computer based DSS will be required. A prerequisite for effective use of DSS is that the farmers' objectives are well defined and measurable, and that the causal relations of the problem at hand are known. Than, DSS can help farmers in exploring farm decision making under risk and uncertainty without having to pay for possible mistakes.

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