Meaning of Risk and Uncertainty

The task of defining and distinguishing the two concepts of risk and uncertainty is intricate. This problem arises because of the different ways in which the scholars have viewed these concepts. The origin of these concepts, which appear to a layman as more or less synonymous, lies in statistical decision theory. Thus, uncertainty is regarded, in the parlance of decision theory, as a state of randomness inherent in nature regardless of whether decision making is involved or not. Another way in which uncertainty can be gauged is 'a state of mind in which the individual perceives alternative outcomes to a particular action'. Uncertainty is thus generally considered in the context of a probability distribution. Risk, on the other hand, is defined as the expected loss from making a decision when underlying true probability distribution is known. This definition requires the availability of probability distribution of all possible states of nature for defining risk.

In economics, Frank Knight introduced the distinction between risk and uncertainty by stating that while risk is susceptible to empirical measurements, uncertainty is non-quantitative type.


2 Heady, Carl U. Distinguishes between risk, subjective risk and pure uncertainty in somewhat different way - "Economics of Agricultural Production and Resource Use", 1966, p.4-31-3.
He maintains that in decision problems under risk, a probability
distribution can be attached to the states of nature. In decision
problems under uncertainty no such probability distribution can be
attached to the states of nature. It implies that there is no
knowledge of the probabilities associated with these states. Knight's
emphasis on the measurability of probability for making distinction
between risk and uncertainty has been gradually replaced by emphasis
on knowledge or lack of knowledge about probability distribution in
different situations. The latter contributions on this aspect make
a distinction between objective and subjective probabilities associated
with various states of nature. Because of hypothetical construct
implied in defining and using objective probability, its use in real
life decision making has been found to be lacking and subjective
probabilities have replaced them in discussion on decision making.
Subjective probabilities are degrees of belief that a person has in
the truth of a proposition. Thus decision maker may assign subjective
probabilities - either normative or descriptive - on the basis of his
personal perception about the likelihood about various states of
nature and take decisions under uncertain conditions. Thus while a
conception of probability distribution exists under decision making
under uncertainty, knowledge about its true form is absent.

In recent literature, therefore, the conception of risk
and uncertainty has undergone change. Thus James H. Hausman.¹

regards uncertainty as a state of mind of a decision maker who perceives more than one possible consequences of a particular act, and thus it can be represented as a probability distribution. He regards risk as a parameter of the probability distribution (such as variance, probability of loss, etc.) making risk as a property of uncertainty. In more abstract terminology, risk is what increase when the density function of returns is subjected to a mean preserving spread. In this sense, risk refers to a measure about a frequency distribution, which together with expected value (mean) describes the choice under uncertainty. In other words, if means of alternative frequency distributions are same, the risk is described by additional measure about frequency distributions which are most useful in making a choice among alternative distributions. Following this conception, risk is equivalent to variance of a frequency distribution. In the terminology of insurance, risk is defined as the probability that returns will fall below a specific (disaster) level, e.g., below zero or some subsistence requirement.


3 This way of defining risk has link with skewness property of the probability distribution. In the literature on uncertainty skewness and Kurtosis are also emphasised as measures of uncertainty. On a discussion on these measures see Hensley, Earl D., Op. cit., pp.443-453.
When the decision making under uncertainty is defined with reference to the subjective probabilities, a distinction can be usefully made between situations where decision maker possessed substantial experience regarding various outcomes and situations where he had very limited information on the basis of which subjective probabilities can be formed. Thus knowledge gained from previous experience is an important variable in characterizing the decision making under uncertainty.

**Nature and Source of Uncertainty**

The problems associated with the conditions of risk and uncertainty differ in nature under situations which characterize them. One simple and meaningful distinction can be made between situations which are wholly under the control of environment involving no direct involvement of decision making process and situations which emerge out of actions taken by persons and thus involving a decision making process. The former situations are caused by natural factors such as weather conditions, insect or pest attacks, or damage caused by flood, etc. These types of randomness are associated with environment and human behaviour does not have any effect on their causation. The second type of situations are such where the source of uncertainty lies in human behaviour. Adoption of high yielding varieties of seeds and use of modern inputs, for example, give rise to situations involving decision making under risk and uncertainty.  

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1 In one view, the first type of situations are regarded as situations under uncertainty and the second type of situations as those involving risk. See Hanada, C.G. "Risk and Uncertainty in Economics of Agricultural Production: A Survey", Unpublished paper, p.5.
Measuring Environmental Uncertainty

In the first type of situations which are caused by environmental factors and which are not caused by human decision making process, the uncertainty has been analysed with the help of several statistical methods. The following four procedures can be stated to illustrate the work in this direction.

1) Approximating the frequency distribution:

This is the most common method used to analyse uncertainty caused by natural conditions. Researchers on farm have tried to use secondary data on the relevant variable such as yield per acre (in most cases) and to plot frequency distribution. Such measures of dispersion as standard deviation or variance or coefficient of variation are taken to imply the extent of degree of uncertainty over time or space. In analysing and deriving crop insurance schemes also, this procedure has been extensively used. The weakness of this method lies in over simplification of the measure of uncertainty. This method is not able to exclude that part of the variability (say agricultural production) which exists due to environment. Under this method, all variability is taken to reveal uncertainty, which is a simplification.

As mentioned by Houmasset (1976), JAIID consultants have recommended this method of crop insurance in Philippines. In India, Prof. V. M. Deshakar has followed this procedure. In the present study a scheme of Crop Insurance using this method has been worked out.
ii) Production Function Approach

This approach is based on fitting production functions, expressing yield in terms of various inputs. In one variant as adopted, e.g., by Roumasset, the residuals are analysed in terms of their frequency distribution for various levels of an input use. Thus residuals may be classified in two groups after ranking them according to the levels of that particular input and then moments of those two groups are worked out and analysed. The results under this method suffer from some defects which characterise the residuals of a regression model. The implicit assumption that residuals show the effect of uncontrollable inputs (of which environmental uncertainty factors may be prominent) may not be mostly correct, since in a regression even if all measured inputs are taken care of, the measurement errors and unmeasured other inputs may also be important and thereby distort the interpretation of the results and their interpretation.

In another variant of production method approach, instead of following traditional approach of estimating fixed coefficients functions, an alternative of assuming 'Stochastic Coefficient' is adopted. This approach is based on fitting a stochastic coefficient model using pooled cross section and time series input-output data.

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This approach has been useful in bringing the combinations of random effects and their correlations to analyze the effect on uncertainty.

iii) Approach based on Stochastic Dominance Rule

This approach has been used to compare and order various uncertain prospects (such as those indicated by traditional and high yielding seed varieties). In this approach, density function for relevant variable (such as yield) are obtained and cumulative frequencies (on the basis of distribution functions) are evaluated over those prospects. Various orders of Stochastic Dominance Rules have been devised on the basis of successive integration and that particular prospect is selected for which cumulative distribution function shows higher value for all values of that variable.\(^1\)

Apart from the heavy emphasis given to estimation of lower extreme values of uncertain quantities and computationally tedious nature of operations, the method of S.D.R. seems promising for deriving useful choices under uncertain prospects.

iv) Method Based on Moments

On the basis of this method, originally developed by Karl Pearson, Pearson System of probability density function for various crops are computed and for various levels of a given input level, uncertainty in yields is estimated on the basis of moments of the density functions.\(^2\)

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2 For a discussion of this method as developed by Dey, R.M. and others, see Neumasset, James A. (1976), pp.106 ff. He discusses his own work using this method, for the estimation of uncertainty in the yields at experimental stations in the Philippines, at different levels of nitrogen use.
From a brief account of various methods, it is clear that the methods to measure environmental uncertainty are based on understanding and estimation of underlying probability distributions behind variations in the relevant variable (such as yield). Except for the first method, all other methods are basically useful in case of experimentation data or individual farm data. So far univariate distributions have been tried since studies have taken one crop at a time. Since mixed cropping techniques are now quite popular, extensions on the basis of bi-variate and multivariate distributions have yet to take place.

Uncertainty reflected through decision-making by human beings

Compared to measuring environmental uncertainties, the uncertainties reflected in human decision-making process, because of their significance in agricultural policy-making, are receiving greater attention in the literature on risk and uncertainty in agriculture. For example, the analysis of performance of new technologies in developing countries and the questions relating to riskiness in accepting new technologies have increasingly received place in the studies in this area. For this type of analysis several approaches have been followed by researchers. We may briefly summarize them:

The theories of decision-making under uncertainty, as mentioned earlier, are increasingly based on the subjective probabilities to deal with the choice problem faced by decision
maker. Among various issues faced in this connection, the important ones are whether the approach is to be normative or descriptive, Bernoullian or otherwise and how the relevant distribution function is to be estimated.\footnote{1}

1) Bernoullian Decision Theory

Dillon defines Bernoullian decision theory as "a normative approach to risky choice based upon the decision maker's personal strength of belief (or subjective probabilities) about the occurrence of uncertain events and personal valuation (or utility) of potential consequences."\footnote{2} As a normative or prescriptive tool, Bernoullian decision theory is primarily regarded as helpful in making production decisions. The basic postulate of this approach is to regard decision makers as utility maximisers. As a descriptive device, this approach ignores decision costs, which play an important role in taking decisions. The nature of subjective probabilities is used as basis changes depending upon the purpose of analysis. If it is normative, then best-guess probabilities perceived by the analyst are to be used. In the other case of descriptive analysis, the estimation of subjective probabilities itself is the problem. Since the problems of eliciting probabilities of decision maker is great, the best course is to base them on the outside, experimental information. In this case the implicit assumption is that these probabilities approximate farmer's own subjective probabilities on the ground that the farmers' experience contains similar information.

\footnote{1} Rousaasat, James A. Rice and Risk, North Holland, 1976, pp.16-47.

\footnote{2} Ibid. p.16.
Sometimes Bayes' Theorem is used to combine decision maker's prior probabilities with other relevant information to generate posterior probabilities so that consistency with the calculus of probability is maintained. The use of decision maker's subjective probability for normative purposes has been criticised by some because of 'psychic bias' inherent in them. Sometimes it is felt that individuals over estimate the probability of loss and under estimate that of gain. For descriptive work, however, no adjustments are needed for psychic bias, etc.

The subjective probabilities are either directly elicited through direct questioning of decision maker about probabilities about various outcomes or through indirectly by knowing preferences of the decision maker about various actions and thus independently estimating the utility function of decision maker. The idea of subjective probabilities in this approach is defined as "Those probabilities which make the individual's preferences consistent with the ranking of acts determined by the expected utility." ¹

This approach can yield correct results only if farmers talk in terms of probabilities, which is a difficult presumption for farmers in developing countries. Implicit in this approach is the assumption that farmers' behaviour is fully

optimal and that their decision making is based on complete ordering of all conceivable outcomes. This is, of course, a very ambitious assumption for the average farmer taking decision in practice. The Expected Utility Maximization approach, which is based on Bernoullian decision theory, discussed latter on, also suffers from these unrealistic assumptions.

11) **Expected Profit Maximisation**

The approach most commonly adopted by economists, traditionally speaking, is based on profit maximization. Behaviour under risk was also sought to be explained by theory that the people acted to maximize expected gains or profits in money terms. This criterion is thus the logical extension of the theory of choice under certainty. In actual real life situations, it was soon discovered that an ordinary man has to base his decision on outcomes from limited number of occasions. He, more often, has no opportunity to observe the outcomes of a conduct repeated large number of times. The assumption of constancy of marginal utility of income is another drawback of this criterion. This criterion is also not able to explain the behaviour of investors or farmers for diversification of their portfolio or cropping pattern because it takes into consideration a narrow view e.g. short period view. The behaviour derived on the basis of this criterion is thus found to be inconsistent with reality. From these shortcomings it should not be assumed that this criterion is fully discarded. In fact in various problems, the help of this criterion
is taken, while at the same time they incorporate in decision making procedure some other indicators also such as variability or dispersion of that variable.

iii) **Expected Utility Maximization**

The expected utility maximization approach to decision making under uncertainty proceeds by measuring preferences of the decision maker, on the basis of introducing some assumptions of rational behaviour to conventional theory of utility maximization. This approach builds a preference for risk aversion into a theory of choice and explains the fact of diversification in observed economic behaviour.

The rational behaviour is the cornerstone of this approach.

It is assumed that the powers of "rational man" are limited and he is less than perfect. But his behaviour conforms to the following postulates or axioms: 1

**Axiom 1**: If P and Q are any two probability distributions of outcomes, then either P is preferred to Q or Q is preferred to P, or both are considered equally good;

**Axiom 2**: If P is considered at least as good as Q and Q is considered at least as good as R, then P is considered to be at least as good as R;

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Axiom 3: If probability distribution $P$ is preferred to, probability distribution $Q$, and if $R$ is any probability distribution at all, then a probability "$a$" of obtaining $P$ and $(1-a)$ of obtaining $R$ is preferred to a probability "$a$" of obtaining $Q$ and $(1-a)$ of obtaining $R$ - as long as "$a$" is not zero.

Axiom 4: If $P$ is preferred to $Q$ and $Q$ is preferred to $R$, then there must exist a number $C$ such that $CP + (1-C) R$ is exactly as good as $Q$.

A rational man conforming to all the axioms may not exist in practice. Therefore, only general principles regarding his behaviour to judge the alternative decision criteria can be formulated. According to various empirical tests of decision criteria, and based on experience, only one decision criteria of expected utility maximization conforms to the tests of rationality. Thus, Markowitz\(^1\) comes to the following conclusion:

"If a set of preferences is in accord with the expected utility maxia, it is consistent with the axioms. An individual acts according to the axioms if and only if he acts according to the maxia. If we understand the conditions and requirements imposed by the axioms we understand the assumptions behind the use of expected utility."

Another ground on the basis of which expected utility maxima as a theory of risky choice is adopted lies in its consistency with the concept of rationality as understood by economists. It has been shown that an individual may have some aversion to risks and no aversion to some other risks, still he behaves according to expected utility maxima. Arrow discusses the risk aversion hypothesis and reconciles the usual puzzling behaviour of a gambler having general predominance for risk aversion. This also explains the attitudes of the aversions to risk found by supporters of expected profit maximization hypothesis. The expected utility maxima also is able to explain the investment in a diversified portfolio.

The expected utility maximization hypothesis has been found to be valid in a wide variety of cases of seemingly inconsistent behaviour. The shape of a utility function is the main determinant of the nature of decision maker, i.e., whether he is a gambler or a risk averter. Since the shape of the utility function determines the decision maker's attitude towards risk, the selection of the appropriate utility function is the most important task while applying the expected utility maxima to empirical analyses (Figure 1a, 1b and 1c).


Figure 1: Attitudes Toward Risk

1a: Risk Averter

1b: Risk Taker

1c: Risk Taker for \( R_0 < R < R_1 \)
Risk Averter Elsewhere

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Generally a utility function for the purpose of this analysis is assumed to exist mainly in terms of either money income or wealth in the current period. This simplification has been viewed with skepticism by some scholars since money income or wealth may not be sole determinant of utility function. However, it is widely felt that a utility function in terms of money income of one period will provide good approximation description and/or prescription for decision making under uncertainty. Taking the simple framework in which a person's utility is a function of his net money income, we may formulate the utility function as

\[ U = U(R) \]

where \( R \) = net income, \( J(R) \) = total utility of money income.

Further it is assumed that this function is continuous and twice differentiable (i.e., \( U'(R) \) and \( U''(R) \) exist). In such a situation for a person to be risk averse we may regard \( U'(R) \) as a decreasing function of \( R \) as a necessary and sufficient condition. Similarly for a risk lover, the condition that \( U''(R) \) is an increasing function of \( R \). In such cases where a person exhibits the behaviour of risk aversion over some range of income and of a risk desiring over another range we may regard:

- \( U'(R) \) as an increasing function of \( R \) for the range \( R_0 < R < R_1 \) (where he is risk lover) and
- \( U'(R) \) as a decreasing function of \( R \) for \( R < R_0 \) and \( R > R_1 \) (where he shows his risk aversion behaviour).

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The decision regarding the choice of appropriate form of utility function is often difficult because each person as a decision maker works according to his own unique utility function. Techniques have been devised to locate some points on a decision maker's utility surface. The well-known procedure is that developed by J. Von Neumann and Oscar Morgenstern. Mr. Boisvert explains the salient features of their techniques in the following way:

"Their technique (N-M) rests on the continuity assumption. That is, if outcome $X_1$ is preferred to $X_2$ and $X_2$ is preferred to $X_3$, then there exists a probability $p > 0$ such that

$$pU(X_1) + (1 - p)U(X_3) = U(X_2)$$

where $U(x_j)$ is the utility of $x_j$. $X_1$ and $X_3$ and their corresponding utilities are set arbitrarily. $X_2$ is determined by the respondent, after which one can solve for $U(X_2)$. Similarly, as many points on the utility function as desired may be obtained."  

Neumann-Morgenstern procedure has been found to suffer from the difficulty that if the subject (or the decision maker whose utility function is to be derived) does not understand the concept of probability or he already has some prior preferences for some probabilities, his objective probabilities may distort the picture since the procedure given above is based on the calculation of objective probabilities. Similarly the subject's biases towards

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gambling as against a certain outcome may also hamper the objectivity of outcome. Because of these difficulties which may work to harm the purpose of the method itself, two alternative techniques have been suggested. One is modified Neumann-Morgenstern approach and the other is Ramsey model. In the modified Neumann-Morgenstern approach, the difficulty is overcome by using neutral probability (p = 1 - p = 0.5) and in the Ramsey model besides using neutral probabilities, the subject is told to select between two gambles.

Once some points on the utility surface of a decision maker are obtained on the basis of any one of the above three techniques, the shape of the respondent's utility function is determined by fitting alternative functions to the obtained points (examples of such function may be linear, quadratic, cubic, etc.).

The utility functions empirically derived on the basis of above procedures suffer from some limitations from the viewpoint of policy making and generalization. Thus the estimates obtained above are specific to the individual decision maker concerned and it will be hazardous to make generalizations for other farmers. In addition as these utility functions are to be used in complex decision models to apply expected utility maximization principle, it is necessary that derived utility functions are mathematically tractable (in the sense that their extreme values can be easily determined). Generally these utility functions have to form a part of mathematical programming.
apparatus. Such functions are limited in number. In most of these
the usual features are the presence of mean income and variance of
income as determinant of the farmers' expectations.\(^1\)

The basic weakness as mentioned earlier also is that the
risk estimation in this approach is specific to the subject concerned
and no general propositions applicable to other decision makers can
be derived. This procedure allows us to approximate the decision
maker's opportunity locus from which decision maker may choose most
appropriate alternative, given his own attitude towards risk.

As a major criticism of the methods used for estimating
utility surfaces is based on the interview technique generally used
by researchers. It is quite possible that different interviewees
using similar technique find dramatically different results.\(^2\) The
way interviewer puts the question to the respondent, most often
determines his response. Roumasset quotes the results of Tversky
to show that 'if a farmer is asked about the prospective gains or
losses from a particular farm enterprise he is likely to exhibit
utility function that is concave in gains and convex in losses\(^f^\)
and 'the same farmer is likely to exhibit a concave utility for all
positive values of wealth'.\(^3\) If this is valid then we will have an
inconsistency for the majority of farmers.

\(^1\) For some such cases of utility functions, see Boisvert, *Ibid.*, pp.10-14.


\(^3\) Roumasset (1976), p.5.
Thus simply by changing the reference point implicit in
the question the interviewer can produce systematically inconsis-
tencies in subjects' answers. Thus for the success of this method
one has to guard against the subjective biases of interviewer also,
besides the subjective biases of the respondent.

Expectation-Variance (E-V) Approach

In economic theory, the producer is assumed to behave as
maximising his net income. If he is also risk averse, his objective
function is defined by the dual criteria of net returns and maximizing
the variance of net returns which is a measure of uncertainty. The
approach is based on quadratic utility functions, expressed differently
by different authors.\(^1\) Implicit is also the assumption that possible
returns associated with each alternative facing the decision maker are
normally distributed. The basic idea under this approach is to
postulate a quadratic utility function.

\[ u(c) = \alpha_1 c + \beta_1 c^2 \]

where \( c \) is the sum of net returns from farm enterprises.

This form results in a set of utility curves of the form shown
in figure 2. On horizontal axis the expected sum of net returns from
farm enterprises \( E(c) \) is measured and on vertical axis variance of
\( c \) is measured.

\(^1\) Among studies based on this approach mention may be made of the
following study: Michael, C.C., Schluter, "The Interaction of Credit
and Uncertainty in Determining Resource Allocation and Incomes on
Small Farms, Surat District, India, Occasional Paper No.63,
Department of Agri. Econ., Cornell University, 1974.
The utility function assumed here limits the number of strategies that need to be considered by the decision maker, to those efficient under this criteria - those maximizing \( L(c) \) for a given \( \text{Var}(c) \) or minimizing \( \text{Var}(c) \) for a given \( L(c) \). The locus to such points is called \( E-V \) frontier and can be illustrated graphically as shown in figure 3.

The relative magnitudes of \( \alpha \) and \( \beta \) determine the shape of utility function of the individual, reflecting the willingness and ability of the individual to bear uncertainty.\(^1\)

A variant of this approach, used by Schluter and Mount\(^2\), is based on minimizing the absolute deviation, defined as the mean over years of the sum of deviations of gross returns from the sample mean-gross returns multiplied by activity levels. This method was used to estimate risk on irrigated farms versus unirrigated farms - both growing high yielding and traditional varieties. It is observed that this procedure is not much different from Stochastic Dominance Rule. Thus the \( E-V \) frontier approach is giving emphasis on lower tails of the probability distribution of yields or incomes.

\(^1\) Ibid, p.4.

FIGURE 2: THE QUADRATIC UTILITY OF INCOME FUNCTION

FIGURE 3: THE OPTIMAL STRATEGY UNDER UNCERTAINTY
Behaviouristic Approaches to Decision Making

The full optimality inherent in expected utility maximization approach makes decisions taken on the basis of this approach unrealistic, since estimation of utility function is a difficult task and even if it is possible to construct a utility function on the basis of one period observation, to expect it to be applicable to future and to be generalisable to all farmers is very unrealistic. The behaviourist school, mainly Shackle, has developed another approach. This approach emphasizes the process of decision making and asks what decision processes and rules of thumb are actually followed to determine the choices. It takes into account the individual’s cognitive processes more realistically.

Shackle’s Focus Less Approach

According to Shackle\(^1\) any venture can be hypothesized in the form of a success or a failure. There can be various hypotheses of success and failure. Among the various hypotheses of success associated with a venture, one alone is accountable in full for the enjoyment which he derives from the thought of venture. Similarly among all hypotheses of misfortune associated with a venture only one hypothesis is accountable in full for the full intensity of distresses. Therefore, his attention will be focused upon these two hypotheses.

The intensity of enjoyment of a given hypothetical outcome (or the intensity of distress by anticipation) is mainly a function of two variables. It is an increasing function of the desirability (or undesirability) of the outcome in question and a decreasing function of the degree of potential surprise associated with it. The functional form for this is given below.

\[ \phi = \phi(x, y) \]

Where \( \phi \) is the intensity of experience either of enjoyment or distress, \( x \) is the desirability (or undesirability) of outcome and it is positively associated with \( \phi \). When the value of \( \phi \) is maximum in case of success or a gain, it gives us an idea of focus gain. Similarly, the maximum value of \( \phi \) in case of distress or loss gives us an idea of focus-loss.

The system developed by Shackle has been explained lucidly by Roussas. The diagrammatical presentation and its explanation has been reproduced from his book.¹

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FIGURE 4: SHACKLE'S PRIMARY AND STANDARDIZED FOCUS LOSS AND FOCUS GAIN
"The curve which looks like a density function reflects Shackle's potential-surprise. The vertical axis measures lack of surprise, i.e., maximum potential surprise minus surprise at that point. Thus there is zero potential surprise at point N and maximum potential surprise where the tails of the surprise distribution intersect the horizontal axis. Primary focus gain is that point on the surprise function that maximizes the ability of an income level to "stimulate mind". To find this we need a function which indexes the extent to which a given gain and surprise combination stimulates the mind. Geometrically we can construct a map of "isostimulus curves" (the lines in the picture that look like indifference curves), and, given the appropriate second order conditions, locate the point of maximum stimulus as the tangency point marked $P_G$ in the diagram. The same procedure is repeated to define primary focus loss $P_L$.

"Standardized focus gain is then defined as the amount of gain necessary to stimulate the mind to the same degree as $P_G$ but with zero potential surprise, i.e., point $S_G$. Standardized focus loss, $S_L$, is the analogous point on the loss side. The individual's ranking of alternatives is then assumed to depend only on the standardized focus gain and loss of each alternative."

The Shackle's use of potential surprise is based on the alleged inability of the decision maker to think in terms of mutually exclusive events. It may be however mentioned that his potential surprise is not fundamentally different than subjective
probability of degree of belief. This approach also is not able to put forward a set of axioms which define the rational behaviour. Arrow has shown that Shackle's system is not able to distinguish two actions, one of which dominates the other in the sense of being at least as good in all states of the world and better in at least one.

The Shackle's system, however, has the quality that decision maker is not subjected to intricate questioning involving lotteries and probabilities as is done in expected utility maximization approach. The questioning involved in this system is more a matter of fact to which respondent is familiar. Because of this advantage the concept of focus-loss has been incorporated in linear programming framework by Boussard and Petit,\(^1\) by adding a constraint that the focus-loss must not be less than some critical minimum level of income.

**Decision Criteria based on Rules of Thumb**

The expected utility maximization and the Bayesian approaches are based on the assumption of personal probabilities. In the former these probabilities are taken as given without considering as to how they are formed. In the latter approach, a mechanism is incorporated for adjusting the personal probabilities as new information is acquired. Both these approaches are, however, regarded as full-optimality models, because these models provide best solutions, given the constraints. None of these two models are based on decision process. They ignore decision costs which is an important aspect constraining the farmers from taking optimal decisions.

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The behavioural models also suffer from some drawbacks, while having the advantage of keeping in mind the importance of decision costs and being based on feasible cognitive process. Although behavioural approach incorporates real-world decision rules into its structure and therefore predictions based on it are more accurate compared to full-optimality models, the approach completely ignores possible changes in decision rules and thereby scope of having wrong decisions. In such cases full optimality approach may be a useful guide for predicting and understanding behaviour.

As a result of pitfalls implicit in each of the two approaches, researchers are more and more relying on a blend of two approaches by incorporating simple decision rules into optimising framework.

The models based on "Rules of Thumb" rely on feasible and practical considerations and are found on the principle of bounded rationality as developed by Simon. As we noted earlier full-optimality models such as expected utility maxima are based on the postulates of rationality, emphasizing the picking up of best possible alternative, given the preferences and constraints, without regard to whether the decision process is used (or even it exists) or not. Bounded rationality models emphasize the

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decision process itself. In this view rationality is a much wider concept than what is supposed by Neumann-Morgenstern theory. It is assumed that a farmer thinks in terms of limited number of alternatives, and he chooses from among them on the basis of his experience by an orderly and finite process of thought which may be described as Rules of Thumb. Among them the well known Rules of Thumb are
time given below.

1) **Safety Principle**

This rule implies the belief that the people have a real concept of what constitutes a personal economic disaster and that they believe that there is a possibility of experiencing such a disaster. Consequently it is hypothesized that people react by minimizing the probability of such a disaster. Each individual, for example, has a minimum acceptable income, say $A$. If his income falls below this level, the person is believed to have experienced an economic disaster.

"If a person has information concerning the expected income ($\mu$) and the variance of income ($\sigma^2$) for all feasible choices open to him, he can minimize the probability of disaster in the following way:

$$\frac{\sigma^2}{(\mu-A^2)^2}.$$  

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This rule which is also called "Minimum X" criterion or Roy principle has the theoretical advantage of introducing the concept of disaster level of income. In practice, however, there may be persons who do not follow this rule of minimizing the probability of disaster.

ii) "Safety First" Principle:

Teller attempted to salvage the safety principle from Roy's conservative assumptions and proposed the "maximum \( \mu \) criterion." In his own words, the principle can be described as follows:

"Suppose that the entrepreneur does not want the probability of his net income falling short of \( R^* \) to exceed \( \alpha \). Hence, he will not choose any action such that \( P(R < R^*; S) > \alpha \) (where \( S \) = action \( S \)). This means all his actions can be put into one of the two classes. The first class consists of all actions "S" such that:

\[
P(R < R^*; S) > \alpha,
\]

and the second class consists of all actions \( S \) such that:

\[
P(R < R^*; S) \leq \alpha.
\]

All the actions in the second class we shall call admissible. Then the entrepreneur will choose that action \( S \) of the admissible actions such that his expected income (\( \mu \)) is maximum."

The objective function in applying this criterion is

\[
\text{Maximise } \mu \text{ subject to } \frac{\sigma^2}{(\mu - R^*)^2} \leq \alpha
\]

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The difficulty with this approach is that the two decision parameters in this approach, \( \alpha \) and \( R^* \), must be chosen before the decision rule can be applied. This principle does not clarify whether these two parameters should be chosen independently or not.

A variant of "safety first" principle is due to Shinji Katoaka,\(^2\) termed as "Safety fixed" rule. This criterion suggests that

"an entrepreneur wishes to ensure himself some non-negative income with some specified high probability \((1-\alpha)\). Each alternative can guarantee him some income at this specified high probability level. Accordingly, he selects the portfolio which maximizes the income which he can be assured \([1(1-\alpha) \text{ per cent of time} \int \text{i.e., ma}] \) subject to \( P (R < R^*) < \alpha \) \). Appealing to Chebyshev's inequality once again, this criterion can be restated (for a given \( \alpha = 1/K^2 \)) as

\[
\text{Max } \mu = K \sigma
\]

Thus for normal distributions, safety first is equivalent to maximizing a utility maximization of the form \( \mu - K \sigma \), where \( \mu \) and \( \sigma \) are the mean and standard deviation of profits.

iii) Change Constrained Programming

Both safety and safety first principles are not particularly appealing when interpreted in terms of utility functions. Under such conditions where farmers are known to be averse to falling below a particular income level, chance constrained programming has been

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advocated to be more promising. Under CCP the objective function $\pi^*$ is maximized subject to a chance constraint of the form of $\pi^*(\Pi < a)$ where $\Pi$ is objective such as profit, $a$ represents exogenously determined disaster level, and $\bar{a}$ shows the probability limit. "Risk aversion in this model takes the form of rejecting any frequency distribution with an unacceptably higher chance of failure. Once this amount of security is ensured, the decision maker is assumed to be risk neutral regarding his choice among remaining distributions."¹

In such cases where no available production technique is found to satisfy the chance constraint, a reasonable rule of thumb would be to come as close as possible to satisfying the chance constraint, i.e., when the chance constraint is found to be violated, the rule of thumb suggested is to switch to safety principle.

Roumasset uses lexicographic ordering in this composite multiple goal model which he terms as U.S.F. ³ This has the form of a full optimality model in the sense that "it prescribes a unique and complete pre-­ordering."² It is pointed out that this method can be used to give an unambiguous representation of Simon's notion of satisfying according to hierarchical objectives and economizing on decision costs.³

² Ibid., p.50.
³ Ibid.
Roumasset has developed another model $L.S.F_{2}$, where chance constrained programming model is combined with safety fixed principle. "If the risk constraint is fulfilled, $L.S.F_{1}$ and $L.S.F_{2}$ predict the same choice. When the constraint is violated, $L.S.F_{2}$ is roughly equivalent to comparing frequency distributions according to their certainty equivalents where the risk premium increases as $\alpha$ increases."\(^1\)

The $L.S.F.$ models have some advantages of both the full optimality and behaviouristic approaches. The models are well defined full optimality models in the sense of having a complete lexicographic ordering fulfilling the usual axioms of consistent choice. At the same time, these models are similar to Simon's bounded rationality involving satisfying behaviour instead of purely maximizing behaviour. Thus as Encarnacion has shown, lexicographic ordering provides a full optimality version of satisfying.\(^2\) Added advantage of lexicographic ordering based models over utility maximization based models lies in their involving reduced decision costs and simplicity. In short, it represents a compromise solution among the two approaches having advantages of both.

The decision models can be divided broadly in two broad groups:

a) Models based on a utility function

b) Models based on simpler safety criteria.

\(^1\) Ibdk.

Hans Binswanger takes note of a casual impression that there is an apparent similarity of predictions of the two classes of models. Of course this has not been verified with the same set of data. Further he says that both the types of approaches require some knowledge of decision maker’s attitude towards risk. Models based on utility function require the estimation of utility function and simpler safety criteria require fixing of disaster level of income, focus loss, etc. Therefore he concludes that unless one chooses some simpler representation of attitudes arbitrarily, the elicitation of disaster level of income or focus loss is not less hazardous than the elicitation of utility function.

Considering the difficulties involved in both the above approaches several researchers have developed the use of game theoretical models for deriving optimal decision rules under risk and uncertainty. It is postulated that nature and farmer are involved in the game. From observations on previous periods indicating various natural conditions under various farmer’s strategies the payoff matrix is developed. The expected payoffs are derived for various strategies and suitable decision rules are applied. Looking to its simplicity and amenability to more aggregative data obtained from surveys the game theoretical approach has been adopted in this study in Chapter V and optimal strategy and payoffs are derived using various decision rules. The game theoretical model and various decision rules are explained in Chapter V itself.

Crop diversification

Diversification means production of several crops at a time. As farm products respond differently to the same weather conditions, farmers try to reduce risk through crop diversification. In other words, they reduce the variability in their incomes by producing several commodities. Diversification is employed as a precautionary measure against uncertainty where the immediate goal of a farmer is not profit maximization but income stabilization.

Income variability can be lessened through diversification only if the prices and yields of the products bear proper correlations. If the correlation coefficient is -1, then the two enterprises serve optimally as a precaution against uncertainty. While adopting crop diversification, the farm operator may think to reduce income variability either over his entire operating career or for a single year. These two considerations are not identical and need not lead to same course of action.

The model with two enterprises can be presented as follows:

$$\min \sigma^2_T = q^2 \sigma^2_A + (1-q)^2 \sigma^2_B + 2 \rho q(1-q) \sigma_A \sigma_B$$

where

$$\sigma^2_T = \text{total variance of income}$$

$$q = \text{proportion of resources allocated to enterprise A.}$$

$$(1-q) = \text{proportion of resources allocated to enterprise B.}$$

$$\rho = \text{correlation coefficient between A and B.}$$

---

Variance minimizing value of $q$ can be found by setting,

$$
\frac{d \sigma^2 I}{dq} = 2q \sigma^2 I - 2(1-q) \sigma^2 A + 2(1-q) \sigma^2 B - 2(1-q) \sigma A \sigma B = 0
$$

If the objective is to minimize income variation relative to income level, the above model can be modified as:

$$
\min (CV)^2 = \frac{q I_A + (1-q) I_B}{[q I_A + (1-q) I_B]}^2
$$

where

- $I_A = \text{income from enterprise A}$
- $I_B = \text{income from enterprise B}$

The value of $q$ that will minimize $(CV)^2$ can be obtained by setting

$$
\frac{d (CV)^2}{dq} = 0
$$

This model can be expanded to consider any number of enterprises.

Time-series data are needed on yield and prices of various farm enterprises to calculate the corresponding income variances.

**SUMMARY**

This chapter has surveyed the various concepts and methods used for defining and measuring the risk and uncertainty. Various models explaining the decision making under risk and uncertainty have been briefly presented. Broadly speaking, it can be said that there is a noticeable shift from objective probabilities to the use of subjective probabilities in decision making process. Measurement of environmental uncertainties has been attempted by several researchers, though a major requirement has been the availability of a meticulously collected information on a time series basis at farm level under more or less
experimental basis. In models used for understanding and analysis of decision making under uncertainty, models based on full-scale optimisation including commonly used mean-variance (E-V frontier approach) are theoretically elegant and provide useful decision rules, but they suffer from the limitation of ignoring the nature of decision process including the decision costs implied therein. The behavioural models also suffer from limitations of ignoring changes in decision rules. The best alternative consists in combinatorial approach as enunciated by Roumsset where the two approaches are combined to ensure optimality and decision making utilising rules of thumb. The efficacy of two sets of models can be judged by comparing their predictions. If Hans Binswanger’s casual finding of similarity of predictions obtained from two approaches is to be relied upon, then the practical criterion for the choice of model could be simplicity. From this viewpoint the use of game theoretical models is made by various researchers where it is postulated that the farmer and nature are involved in the game. Several decision rules have been evolved for this purpose. The present study adopts game theoretic approach for analysing optimal strategies and applies these decision rules in Chapter V.