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DECISION THEORY: A REVIEW AND CRITIQUE
OF APPLICATIONS IN AGRICULTURE

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Beverly Fleisher

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DECISION THEORY: A REVIEW AND CRITIQUE
OF APPLICATIONS IN AGRICULTURE

By
Beverly Fleisher

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

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ABSTRACT

DECISION THEORY: A REVIEW AND CRITIQUE OF APPLICATIONS IN AGRICULTURE

By

Beverly Fleisher

The degree to which state of the art decision theory and its applications can explain and predict farmers decision making behavior under uncertainty is assessed from an economist's perspective.

Section One, "Describing Decision Problems Under Uncertainty", describes the framing of decision problems, sets forth basic definitions, and establishes a framework for the study. Section Two, "Models of Decision Making Under Uncertainty", examines the models which underlie the empirical work reviewed including 'rule of thumb' models, safety first models, lexicographic ordering models, and the expected utility hypothesis. Section Three, "Applications of Decision Theory", focuses on the application of these models in agricultural settings. It includes a discussion of methods used to obtain utility functions and risk attitude coefficients. More importantly it examines and questions the assumptions commonly employed in empirical studies. Section Four, "Looking Ahead", explores theoretical extensions of existing models and suggests priorities for future research.

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SECTION ONE

DESCRIBING DECISION MAKING PROBLEMS UNDER UNCERTAINTY

Nowhere in economic life is choice more fraught with unknown consequences than in agriculture. Because of the unique nature of agriculture, which is influenced by weather, pests, and other environmental factors beyond the farmers control, volatile commodity markets and lag time in adjustment, uncertainty about returns has a major influence in the producers decision process.

The goal of this paper is to determine the degree to which state of the art decision theory and its applications can explain and predict farmers decision making behavior under uncertainty. This will be accomplished through a careful examination and critique of decision theory from an economist's perspective.

In this, the first of four sections, an overview of the study is presented, risk and uncertainty are defined, and the parameters of the decision problem are set forth.

CHAPTER I

AN INTRODUCTION

Decision theory is the study of the selection of action choices under uncertainty. Economic disciplinary research on decision theory focuses on the formation of models of decision making behavior, characteristics of decision makers, and the ability to predict action choices within contrived or actual environments. Decision theory, as a theory, is also concerned with the optimal size of efficient sets and trade-offs between Type I and Type II error. Applied decision theory requires an antecedent theory or hypothesis about decision making processes. The theory or hypothesis need not be well formed or justified, but nevertheless must be a theoretical statement in the logical form "if, then." Only then can one formulate a prediction which is also of the "if, then" form.

This paper examines the theoretical aspects and applications of models of decision making under uncertainty. The examination of decision theory is presented in four steps. Step one describes decision problems under uncertainty. Step two describes existing decision models and their tests. Step three examines the validity of the assumptions underlying the models and reviews empirical applications of the models described in step two. Step four returns to an examination of existing decision theory in light of what has been learned from its applications in studying farmers' decision making behavior and attitudes towards risk.

Chapter I sets the stage for the remaining chapters by presenting an overview of the study and the general concepts of decision problems under uncertainty.

In Section Two, Chapters II and III trace the development and examine the axioms of two major models of decision making under uncertainty. Chapter II focuses on safety-first models and the questions of whether attitudes towards risk¹ affect cropping decisions within a safety-first framework. Chapter III examines the expected utility hypothesis and reviews two tests of this hypothesis.

As part of Section Three, which focuses on applications of decision theory, Chapter IV describes and discusses alternative measures of local attitudes towards risk which are often used as a tool in predicting decision choices. Chapter V examines several of the methods used to empirically determine the utility functions of individuals within the expected utility framework. Also discussed are the implications of the utility function's form on measurement of risk attitude coefficients described in Chapter IV. Chapter VI builds upon the previous two chapters by reviewing the methods used and conclusions reached in many applied studies which measure farmer's

¹Use of the term 'attitudes towards risk' has been the source of some confusion since risk aversion and risk preference have often been equated with an aversion to or love for taking chances. But unless some measure of the degree of chance taking associated with a particular choice is explicitly included as an argument in the individual's utility function, his choices are assumed to be unaffected by the degree of chance taking involved. 'Attitude toward risk' as used here and in most of the current literature on decision theory is a measure derived through several methods including the rate of bending of a utility function with a single argument such as wealth or income. As Friedman and Savage (1948) demonstrate, a utility function can be used to explain why gambling and/or insuring is done without requiring that love for or aversion to taking chances per se be measured. Measures of attitude towards risk are explained in detail in Chapter IV.

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risk attitudes and their correlation with socioeconomic variables. Chapter VIII concludes the section on applications of decision theory by taking a critical view of the empirical work discussed in Section Three in light of questions which have been raised regarding the universality of utility functions and risk attitude coefficients, two of the major tools of applied decision analysis.

Chapter IX, the first chapter in Section Four, returns the readers attention to the theoretical realm in a discussion of extensions of the expected utility hypothesis which have been proposed in an attempt to improve its predictive powers. Chapter X, the final chapter of this paper, provides a summary of the evidence presented regarding the usefulness of safety-first and expected utility models for predicting and understanding farmer decision making. This discussion concentrates less on the theoretical aspects of the models, which are covered in part in Chapter IX, than on the difficulties which have been pervasive in their application. The basis for this discussion is presented in Chapter VIII of Section Three. The chapter, and the paper, conclude with the presentation of the author's suggestion of fruitful directions for future research in decision theory.

Figure 1.1 provides the reader with a schematic diagram of the conceptual organization of this paper and the chapters which comprise each of the four sections outlined above.

Defining Risk and Uncertainty

The definitions of risk, uncertainty, and attitude towards risk used in decision theory do not correspond to the everyday meaning of these words. In decision theory as in other sciences, the definition of common words must be refined and formalized if they are to

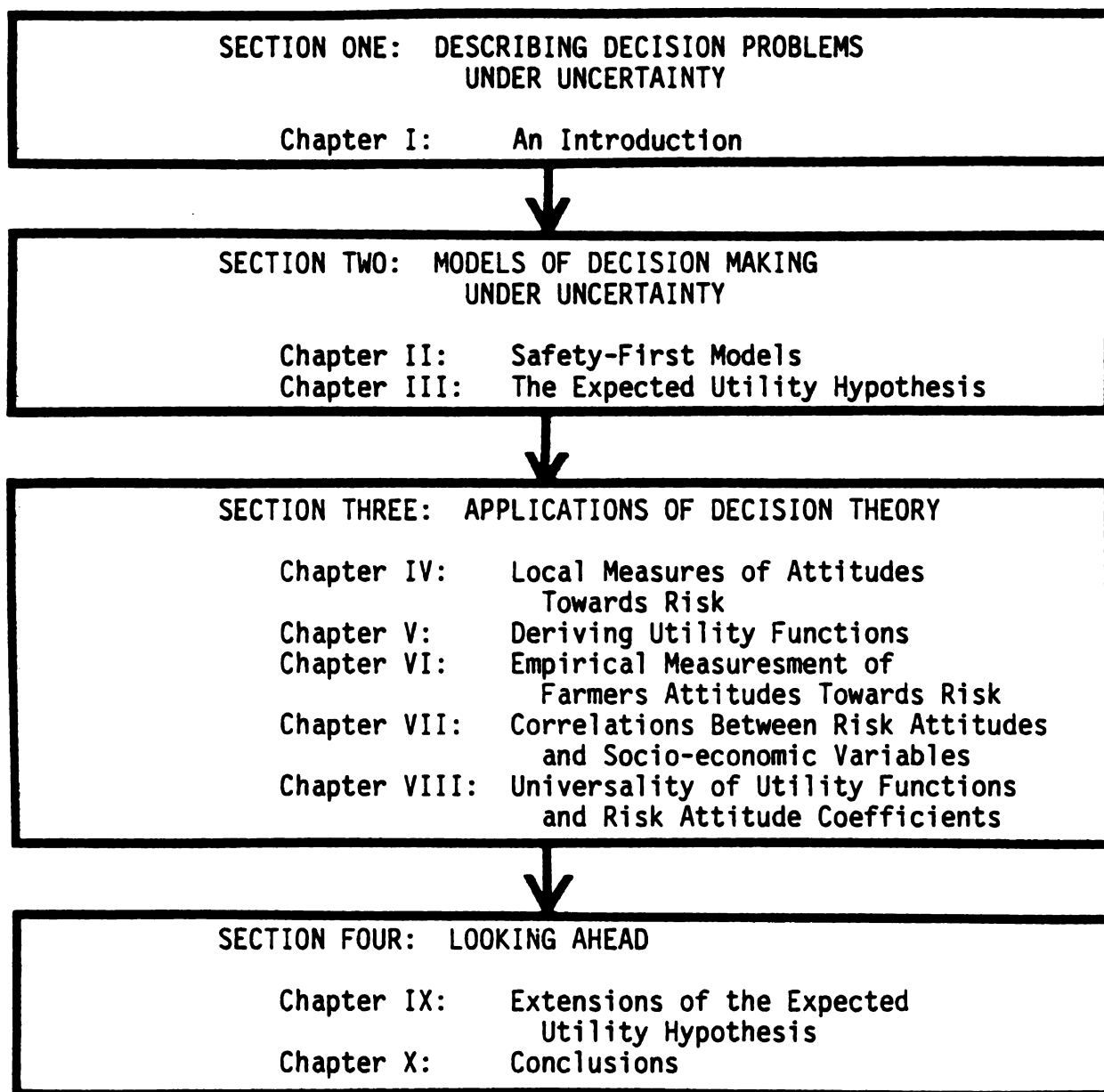


Figure 1.1. Schematic Diagram of the Conceptual Organization of the Paper and the Chapters which Comprise each of its Four Sections

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be operationalized and used in the deduction of theories and hypotheses.

The concepts of risk and uncertainty are commonly linked and often used as substitutes. Knight, in his seminal work, Risk, Uncertainty, and Profit (1921) distinguished between risk and uncertainty, defining risk as occurring in a situation in which the probabilities associated with different outcomes are measurable and uncertainty as a situation in which these probabilities are not measurable.

In modern decision theory uncertainty is treated as a state of mind in which the individual perceives alternative outcomes to a particular action choice. Risk, on the other hand, has to do with the degree of uncertainty in a given situation. Among applied researchers the two most popular definitions of risk are measures of dispersion of outcomes such as variance, and the 'chance of loss' or the probability that a random net income will fall below some critical level. A third approach, expressed by Stiglitz (1979) is that risk is like love; we have a good idea of what it is but we cannot define it precisely.

Defining risk is more than a problem of semantics. The question of how to model decision making under uncertainty and how to determine the role of risk aversion in decisions are dependent upon the definition of risk accepted. Researchers favoring minimax, maximax, safety first, and other 'rule of thumb' decision models prefer to define risk as the chance of loss, while those using expected utility maximizing models employ the definition of risk as the dispersion of outcomes from a given action choice.

Both of these "definitions" of risk confuse a measure of risk with its definition. For the purpose of this essay, risk will be

defined as uncertain outcomes which can affect an individual's well being positively or negatively.

Uncertainty, if couched in terms of information, or the lack thereof, about a particular action choice implicitly assumes that there exists a deterministic world. Acceptance of this definition might lead to the prescription of gathering more information to reduce uncertainty. This prescription can be questioned in light of the fact that all perceptions of information are subjective, and the generalized acceptance of Heisenberg's uncertainty principle which states in its broadest terms that one cannot know with certainty both the position and momentum of an object at the same time. In other words, it is impossible to escape from an element of uncertainty in even the most basic physical measurements, such as the position and momentum of an electron. Therefore, in this essay, the definition of uncertainty used will not be limited to imperfect information in a deterministic world, but will instead be treated as unknown outcomes.

This study focuses on one sub-step of the managerial process: the preference ordering of action choices within the decision function. (Johnson, et al., 1961) When studying the managerial process in its entirety the decision maker's state of knowledge and the role of learning are extremely important. The interdependency between learning processes and decision making raises a question as to whether the study of decision making can be isolated from the study of other managerial processes.

The Decision Problem

For a decision problem to exist, the decision maker must have more than one action choice available to him. The decision problem

can be conceived of as the selection of an action choice from among a set available to the decision maker noted as a_j ($j = 1, \dots, n$). The outcomes which may result from an action choice depend on unknown or random states of nature denoted as S_i ($i = 1, \dots, m$) to which the decision maker assigns probability measures $g(S_i)$ ($i = 1, \dots, m$). Consistency requires that $g(S_i)$ be non negative, and that $g(S_1) + g(S_2) + \dots + g(S_m)$ equal one. The final outcome resulting from the decision maker's action choice and the possible states of nature is described as O_{ij} ($i = 1, \dots, m$; $j = 1, \dots, n$). O_{ij} is therefore the outcome resulting from the occurrence of the i -th state of nature given the decision maker's choice of the j -th action. The elementary outcomes O_{ij} may be in nonhomogeneous units. For example O_{i1} may be in yields of soybeans per hectare, while O_{in} may be in hundredweights of milk. Because of the nonhomogeneity of possible outcomes from different action choices, the outcomes are commonly stated in terms of their cash value equivalent.

Table 1.1 illustrates the decision environment just described. The first column lists the possible states of nature while the second shows the decision makers subjective probability of each state's occurrence. The next n columns designate the action choices available to the decision maker. The premaximized outcomes π_{ij} in the body of the table indicate interaction between an action choice and the occurrence of a state of nature.

If the outcome of each action choice is known with certainty, e.g. $g(S_1)(i=2, \dots, m)=0$, then the decision problem is a simple one. The decision maker's selection from among the available action choices depends solely upon the magnitude of the outcomes π_{ij} ($i=1, j=1, \dots, n$) with the largest outcome being preferred. In this case the value

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Table 1.1

Tabular Description of a Decision Environment

States of Nature	Probability of States of Nature Occurring	Action Choice		
		a_i	a_j	a_n
S_1	$g(S_1)$	π_{11}	π_{1j}	π_{1n}
.				
S_i	$g(S_i)$	π_{i1}	π_{ij}	π_{in}
.				
S_m	$g(S_m)$	π_{m1}	π_{mj}	π_{mn}

adapted from Robison and Fleisher, Table 2.1

of π serves as an index which can be used to infer preference ordering. The values of outcomes could be transformed by any function such as U to create a new index. The preference ordering would be unaffected as long as the function U is a monotonically increasing function of π . As a result, under conditions of certainty it makes little difference whether the decision maker maximizes the function $U(\pi)$ (the utility of income) or π (income) to find the preferred action choice. The traditional approach of static production economics, which assumes perfect knowledge, and hence certainty, has been to ignore the function $U(\pi)$ and maximize over π .

When uncertainty as to the state of nature which may occur is introduced, the decision problem becomes more complicated because of the multiplicity of outcomes which may occur with probability greater than zero. Under uncertainty there is only one case in which the action choice is obvious. This occurs when, no matter what the state

of nature, the outcomes from one action choice are always greater than the outcome from all other action choices. This case, known as first degree stochastic dominance, is extremely rare.

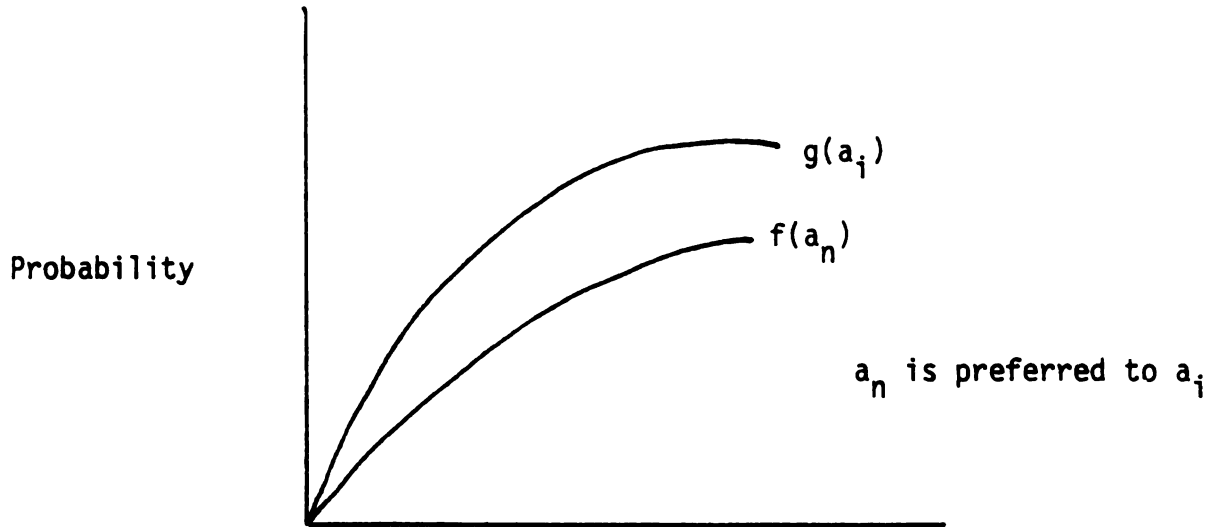


Figure 1.2. First degree stochastic dominance in an uncertain decision environment.

For those choices where the inequality is reversed over at least one of the states of nature, preference is again uncertain.

The probability density function of outcomes associated with each action choice can be characterized by its expected value, the mean, and a measure of its dispersion, usually the variance or standard deviation. A long tradition has held that if two action choices have the same mean, the one with the largest variance is considered to be the riskier of the two.

Rothschild and Stiglitz (1970) have refined this concept and presented it in terms of mean preserving spreads. In Figure 1.3 the area under $g(a_i)$ equals the area under $f(a_n)$ which equals one, and the areas $A=B=C=D$. $f(a_n)$ can be obtained from $g(a_i)$ by shifting the probability from the tails of $g(a_i)$, areas A and D, to the center,

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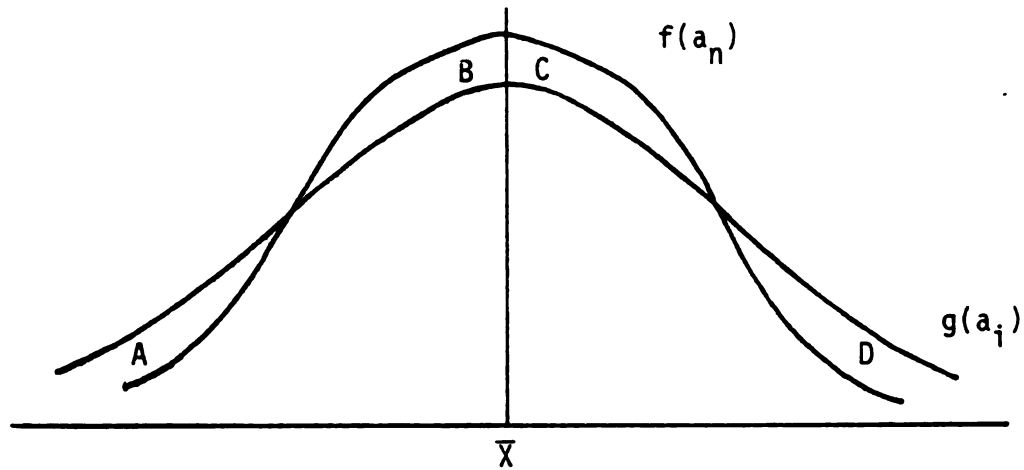


Figure 1.3. Probability density functions of action choices a_n and a_i under uncertainty with equal means and unequal variances.

areas B and C. For a risk averter, who has decreasing marginal utility for money, the expected utility of gain from reducing the probability of low incomes over the domain of A in exchange for increased probability over the domain of B more than offsets the reduced prospects of income over the domain of D in exchange for a greater probability of their occurrence over the domain of C. Therefore, action choice a_n would be preferred to a_i by a risk averse decision maker.

It is not uncommon to have distributions compared based on their riskiness. But, action choices can not be ordered solely on the basis of their riskiness. Ordering of action choices connotes preference and to establish preference among probability density functions requires the establishment of a preference ordering rule. It can be expected that the ordering of probability density functions will vary between individuals and will depend, in part, upon their attitudes towards risk.

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SECTION TWO

MODELS OF DECISION MAKING UNDER UNCERTAINTY

Introduction

In Section One the decision problem was introduced and a method for describing action choices was illustrated. The reader was left with the problem of how to index action choices so that they can be ordered according to preference. Several approaches to indexing action choices and modeling decision making under uncertainty have been suggested. This section presents two types of decision models. Safety first type models are presented in Chapter II. Chapter III discusses the second major decision model used by economists, the expected utility hypothesis. Both chapters also discuss tests of the relevant hypothesis. Therefore, before embarking upon a discussion of the models and their validity, one must first establish the criterion by which to test a theoretical hypothesis.

Testing an Hypothesis

According to Giere (1979) a good test of a theoretical hypothesis requires an experiment or a set of observations which involves the hypothesis, initial conditions, auxiliary assumptions, and a prediction. For the hypothesis to be supported, two conditions must be met. The first condition is that if the hypothesis, initial conditions, and auxiliary assumptions are true, then a correct prediction will probably follow. This condition requires an experiment which

involves careful identification and definition of the hypothesis, initial conditions and auxiliary assumptions and the making of a prediction. A comparison of the actual and predicted outcomes constitutes completion of test condition one. Condition one can be viewed as a test of correspondence.

The second condition for a test of a hypothesis is that if the initial conditions and auxiliary assumptions are correctly specified but the hypothesis is not true, then the probability of making a correct prediction is small. In addition, given the same initial conditions and auxiliary assumptions, an alternative hypothesis would not predict behavior as well as the one which is being tested. If the same prediction results from many alternative hypothesis, the second test condition would not be met and the theoretical hypothesis is not fully justified. Condition two is a test of clarity or lack of ambiguity.

The word 'probably' in test conditions one and two identifies the model in question as probabilistic rather than deterministic. Therefore, perfect prediction is not expected. Instead what is required is that evidence does not permit a rejection of the model. In summary, a good test of a theoretical hypothesis requires not only that it is able to predict an outcome, but that competing hypotheses do not predict the outcome as well. Additional tests which should be carried out are the tests of consistency, that the hypothesis can be logically deduced from the assumptions, and if one is a pragmatist, the test of workability. (Johnson, 1982)

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CHAPTER II

SAFETY-FIRST MODELS

This chapter is concerned with a basic set of decision rules known as the minimax and maximax criteria, safety-first criteria, and lexicographic ordering. All of these decision rules share the assumption that the decision maker is concerned with more than one aspect of the outcome of his action choice.

With very few exceptions, these decision rules have not been tested through the criteria set forth in the introduction to this section. Instead, their 'tests' have focused on the question of whether or not attitudes towards risk affect the action choices selected by farmers within a safety-first framework.

Maximax and Minimax Rules^a

The maximax and minimax indexing rules describe the extremes of response to uncertainty. The maximax rule, which considers only the most favorable outcome of each action choice while ignoring all other possibilities, reflects extreme optimism. In contrast, the minimax rule which orders action choices on the basis of only the least favorable outcome of each reflects pure pessimism.

The maximax rule uses the maximum outcome which occurs under

^aThis section and the one immediately following are adapted from Ch. III pp. 24-30 in L. J. Robison and B. Fleisher, "Attitudes Towards Risk: Their Interpretation, Measurement in Agricultural Settings and Application to Decision Makers in Small Farms in Developing Countries," forthcoming.

each action choice as an index. Using this rule, each action choice is first searched to find the most favorable outcome. Then the best of the set of most favorable outcomes is selected and its associated action choice is considered to be the one which is preferred. Suppose that the decision maker was faced with the decision problem described in Table 2.1 and that the most favorable outcomes for action choices a_i and a_j were π_{1i} and π_{1j} respectively. The values of π_{1i} and π_{1j} become the index values for their associated action choices and are used to indicate preference. If $\pi_{1j} > \pi_{1i}$ the j th action choice would be preferred over the i th action choice by the decision maker.

In contrast to the maximax rule the minimax rule uses the worst possible outcome of each action choice as the index value of that action. Suppose that given the decision problem presented in Table 2.1 the worst possible outcomes of a_i and a_j were π_{mi} and π_{mj} . The decision maker would prefer the best of these "worst possible" outcomes. Therefore if $\pi_{mj} > \pi_{mi}$, the j th action choice would be preferred.

The mixed strategy model attempts to find an intermediate point between extreme optimism and extreme pessimism from which to develop an index for action choices. This method identifies both the most favorable outcomes, $\pi_{\max,i}$ and $\pi_{\max,j}$ and the least favorable outcomes, $\pi_{\min,i}$ and $\pi_{\min,j}$ from the i th and j th action choices. Then using α , a coefficient for each action choice, a linear combination is formed equal to:

$$\alpha\pi_{\max,i} + (1-\alpha)\pi_{\min,i} = \pi_i^*$$

$$\alpha\pi_{\max,j} + (1-\alpha)\pi_{\min,j} = \pi_j^*$$

where π_i^* and π_j^* become the preference indexes for the action

choices. This rule can only become operationalized if the decision maker can identify the coefficient α .

Table 2.1
A Comparison Between the i-th and j-th Action Choice

States of Nature	Probability of Nature States	Action Choice	
		a_i Premaximized	a_j Outcomes
s_1	$g(s_1)$	π_{1i}	π_{1j}
.		.	.
.		.	.
.		.	.
.		.	.
s_m	$g(s_m)$	π_{mi}	π_{mj}

Two of the major criticisms of these models are that they ignore all values between $\pi_{\min}$ and $\pi_{\max}$ and that they do not consider the probabilities associated with each outcome of an action choice. In response to the latter criticism proponents of these rules have argued that when no data are available from which subjective probability density functions can be formed the decision maker has no basis from which to infer anything about the distribution beyond its upper and lower bounds. But if no data except the highest and lowest values of the distribution are available, then each data point in between should be weighted equally. This results in a uniform probability density function as shown in Figure 2.1. As a result the models bear little relation to reality and have extremely limited practical relevance.

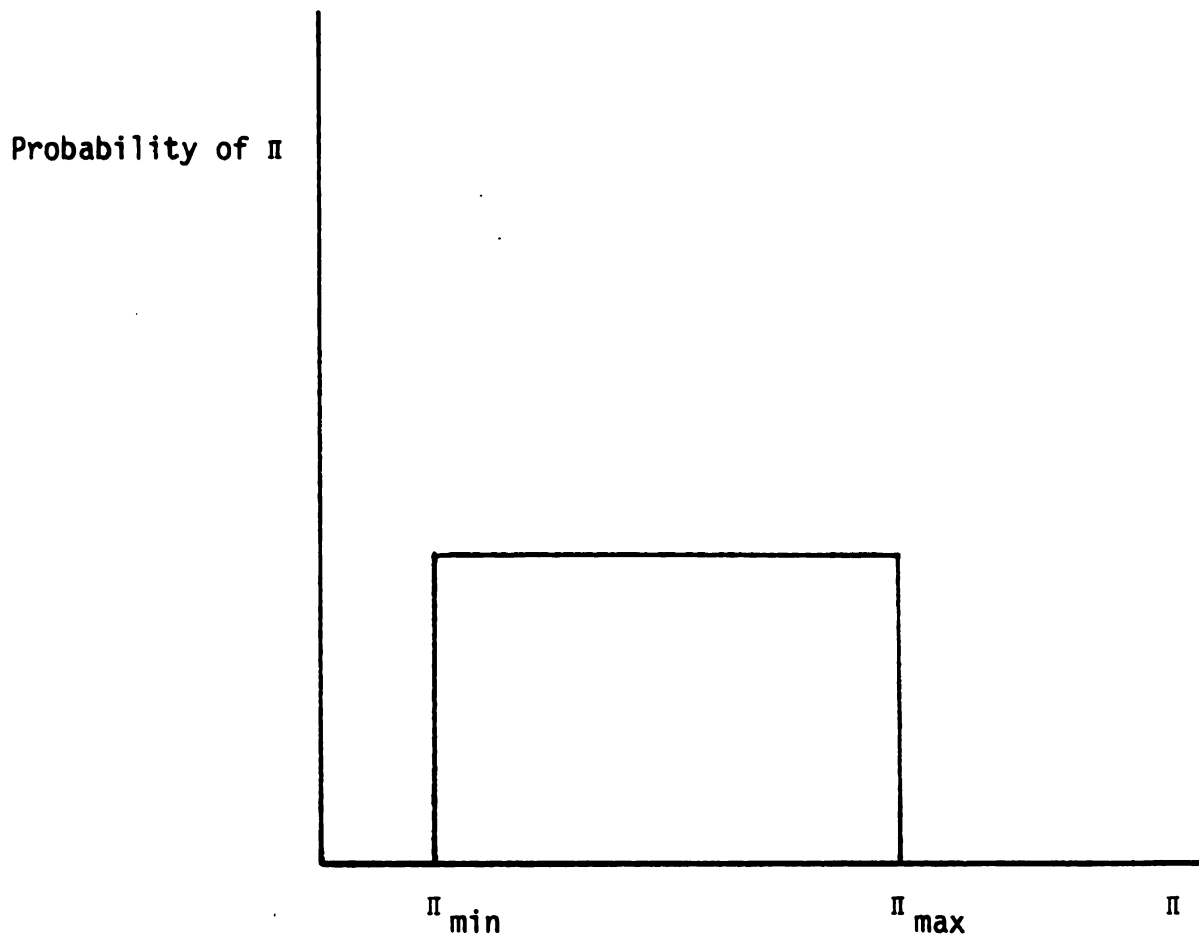


Figure 2.1. A Uniform Probability Density Function in Which Each Outcome Between the Maximum π_{max} and the Minimum π_{min} is Equally Likely

Safety-First Models

The safety-first or focus-loss model improves upon earlier models by focusing on an outcome Π_d which may be different than either the most favorable or worst possible outcome of each action choice. This outcome of concern, Π_d , is often referred to as the safety or disaster level of outcome below which a firm fails to meet its cash obligation or becomes bankrupt. In a developing country context the disaster level is interpreted as the minimum level of production yields or returns needed to meet subsistence requirements. Whatever the interpretation of Π_d , this model assumes that the decision maker's primary goal is to select action choices so as to minimize the chances of experiencing outcomes at or below the disaster level, Π_d .

Roy (1952) suggested that investors have in mind some disaster level of returns, Π_d , and that they behave so as to minimize the probability of returns below that level. Later safety-first models proposed by Telser (1955) and Kotaoka (1968) incorporated a recognition of the objective of maximizing returns or income subject to the constraint of minimizing the chances of receiving returns less than Π_d .

The three alternative specifications of safety-first criterion can be stated as:

1. minimize $P(\Pi_i \leq \Pi_d)$
2. maximize Π subject to $P(\Pi_i \leq \Pi_d)$, where $P \leq \alpha$
3. maximize u subject to $P(\Pi_i \leq \Pi_d)$, where $P \leq \alpha$

where Π_i is the level of returns, Π_d is the disaster level, α is the probability of disaster, and u is utility.

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The general concept of the safety-first models can be illustrated through the use of Figure 2.2. which shows the cumulative density functions of the outcomes of two action choices a_i and a_j . A cumulative density function for each action choice can be obtained by summing its probability density function. Point B on the cumulative density function $G_j(\Pi)$ can be interpreted as the probability of outcomes equal to $\Pi_{b,j}$ or less occurring. The maximum value which $G_j(\Pi)$ can take on is one, which is the sum of all probabilities of $\Pi_{k,i}$ occurring.

If the decision maker acted in accordance with the safety-first model proposed by Roy when faced with the cumulative density functions presented in Figure 2.2 they would prefer the action choice a_j represented by $G_j(\Pi)$. At the disaster outcome level Π_d , $G_i(\Pi_d)$ is greater than $G_j(\Pi_d)$ indicating that the probability of Π_d or something worse occurring is greater with the i th action choice than with the j th action choice. Thus action choice a_j would be preferred even though it has a lower maximum possible outcome ($\Pi_{\max,j} < \Pi_{\max,i}$) and a worse minimum outcome ($\Pi_{\min,j} < \Pi_{\min,i}$).

If a decision maker faced with the same decision problem was using the criteria proposed by Telser, however, he would prefer action choice a_i over action choice a_j . Under Telser's restrictions the decision maker attempts to maximize expected returns ($E(a_k)$ ($k=1, \dots, n$)) subject to the constraint that the probability of return less than the disaster outcome Π_d does not exceed a given probability α . Both of the cumulative density functions in Figure 2.2 show that probability of Π_d or less occurring is less than α for their respective action choices. Since this constraint is satisfied, the decision maker will base his choice on expected returns which are greater for

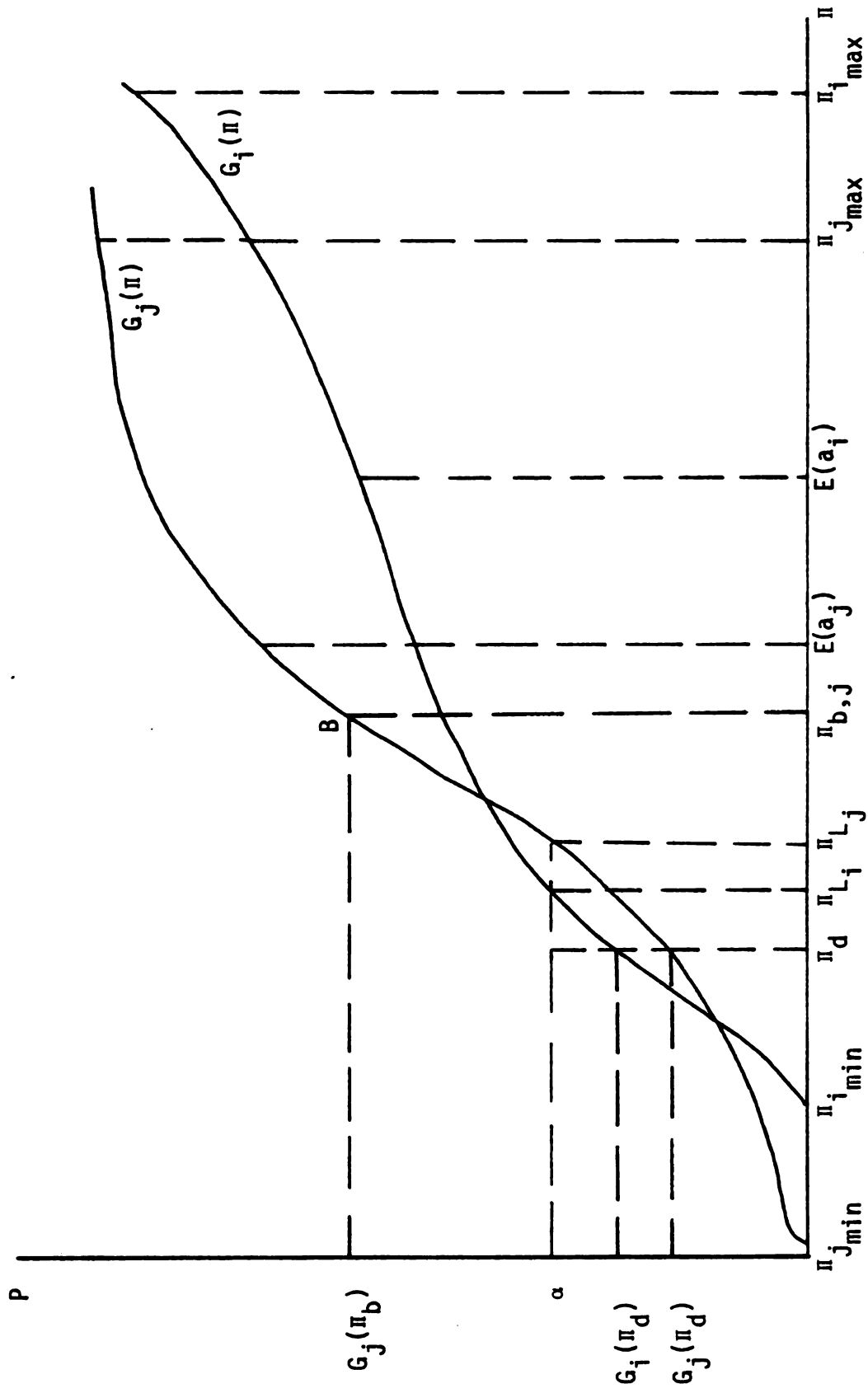


Figure 2.2. Cumulative Density Functions $G_i(\pi)$ and $G_j(\pi)$ Describing Probabilistic Outcomes of Receiving π or Something Less

action choice a_i than for action choice a_j ($E(a_j) < E(a_i)$).

If following the third safety-first rule, proposed by Kataoka, the decision maker would again prefer action choice a_j . This rule is based on a particular probability value of $G(\pi_L)$ occurring, which is again indicated by α . The decision maker will prefer the action choice with the largest value of π_L at a given value of $G(\pi_L)$. In Figure 2.2 $G_j(\pi)$ is preferred to $G_i(\pi)$ since the value of $\pi_{L,j}$ is greater than $\pi_{L,i}$.

One thing which should be noted about all of the safety-first models is that they focus on only one level of outcome or one level of probability of outcomes. But should this limited view be accepted as the basis for modeling decision making under uncertainty? It would appear that if each possible outcome, π , may influence the well being of the decision maker, all possible outcomes and their attendant probabilities should be allowed to influence the preference index.

Lexicographic Ordering

All three of the safety-first models imply that the decision maker is concerned with more than one aspect of the outcome of his action choice. In safety-first models the outcomes of concern are income or wealth and the probability of receiving an outcome lower than π_d , the disaster level. A more general theory which recognizes a multiplicity of objectives is the theory of multidimensional vector ordering, or what is now more generally known as lexicographic ordering. Lexicographic ordering differs from utility analysis of a multidimensional objective function in that the trade-off weights between vectors are not measurable. Applications of lexicographic ordering to decision problems was suggested by Encarnación (1965) and elaborated

upon by Ferguson (1974).

They propose that a decision maker has a lexicographic utility function that ranks a hierarchy of objectives $Z_1, \dots, Z_n$ in which Z_1 is more important than Z_2 , Z_2 more important than Z_3 , etc. Given two alternative action choices Z^0 and Z^1 the decision maker will prefer Z^0 to Z^1 if $Z_1^0 \geq Z_1^1$, irrespective of the relationship between Z_i^0 and Z_i^1 for $i > 1$. If the two choices both satisfy the goal Z_i ($Z_i^0 = Z_i^1$), then the choice between them is based on the relative value of the second components Z_2^0 and Z_2^1 . If $Z_2^0 = Z_2^1$, the choice is made with reference to the third component and so on. It is assumed that the marginal utility of overachievement of goal Z_i is zero.

One form of a lexicographic utility function in a problem of decision making under uncertainty is a function with two goals where Z_1 is a firm survival goal and Z_2 is a profit maximizing goal. Suppose that the decision maker feels that an income of less than $\$X_0$ is not acceptable and that he is only willing to run the risk of an income less than $\$X_0$ with a probability of .01. Goal Z_1^* is then defined as equal to one if $p(I > \$X_0) \geq .01$ and equal to zero otherwise. Given two action choices, the decision maker will first ensure that Z_1^* , the firm survival goal, is met before expected income is maximized. Thus a distribution of outcomes with a lower expected income which satisfies Z_1^* will be preferred over one with a higher expected income which does not satisfy goal Z_1^* .

One of the most common applications of this two goal lexicographic utility approach is in focus-loss programs (Boussard and Petit, 1965) which assume that farmers want to maximize the "normal" or mean value of their incomes under the constraint that the focus of loss for the optimal crop pattern is at least equal to the permissible loss.

Although this simple two goal lexicographic utility function may provide the researcher with a measure of the relative levels of risk aversion present in the population (in the form of $\$X_0$ or the probability), lexicographic utility, in general, cannot be used for this purpose. This is due to the fact that goals are not always easily quantifiable and that each member of the population is likely to have different goals, or order similar goals in different ways.

Tests and Applications of Safety-First Type Models

Most applications of the safety-first model do not meet conditions one and two of a good test of a hypothesis. Their major emphasis appears to be the determination of the importance of including risk attitude considerations in mathematical programming models designed to predict farmers' cropping choices.

One of the first attempts to use a mathematical programming model to demonstrate the impact of risk attitudes on farmers' decisions within a safety-first framework was done by Boussard and Petit (1967) in a study of farmers in southern France. Following the assumption that farmers maximize profits, provided that the possibility of ruin is so small as to be negligible, the researchers introduced a focus loss constraint into the linear programming format. This assumption implies a lexicographic order of preferences (Encarnación, 1965). A chance constrained program with a zero ordered decision rule was not used because such a model would require knowledge of the joint probability distribution of receipts by hectare of each crop planted and to be able to combine them to obtain the probability distribution of income obtained from the optimal combination of crops. This would be prohibitively difficult as there are strong indications that neither

yields nor prices are normally or symmetrically distributed. (Day, 1965, Mandelbrot, 1965).

In specifying the focus-loss of a cropping pattern, farmers were assumed to diversify so that there is only a small possibility that their incomes will fall to the minimum or below. The authors assume that the focal loss on one crop is only a fraction of the total permitted loss, signified as $1/k$. One of the weaknesses of this approach is the arbitrariness of the estimation of the parameters such as the focal loss of each group crop activity, the minimum income, and the fraction $1/k$. In this study, the values were determined by extension agents who worked in the region, not by questioning farmers in the sample.

The actual cropping pattern of forty-four farmers was compared with predictions using models which contained either only technical constraints, only security constraints, or security and credit constraints linked together. The model which included both security and credit constraints predicted actual cropping patterns much more closely than did the other two models. One implication is that both security and credit constraints affect cropping decisions. But since the parameters were based on nonfarmers' estimates of regional focal-loss points and not on individual farmers' responses, the model tells us little about how individual farmers alter their decisions in the face of uncertainty.

In a developing country application of the safety first model, Low (1974) employed a linear programming model which included a game theoretic decision criterion which minimizes the cost of providing against ruin. It was assumed that farmers in his sample in S.E. Ghana attempted to maximize expected income subject to ensuring that his subsistence requirement is met under the most adverse conditions he

considers likely to happen. Low called this decision rule the minimum cost of security criterion.

The model was tested in S.E. Ghana where uncertainty was introduced through the output level of forest maize which depends upon the relationship between time of planting and pattern of seasonal rainfall. The security constraint set employed ensured that the maize yield under the most adverse circumstances is at least equal to the maize subsistence requirement. The value of the objective function, therefore, represented the expected income after subsistence requirements have been met. The model was based on the choice situation facing the modal village household, with restrictions applied to represent the situation facing households which were less well endowed. It was found that the model's results were close to observed behavior, suggesting that the assumptions used in the model were valid. It was also found that different production patterns employed by farmers with different levels of income or wealth were based on different levels of resource availability rather than on different objectives.

It can be inferred from Low's results that resource constraints and not different objectives or attitudes are responsible for different cropping patterns among farmers in S.E. Ghana. Roumasset's study of fertilizer application decisions of Philippino farmers supports this hypothesis. (Roumasset, 1975). Roumasset initially assumed that if farmers are especially averse to low levels of income, their behavior can best be described by a safety first rule of thumb. A risk neutral solution and a risk sensitivity index representing the profit per hectare needed to avoid selling nonliquid assets were formulated for each farmer. The actual amount of nitrogen farmers used per hectare was regressed on the predicted values obtained from a

risk neutral and two safety first models. No significant difference was found in the R^2 values for the three models.

Roumasset argues that his results show that supplementing a risk neutral model with additional concern for security does not increase the model's power. However, the results from this study may be influenced by the fact that farmers in this sample were not particularly averse to risk, or because risk was inversely proportional to expected profits for the technique under consideration. Two other factors should be considered. One is that fertilizer cost amounted to only ten to twenty percent of total costs for farmers in the region. Secondly, although the R^2 values may not be significantly different, they were all uniformly low, at about .5, indicating that none of the models was particularly well specified.

Brink and McCarl (1980), in a study utilizing the Purdue Top Farmer Cropping Model, investigate whether or not risk should be introduced explicitly in operational farm planning models. More specifically, they test whether a risk consideration in the model helps to better predict actual farmer behavior in terms of crop acreages chosen. If explicit consideration of risk attitude is helpful, and the diversity between farmers in terms of their tradeoff between expected return and variance of return is small, a common default value for the tradeoff can be used.

The portfolio choice model employed uses the negative deviation from the expected return as a measure of risk. This requires the assumption that outcomes are normally distributed or that farmers have quadratic utility functions. For this study the actual negative deviation was converted to a standard deviation so that the measure would be compatible with that used in other studies. This conversion

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requires the assumption that total negative deviation is exactly one half of the total absolute deviation. Each farmer's 1975 acreage and income data was used to specify the nonrisk portion of the objective function while the risk portion was specified using gross margin outcomes synthesized from historical data and assumed to be constant for all farmers.

Twenty farm plans with a measure of standard deviation between 0 and 1.95 were presented to the farmers. The risk coefficient for each farmer was taken to be the parameterized coefficient which minimized the difference between the associated plan in the choice set and the farmers present plan measured in terms of total absolute deviation in acreage of each of four crops.

The null hypothesis of no difference in effects of varying risk aversion coefficients was rejected at the .01 level of significance. Several qualifiers should be added to this result. One is that attributing all of the differences to risk embodies strong assumptions since the present farm plan is affected by other factors as well. In addition, the choice set did not include any of the farmers present mixes of corn and soybeans, suggesting model misspecification. There was no significant difference in results for risk aversion coefficients less than .62. Considerable variation in acreages was observed as the coefficient became larger than this. The majority of the farmers in this sample, who paid to participate in the Top Farmer Cropping Program, had risk aversion coefficients which were less than .25, indicating that risk attitude, in general, is an important factor in the choice of crop acreages by the study group.

The low levels of risk aversion found by Brink and McCarl may be a peculiarity of their select sample of corn belt farmers. Their

results add to the store of conflicting conclusions reached by studies which examine the relative importance of subjective factors such as risk aversion and liquidity requirements and objective factors such as credit or input availability on peasant decision making. Wiens (1976), in a quadratic programming study, utilizes historical Chinese sample survey data to demonstrate that the behavior of peasants facing choices comparable to those confronted elsewhere in Asia today exhibited substantial aversion to risk. Instead of using a quadratic utility function, Wiens assumed an exponential utility of income function which allowed for the use of information derived from both primal and dual solutions. The use of dual solutions allows for the discovery of shadow prices and direct estimation of the risk aversion parameter.

The primary decision problem was to determine the amounts of owned and hired factor services to devote to cotton, maize, and sorghum, each of which have markedly different degrees of yield stability and initial cash outlay requirements. The crops shared a single growing season and, because of a properly functioning market, may be seen as substitutes. When estimates of the risk aversion parameter were made for large and small farm operators it was found that decreasing absolute risk aversion with increased wealth was required to explain the behavior of both groups. To ascertain that the same results would not be obtained with a risk neutral model or when working capital was treated as the sole constraint, additional runs were made. The results of the risk neutral model was distinctly contrafactual. When working capital was the sole constraint, specialization in cotton or maize was optimal. In contrast, the risk aversion model conforms with the average behavior of the peasants with primal solutions calling for full diversification among the three crops in proportions similar

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Conclusions

One of the fundamental assertions underlying safety-first and lexicographic ordering models is that decision problems cannot be collapsed into a comparison of the expected value or utility of the outcomes of action choices. Supporters of these hypotheses assert that other factors, such as the disaster level of outcomes, must become a focal point of decision analysis. Applications of these models to real world situations lead to conflicting results.

Low and Boussard and Petit found that resource availability and security and credit constraints influenced farmers cropping decisions more than did different objectives held by farmers. Studies which attempted to determine the effect of attitudes towards risk on cropping decisions within a safety first and focus loss constraint also found conflicting evidence. While Roumasset argues that farmers are risk neutral and that consideration of risk attitudes does not enhance mathematical programming models, Wiens found exactly the opposite to hold true. Brink and McCarl discovered that while risk attitudes were important to farmer cropping decisions, there was not a wide variation in risk attitudes among farmers in their study.

Because of this conflicting evidence, it is not possible to conclude that the safety first model has passed the tests of a theoretical hypothesis set forth by Giere. Not only have these studies shown that the safety first models do not accurately predict farmers action choices (failure of test one) but they have shown that other models may, in fact predict better than safety first (failure of test

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CHAPTER III

THE EXPECTED UTILITY HYPOTHESIS

One of the most commonly used decision rules throughout history has been the weighing of outcomes according to their monetary value and selection of the action choice with the highest expected value. This decision rule is still used today. One of its most popular applications has been in linear programming models where uncertain parameters are replaced by their expected values. The solution is then the outcome which maximizes the expected value of the uncertain parameter.

This decision rule has two advantages over safety first and lexicographic ordering rules: all of the outcomes which result from action choices are considered in formulating the preference index, and the preference index is unidimensional or, in other words, the decision problem is collapsed into a comparison of a homogeneous unit, money. Despite these advantages, many decision theorists argue that an expected profit maximization approach is not adequate for modeling decision making under uncertainty. Their reservations regarding this model rest upon the pioneering work of Daniel Bernoulli who showed that the degree of satisfaction which an individual derives from income is not necessarily a linear function of the amount of money.

Bernoulli's statement of the concept of diminishing marginal utility for income provided the impetus for the development of the expected utility hypothesis which incorporates the decision makers

utility for income or wealth and his attitude towards risk into a preference ordering rule. Although the expected utility hypothesis has not been proven to be the perfect decision rule, it is the most generally accepted decision paradigm and is the basis for almost all of the disciplinary work done on the economics of uncertainty.

This chapter will review the development of Bernoullian utility analysis, present the expected utility hypothesis, and examine tests of the hypothesis using the criteria set forth in the introduction to Section Two.

Bernoullian Utility Analysis

Daniel Bernoulli, an eighteenth century mathematician who studied decision making behavior found an inconsistency between the expected value rule and the way that decision makers actually behaved. He postulated that this inconsistency arose because the satisfaction or "utility" which individuals gained from a unit of money was dependent upon more than the face value of the money. He reached this conclusion after observing two phenomenon. The first was that a given small amount of money was worth more to a poor man than a rich one. The second was the inconsistency which arose when individuals played a gamble known as the St. Petersburg paradox. The gamble paid depending on the number of flips of a coin required to obtain heads. If heads occurred on the first flip, the gamble paid a small sum such as \$2. If heads occurred on the second flip the gamble paid $(\$2)^2$ or \$4, if they occurred on the third flip it paid $(\$2)^3$, and so on. The probability of heads occurring on the first flip, is $1/2$, $1/4$ on the second flip, and $1/8$ on the third flip. The expected value of the gamble $E(G)$ could be written as the sum

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$$E(G) = 1/2 (\$2) + 1/4 (\$4) + 1/8 (\$8) + \dots$$

The value of each element in the gamble is one. But the number of possible elements is infinitely large so that the sum, or expected value, is infinite. If decision makers played this gamble in accordance with the expected value rule they should be willing to pay a relatively large amount to play since the gambles expected value is infinite. But Bernoulli observed that gamblers were only willing to pay a small amount to play.

Bernoulli proposed that decision makers playing the St. Petersburg paradox maximize the log function of the premaximizing outcomes. This is equivalent to maximizing the geometric mean of a gamble, which will result in either maximizing the expected value of terminal wealth or minimizing the number of plays required to achieve some level of wealth in a repeated gamble. Although it is now realized that the log function is not necessarily an appropriate or universal weighting function for income, Bernoulli's work represented a significant step towards modern decision theory.

The Expected Utility Hypothesis

Bernoulli's concept of utility of income provided the basis for the expected utility hypothesis (EUH) first formally deduced from a set of axioms by Ramsay (1926) and later developed more fully by von Neumann and Morgenstern (1944). The EUH asserts that if a decision makers behavior is consistent with four axioms of "rational behavior" they will weight outcomes of action choices according to a personalized and unique function $U(\pi)$. The expected value of $U(\pi)$ for each action choice provides the single valued index which orders action choices in accordance with the decision makers preferences or attitudes toward

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The four axioms of "rational behavior" which expected utility maximizes are assumed to follow are:

1. Ordering. If an individual confronts two risky prospective action choices a_1 and a_2 , each with more than one potential outcome or with a probability distribution of outcomes, he will prefer one of the two risky prospects or will be indifferent between them.

2. Transitivity. If the individual confronts three risky prospects, a_1 , a_2 , and a_3 and prefers a_1 to a_2 , and a_2 to a_3 then he will also prefer a_1 to a_3 .

3. Continuity. If an individual prefers a_1 to a_2 to a_3 , then there exists a unique probability, p , such that he will be indifferent between a_2 and a lottery of the form $pa_1 + (1-p)a_3$.

4. Independence. If action choice a_1 is preferred to a_2 and a_3 is some other lottery, then the individual will prefer a lottery of $pa_1 + (1-p)a_3$ to the lottery $pa_2 + (1-p)a_3$.

If a decision maker obeys these axioms, a utility function $U(\pi)$ can be formulated which reflects the preferences of the decision maker (Hey, 1979). According to Dillon (1971), a utility function $U(\pi_i)$ derived for an expected utility maximizer has the following properties:

1. If a_1 is preferred to a_2 then $U(\pi_1) > U(\pi_2)$.
2. The utility of a risky prospect is equal to the expected utility of its possible outcomes.
3. The scale on which utility is measured is arbitrary. Therefore the utility function is unique only up to a linear transformation.

Utility functions are discussed in greater detail in Chapter VI.

The EUH assumes that individuals meet two initial conditions in addition to following the axioms of rational behavior already introduced. The initial conditions are that they can identify a set of action choices $a_1, \dots, a_n$ and that they can associate probability density functions $g_1(\pi), \dots, g_n(\pi)$ with the action choices. The probability density functions are subjective and assumed to obey the calculus of probability.

The expected utility hypothesis proscribes the following solution for an uncertain decision problem:

1. Identify the action choices as $a_1, \dots, a_n$, and the possible states of nature $\theta_1, \dots, \theta_m$ under which the action choices may be experienced.
2. Assign probability weights to the states of nature $p(\theta_1), \dots, p(\theta_m)$ consistent with probability calculus.
3. Calculate the expected utility value of the consequences for each action choice.
4. Implement the action choice with the highest expected utility.

Although the safety first criteria introduced in Chapter II were originally developed as an alternative to the EUH, Pyle and Turnovsky (1970) have shown that there is a strong relationship between the two. In the absence of a riskless asset, a correspondence can be established between safety first criterion and expected utility maximization when that maximization results in concave indifference curves in a mean-standard deviation space. If a riskless asset is available, however, the criterion do not normally correspond.

Some supporters of the EUH claim that if the decision maker selects an action choice using the procedures outlined by the EUH

he will be acting in accordance with his expressed preferences. The utility function is only a device for attributing numbers or an index to possible outcomes of an uncertain prospect in order to help the decision maker select from among a set of prospects. Others argue that the EUH is a useful tool for predicting decision maker behavior whether or not they have consciously followed the procedures outlined by the EUH. Dillon (1971) makes this distinction through the analogy that catching a ball requires the intuitive solution of complex differential equations. The fact that the ball is caught does not imply that the differential equations were actually solved by the catcher, only that the catcher behaved as if he had solved the equations.

Tests of the Expected Utility Hypothesis

The concepts of statistical decision theory which form the basis of the expected utility hypothesis are essentially prescriptive; they describe how a rational decision maker ought to behave given his beliefs and preferences. Whether or not they provide a model which explains rational behavior can only be determined by empirical test. After more than twenty years of experimental investigation of decision making under uncertainty the evidence regarding the descriptive validity of the expected utility hypothesis is still inconclusive. Very few of the experimental applications of the expected utility model meet both conditions one and two of Giere's test of a theoretical hypothesis. These studies will be reviewed in this section. Many of the agricultural applications of the expected utility model have focused on the determination of farmer's attitudes towards risk and have not attempted to test the validity of the model. These studies will be reviewed in Chapter VII.

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Lin, Dean, and Moore (1974) developed a test of the expected utility hypothesis which met Giere's conditions one and two. Three alternative decision criteria, expected utility maximization, profit maximization, and maximization of utility in a lexicographic context, were tested to determine how well they predicted individual producer behavior. Condition one was met as the predictions made by the expected utility hypothesis were compared to individual producer behavior. Condition two was met because the authors compared the accuracy of these results with the accuracy of alternative models.

To describe the action choices facing six farmers in California's San Joaquin Valley, the authors used quadratic programming techniques to develop expected value-variance (EV) efficient sets for each farmer. Utility functions for each farmer were developed using subjective probabilities to simulate the decision environment. This was done to avoid the downward aggregation bias which would be caused by the use of probability estimates derived from countywide statistics. (Derivation of utility functions is discussed further in Chapter VI). The four goals assumed in the lexicographic model were family living standard, firm growth, net income, and farm survival.

Predictions made by each of the three models were compared to actual farm plans. The expected utility model was the most accurate in three cases while the lexicographic utility model most closely predicted the decision makers choice in two out of the remaining three cases. None of the models predicted actual behavior well; all tended to predict more risky behavior than was actually observed. In fact it would have been impossible for the expected utility hypothesis to predict the actual farm plans used by the farmers because these

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plans were not included in the EV efficient choice set. Thus an important initial condition required for the test, the correct identification of the choice set, was misspecified.

The test was then repeated with the models predictions compared to the farmers preferred farm plan from among those presented in the choice set. In this test the expected utility model prediction corresponded exactly with the farmers preferred plan in three out of six cases and was more accurate than either of the competing models in the remaining three cases. These results lend support to the expected utility hypothesis.

Haneman and Farnsworth (1980) studied the ability of the expected utility maximizing and profit maximizing models to predict farmers choice between integrated pest management (IPM) and conventional chemical control strategies. In developing the utility function for each of the forty-four farmers in their sample, the researchers used subjective probability distributions for both profits and yields. They found no significant difference in the risk attitudes of the two groups. However, they did find significant differences in the subjective expectations regarding yields and profits between the IPM and chemical control groups despite the fact that historically there was no significant difference. Each group was able to nominate subjective probability distributions for their own control strategy which were similar to the objective probability distributions developed using historical data. Each group, however, tended to underestimate the expected value of profits and yields which could be obtained through the use of the alternative strategy.

The authors found that the expected utility maximizing model was able to predict the farmers choice of pest control strategy in

thirty-five out of the forty-four cases. Thus, condition one of the test was completed. They then found that the expected profit maximizing model also correctly predicted the farmers' preferred strategy in thirty-five out of the forty-four cases. Although the expected utility hypothesis passed condition one of a good test of a theoretical hypothesis, it failed condition two because an alternative hypothesis was shown to produce the same results. Therefore, this study provides only weak support for the expected utility hypothesis. Haneman and Farnsworth infer however that the subjective perceptions of outcomes rather than the type of choice criterion or the farmers' attitudes towards risk explain the prediction. Since no test of the models was completed using objective probability distributions, this inference still requires empirical validation.

Conclusions

Although the expected utility hypothesis is considered by many decision theorists to be the best available model of decision making under uncertainty empirical tests of the model have not given it unconditional support. While it has been shown that the expected utility hypothesis can predict decision makers' choices in a hypothetical setting, its predictive ability is not clearly superior to that of competing models. The two tests discussed in this chapter leave unanswered several important questions about the expected utility hypothesis. They do not test whether decision makers actually calculate the expected utility to be obtained from each risky choice before selecting the preferred action, or whether they only act as if they do. Nor do the studies question the logical validity of the expected utility hypothesis; the hypothesis follows logically from the axioms.

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Several decision theorists have questioned the axioms and assumptions underlying expected utility analysis. Extensions of the expected utility hypothesis made on the basis of their findings are the subject of Chapter IX.

SECTION THREE

APPLICATIONS OF DECISION THEORY

During the past thirty years there have been numerous applied studies within the framework of safety-first and expected utility models described in Section Two which attempt to understand farmers attitudes towards risk and decision making under uncertainty. The various methods of used and results obtained are presented in this section.

In order to understand the implications which can be justifiably drawn from the results of these studies, one must first examine the assumptions upon which they are based, and the limitations of the methods used. Therefore, this section begins with a discussion of measurement of attitudes towards risk. Because many of the measures of attitudes towards risk and other methods of predicting decision making behavior under uncertainty rely on the existence of a cardinal utility function for the decision maker, Chapter V discusses different methods of deriving utility functions and the influence of the functional form of the utility function on attributed risk attitudes and predicted behavior.

Chapter VI examines the use of the methods described in Chapters IV and V in empirical studies of farmers attitudes towards risk and decision making under uncertainty. Chapter VII extends this discussion to those studies which have also attempted to correlate attitudes towards risk with different sets of socioeconomic variables. The

chapter concludes with a discussion of the implications of the general finding that local measures of attitudes towards risk are highly correlated with socioeconomic variables.

Farmers attitudes towards risk are often determined for use in current and future personal and policy decisions. Section Three concludes with a chapter which points out the major limitations which prevent the results of the studies reviewed in Chapters VI and VII from being justifiably used for these purposes. To do so, Chapter VIII presents arguments from the increasing body of evidence which calls into question assumptions regarding the stability of preference over time, income, and situations, and our ability to rank individuals according to their derived risk attitude coefficient. If these assumptions are not warranted, then it is not reasonable to expect that long term generalizations or global comparisons can be made from what are essentially local, time and place specific measurements.

CHAPTER IV

LOCAL MEASURES OF ATTITUDES TOWARDS RISK

The ability to explain, predict and prescribe behavior under risk is dependent upon knowledge of the individual's willingness to bear risk. While the existence of risk aversion can be used as an explanation of economic activities, a suitable numerical measure is needed to arrive at quantifiable theories. Several measures have been developed; according to Arrow (1965) the ultimate justification for any particular measure is its usefulness in theories of specific types of behavior under uncertainty.

Classification According to the Shape of the Utility Function

One method of classifying individuals attitudes towards risk is by the shape of their utility function over wealth. It is assumed that all investors display marginal utility for additional wealth such that $U'(x) > 0$; that is their preferences are represented by an expected utility function, $U(x)$, which is monotonically increasing and twice differentiable. The concavity, convexity or linearity of the utility function reflects the decision makers attitude towards additional income with concavity indicating diminishing marginal utility (risk aversion), convexity indicating increasing marginal utility (risk preferring) and linearity reflecting constant marginal utility (risk neutrality).

Figure 4.1 represents the linear utility function of an individual who has constant marginal utility of income and hence, is classified as risk neutral. If this decision maker is presented with a choice between receiving a sure amount, $\bar{y}$, or participating in a gamble with a fifty percent chance of receiving y_1 and a fifty percent chance of winning y_2 , with a mean value of $\bar{y}$, he will be indifferent between the two options. Because of the linearity of his utility function the expected utility to be gained from $\bar{y}$ is exactly equal to the expected utility of the gamble which can be expressed as $EU [.5y_1 + .5y_2] = \frac{1}{2}U(y_1) + \frac{1}{2}U(y_2) = U(\bar{y})$. Similarly, if the same decision maker is presented with a third alternative, a fifty percent chance of winning y_3 and a fifty percent chance of winning y_4 which also has a mean value of $\bar{y}$, he will be indifferent between all three options. Furthermore, he will be indifferent between any gambles whose expected values are equal.

In contrast to this risk neutral decision maker whose utility function is shown in Figure 4.1 is the risk averse decision maker for which a representative utility function is shown in Figure 4.2. If presented with the same action choice as the risk neutral decision maker, the risk averse decision maker will not be indifferent between $\bar{y}$ and a gamble in the form of $\frac{1}{2}(y_1) + \frac{1}{2}(y_2)$. The expected utility of the gamble $EU(y)$ is $\frac{1}{2}[U(y_1) + U(y_2)]$ which is equal to an income y_{CE} which, if received with certainty, would give the same amount of utility as the lottery. Note that for the risk averse decision maker y_{CE} is not equal to $\bar{y}$. In fact the wider the dispersion of outcomes of the lottery, the greater will be the difference between $\bar{y}$ and y_{CE} .

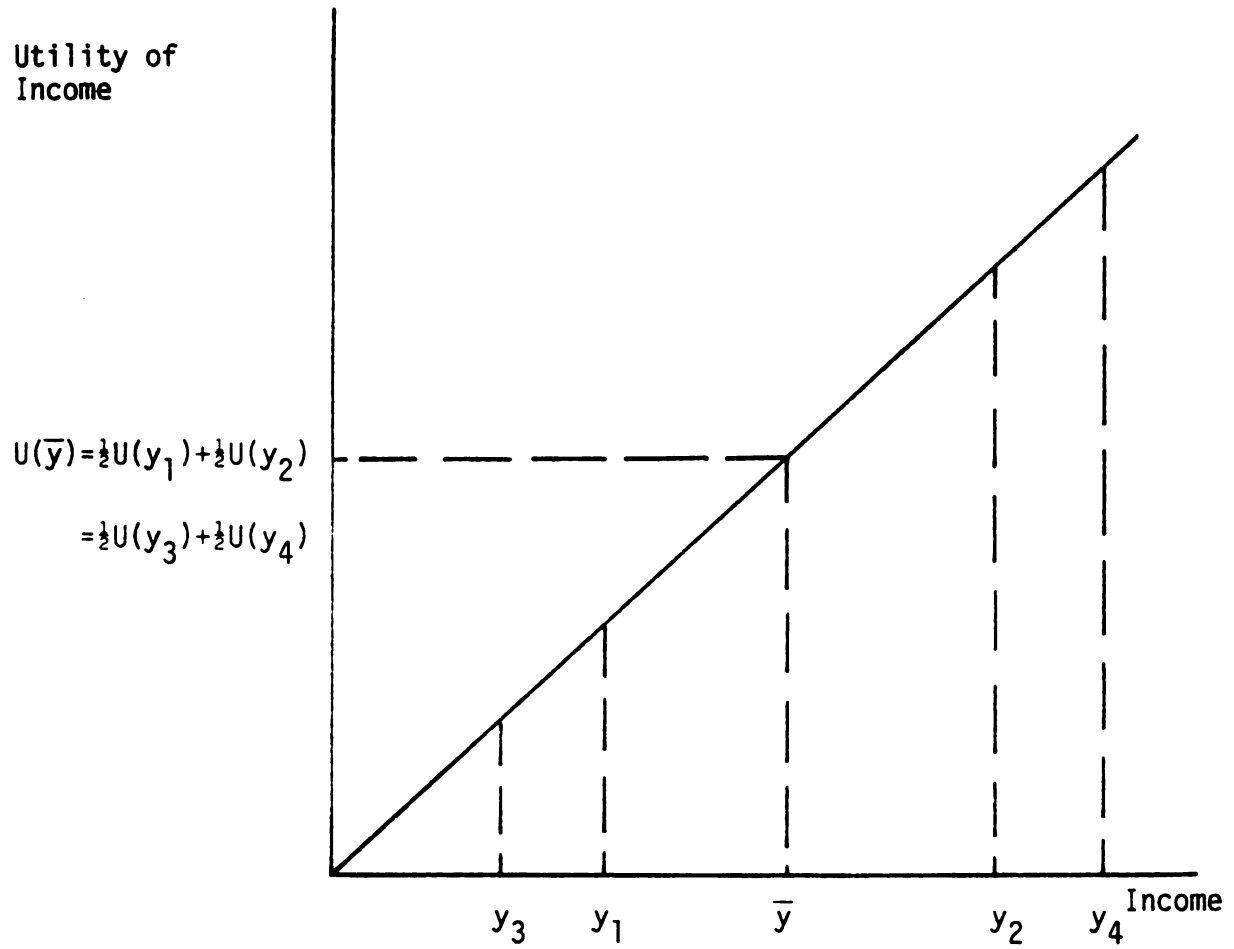


Figure 4.1. Linear Utility Function Displaying Constant Marginal Utility of Income and Risk Neutrality

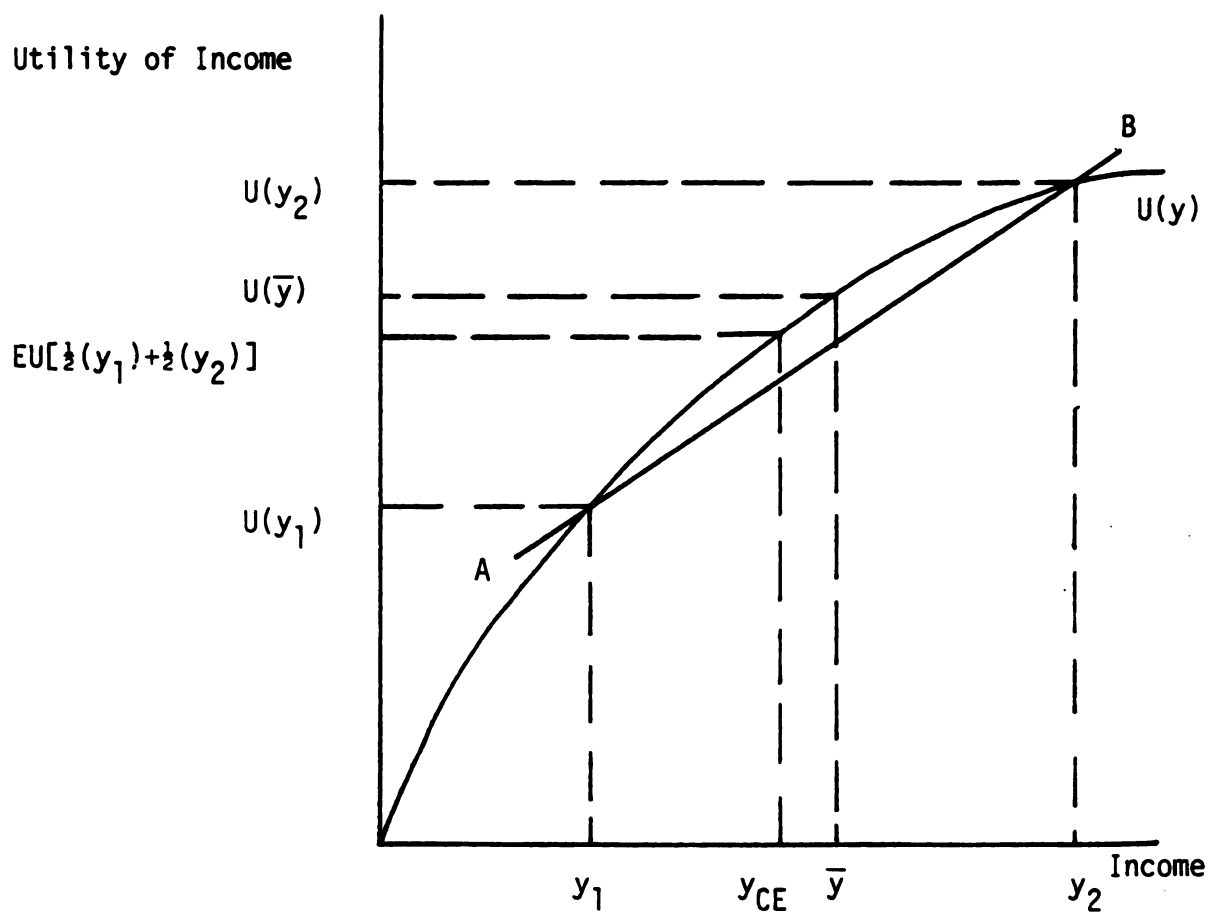


Figure 4.2. Concave Utility Function Displaying Decreasing Marginal Utility of Income and Risk Aversion

This result should not be surprising if one considers also the slope of the line AB drawn tangent to the utility function (y) which indicates marginal utility. The fact that it is below the utility function indicates that the decision maker has diminishing marginal utility for additional income.

For a decision maker whose utility function shows increasing marginal utility for income or risk preferring behavior, as illustrated in Figure 4.3, the certainty equivalent for the gamble between y_1 and y_2 is greater than $\bar{y}$.

The shape of the utility function can be used to classify decision makers into three broad categories of risk loving, risk averting and risk neutral. However, this method does not have the capacity to order individuals within each category according to their attitude towards risk. To do so requires a more discriminating measure.

Ordering Individuals

According to Their Required Risk Premium

One method of ordering individuals according to their attitude towards risk is to determine how they would respond to an identical gamble. Assume that there are two risk averse decision makers whose utility functions are shown in panels a and b of Figure 4.4. When presented with the choice between a sure outcome of $\bar{y}$ and the outcome of a gamble with an equal chance of receiving y_1 or y_2 both of the individuals would prefer $\bar{y}$. This information alone does not permit the ordering of individuals according to their attitudes towards risk. But ordering can be accomplished through the determination of each individual's "risk premium" or the difference between the expected value of the lottery, $\bar{y}$, and the individual's certainty equivalent, y_{CE} . The risk premium is usually noted by π . Within the class of

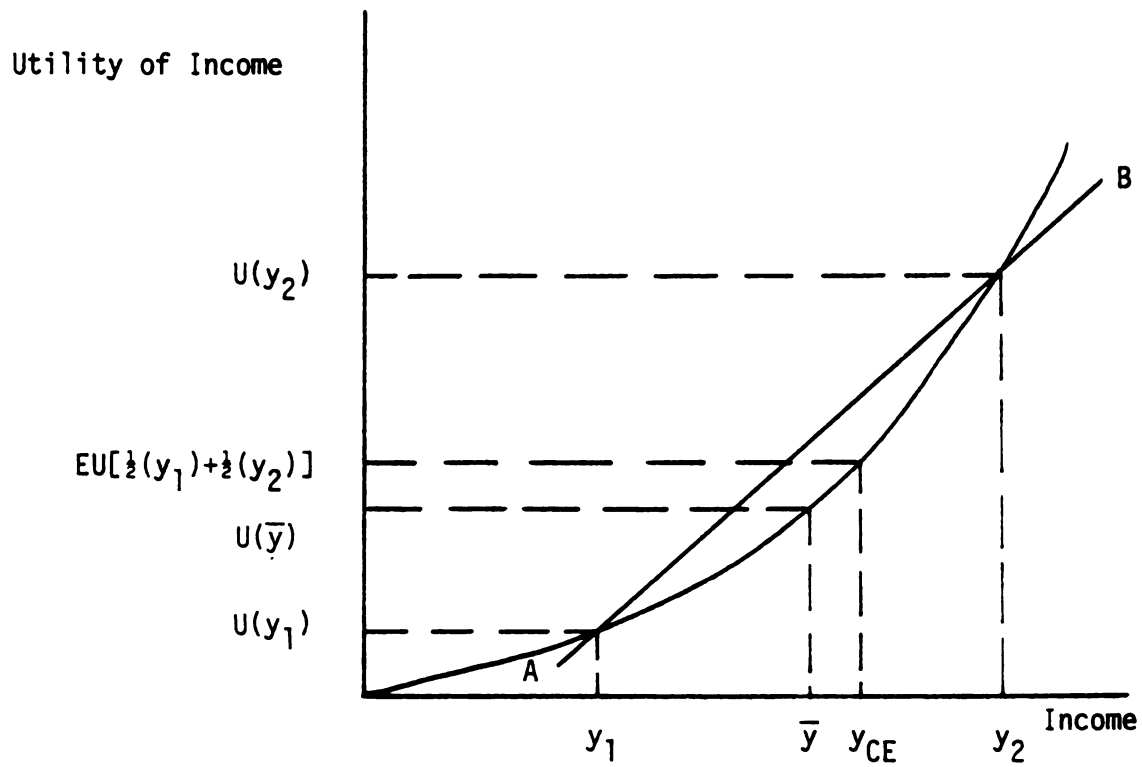


Figure 4.3. Convex Utility Function Displaying Increasing Marginal Utility for Income and Risk Preferring

individuals who are risk averse, the larger the risk premium, the more averse to risk the individual.

Returning to Figure 4.4 it can be seen that individual B has a larger risk premium than individual A. Hence, he is more risk averse. The size of the risk premium required is determined by the degree of concavity of the utility function, with a more concave utility function indicating a greater degree of risk aversity. On this basis the individual whose utility function is depicted in panel b of Figure 4.4 is classified as more risk averse than the individual whose utility function is shown in panel a.

As the bending of the utility function in a negative direction approaches zero, the utility function $U(y)$ approaches a straight line and the risk premium approaches zero. The certainty equivalent of a risk neutral decision maker with a linear utility function equals the mean of the lottery, $\bar{y}$, and the individual requires no risk premium.

For a risk loving decision maker whose utility function is convex, the risk premium will be negative. In other words, the certainty equivalent will be greater than the mean of the lottery. The larger the absolute value of the risk lover's risk premium, the more risk preferring he is.

The shape of the utility function, concave, convex, or linear can be expressed by the second derivative of $U(y)$. For a risk averse decision maker $U''(y) < 0$, for a risk neutral decision maker $U''(y) = 0$ while for a risk loving decision maker $U''(y) > 0$. This analysis assumes that the decision maker has a fairly constant attitude towards risk over all levels of income. There is no reason, however, why one individual cannot have a utility function, such as the Friedman-Savage

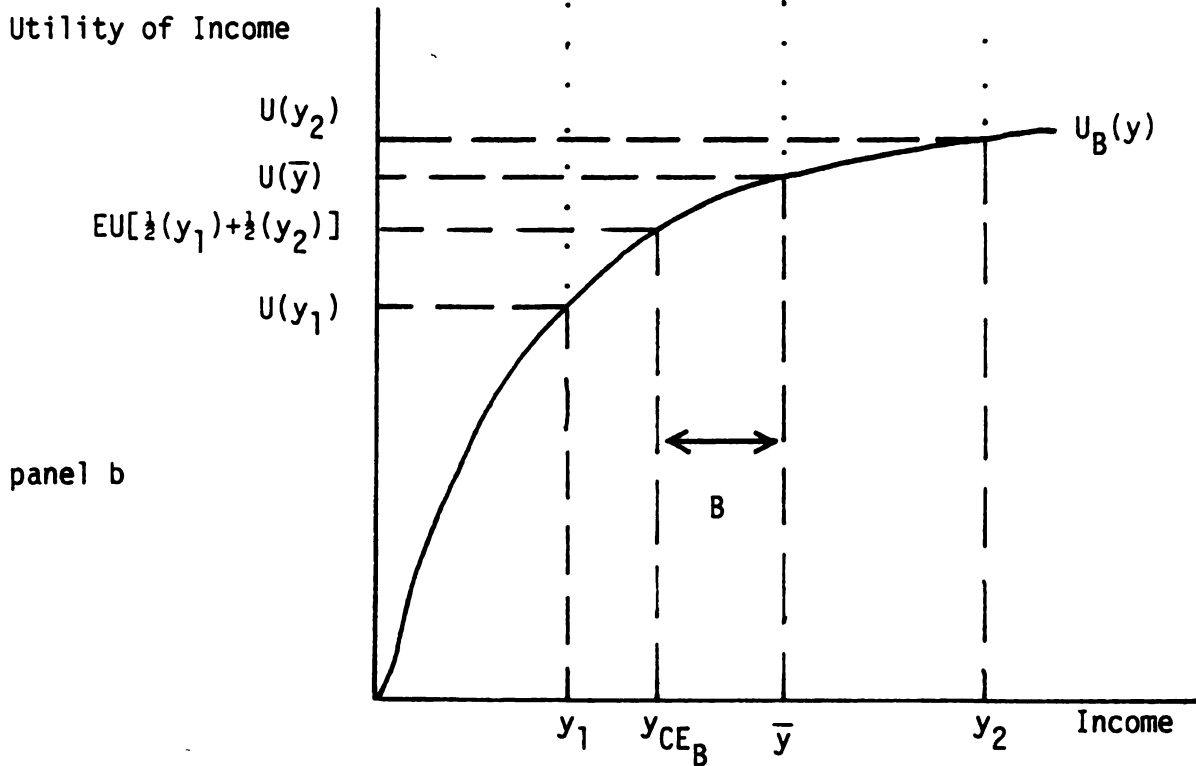
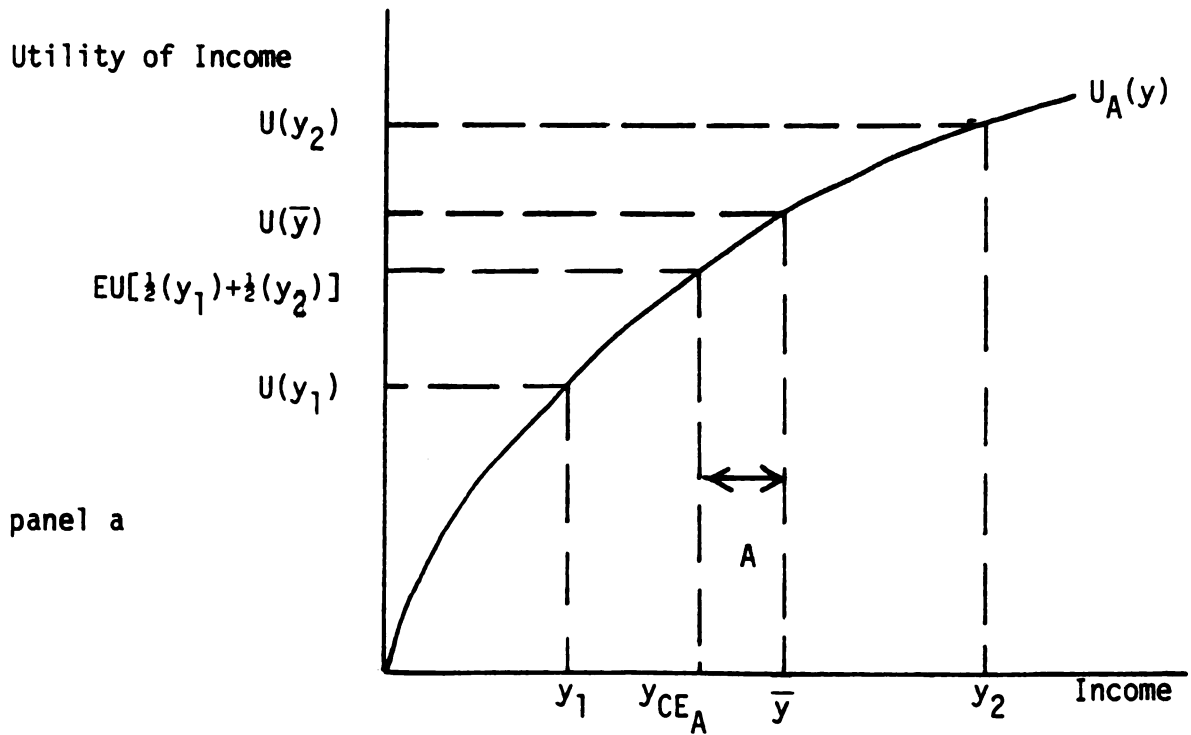


Figure 4.4. A Comparison of Risk Attitudes of Individuals A and B with Utility Functions $U_A(y)$ and $U_B(y)$ and Certainty Equivalent Incomes y_{CE_A} and y_{CE_B}

utility function, which has a combination of convex, linear, and concave segments.

Although this method of determining attitudes towards risk is appealing in its simplicity, it does have one major drawback. Because an individual's utility function is unique only up to a linear transformation, the risk preference indicator $U''(y)$ can be arbitrarily varied by multiplying the utility function by a positive number. Therefore, a measure is needed which remains invariant under positive linear transformations of the utility function.

Arrow-Pratt Coefficients of Absolute and Relative Risk Aversion

Although the non-uniqueness of utility functions prevents their use as a reliable measure of attitude towards risk, the rate at which the utility function bends is unique. Thus, a measure based on the rate of change in slope of the utility function will provide a unique, reliable indicator of an individual attitudes towards risk.

Arrow (1965) and Pratt (1964) independently developed two measures based on this rate of change in slope of the utility function. The first measure, known as the Arrow-Pratt coefficient of absolute risk aversion, directly measures the insistence of an individual for more than fair odds, at least when bets are small. It is defined as:

$$R(y) = \frac{-U''(y)}{U'(y)}$$

A related measure, the Arrow-Pratt coefficient of relative risk aversion measures the elasticity of the marginal utility of wealth. It is defined as:

$$R_r(y) = \frac{-YU''(Y)}{U'(Y)} = \frac{-U''(y)}{U'(y)}Y$$

The Arrow-Pratt coefficient of relative risk aversion is invariant not only with respect to changes in units of utility but also with respect to changes in the units of wealth. Therefore the absolute coefficient of risk aversion is replaced by the relative coefficient of risk aversion when the bet is measured as a proportion of wealth rather than in absolute terms. Both coefficients are positive for risk averse decision makers, zero for risk neutral decision makers, and negative for risk loving decision makers. Arrow has hypothesized that individuals exhibit decreasing absolute and increasing relative risk aversion over wealth.

Coefficient of Partial Relative Risk Aversion

Menzes and Hanson (1970) and Zeckhouser and Keeler (1970) have defined a measure of size of risk aversion, or partial relative risk aversion as:

$$P(y,t) = \frac{-tU''(y+t)}{U'(y+t)}$$

where t is a multiple increase in the distribution of a risky prospect. The advantage of this measure over absolute and relative risk coefficients is that for measurement it requires only that the risk associated with an activity be changed while the wealth level of outcomes remains constant. This may eliminate problems encountered in measuring utility over a range of wealth levels which are beyond the experience of the respondent.

Risk Aversion in the Small and in the Large

The measures of risk aversion discussed so far all rely on attributes of an individual's utility function, whether it be the general shape or its slope. It has been pointed out that these measures are commonly used to compare individuals' attitudes towards risk. Three factors of concern prevent the conscientious student of decision making under uncertainty from glibly accepting these measures as an accurate basis upon which to rank individuals. These include the fact that it is still unclear what utility functions actually represent, the fact that the Arrow-Pratt measures and the related Zeckhouser-Keeler measure of risk aversion are point measures, and findings related to risk aversion "in the large" which indicate that risk attitude coefficients are not independent of probability measures.

No definite conclusion can be reached regarding the concern over what the utility function actually represents. $U(y)$ is simply a function defined over income or wealth, y . The manner of its derivation, through finding points of indifference between risky alternatives, makes it unclear whether the function represents only an ordinal ranking of certain incomes or whether it is also a measure of attitudes towards risk. The ordinal utility function itself contains no element of risk or uncertainty in it. Nevertheless it is accepted by many decision scientists as an adequate base from which to derive measures of attitudes towards risk.

In the section of this chapter on ordering individuals according to their required risk premiums it was asserted that "the larger the risk premium the more averse to risk the individual". This assertion

is substantiated by Pratt (1964) who has derived an approximate relationship between the risk premium and the Arrow-Pratt measure of absolute risk aversion. The Arrow-Pratt coefficient of absolute risk aversion can be taken at any point on an individual's utility function. This arbitrary point can be specified as $\bar{y}$. Similarly, a risk premium measure of attitude towards risk can be derived from the same individual's utility function by asking "for a small gamble with variance σ^2 and mean y_m , what risk premium, π , would the individual be willing to pay to eliminate the uncertainty?" The approximate relationship Pratt found between these two measures is that:

$$\pi = Ra(\bar{y}) \sigma^2 / 2$$

or the risk premium π is equal to the value of the coefficient of absolute risk aversion at $\bar{y}$ times the variance of the action choices divided by two. The certainty equivalent of the gamble can be found by replacing π , the risk premium, with $y_{CE} - \bar{y}$. This can be expressed as

$$y_{CE} = \bar{y} - Ra(\bar{y}) \sigma^2 / 2.$$

It can thus be inferred that the more risk averse the individual, the larger the risk premium he will require. Therefore, at a point, or "in the small," individuals can be ordered according to their attitude towards risk measured in terms of a risk coefficient or a risk premium.

The important qualifier in the above statement is the phrase "at a point". Although individuals can be ordered according to attitude towards risk "in the small" through the use of the risk premium or coefficient of risk aversion, these point measures do not allow for the global ordering of individuals. As a case in point consider

the two individuals, whose absolute risk aversion functions, $R_a, i(y)$, are shown in Figure 4.5. When presented with a gamble with outcomes of y_1 and y_2 and a mean of $\bar{y}^*$ individual B is more risk averse than A since $R_a, B(\bar{y}^*)$ is greater than $R_a, A(\bar{y}^*)$. On the other hand, when presented with a gamble with outcomes y_3 and y_4 with a mean of $\bar{y}^{**}$ individual A is determined to be more risk averse than B since $R_a, A(\bar{y}^{**})$ is greater than $R_a, B(\bar{y}^{**})$.

If the individuals are presented with a gamble whose outcomes are y_2 and y_3 with a mean of $\bar{y}$, it cannot be determined, on the basis of a local or "small" measure of risk aversion, which individual is more risk averse. Furthermore, determining the individuals risk premiums for the gamble will not solve the quandry as many utility functions with corresponding absolute risk aversion functions also have identical risk premiums. In addition, by shifting the probability weights between y_2 and y_3 , the outcomes of the gamble, the risk averse orderings of the two individuals, based on risk premiums, can be reversed. This is inconsistent with the commonly accepted notion that attitudes towards risk are independent of probability measures.

This simple example is powerful in that it shows that efforts to globally order individuals according to attitudes towards risk measured "in the small" can lead to grossly inaccurate conclusions. This point should be kept in mind as the reader reviews chapters VI and VII on empirical measurement of farmers attitudes towards risk and the correlations between risk attitudes and socioeconomic variables.

What conditions must be met before it can be stated that one decision maker is globally more risk averse than another? One sufficient condition is that the utility function $U^*(y)$ bends at a greater

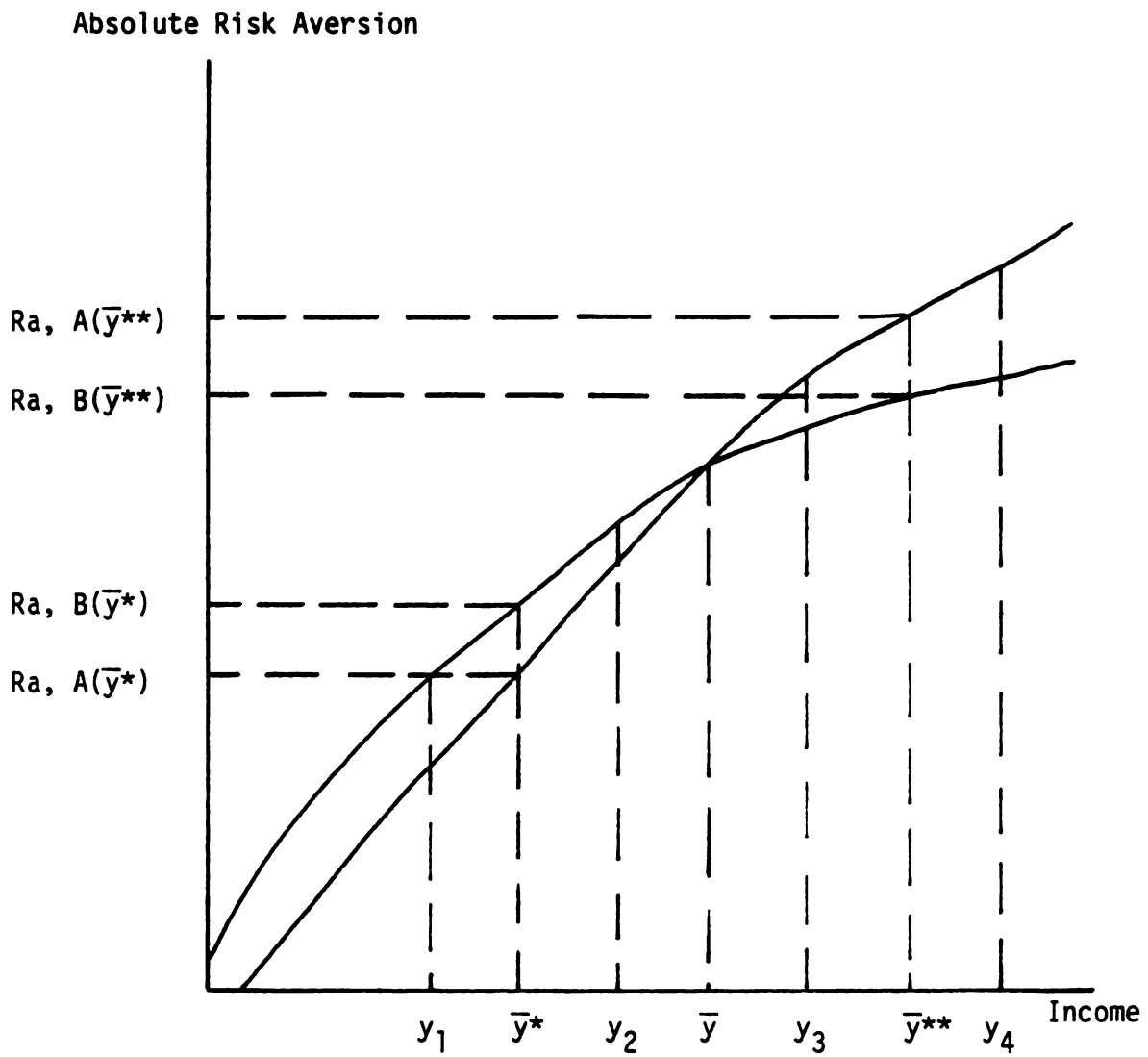


Figure 4.5. A Comparison of Risk Aversion Functions $Ra, A(y)$ and $Ra, B(y)$ Over Outcomes y for Individuals A and B

rate everywhere than does utility function $U(y)$. Pratt (1964) has demonstrated that this condition will hold if $U^*(y)$ is a concave transformation of $U(y)$. For a mathematical demonstration of this see Pratt (1964) or Robison (forthcoming).

If one decision maker is globally more risk averse than another, it can be shown that for every lottery faced by the two individuals the more risk averse will pay a larger risk premium than the other to eliminate uncertainty. In addition the more risk averse decision maker will have a higher Arrow-Pratt coefficient of absolute risk aversion at every income or wealth level than his relatively less risk averse cohort.

Although global ordering of individuals according to their risk aversion "in the large" is an important concept it is rare to find two individuals which can be ordered in this manner. This fact does not diminish the salience of the point that for distributions with dispersion beyond local bounds it is untenable to assume that individuals can be adequately ordered on the basis of local measures of attitudes towards risk.

Expected Value-Variance Tradeoffs

Although not explicitly used to measure individuals attitudes towards risk it is common practice to infer risk attitude orderings from the choices made by individuals from within an expected value-variance (EV) efficient set. Describing the efficient choice set faced by individuals in terms expected values and variances of the probability distributions of outcomes has been popular because quadratic programming models can be used to define an efficient set for any individual. If the individual is a risk averse expected utility

maximizer and the probability distribution functions are normal or have spherical symmetry, his preferred choice will always be a member of the EV set. Once the equilibrium action choice is selected, risk attitude orderings can be inferred from the slope or tradeoff between risk attitude measures "in the small" and "in the large."

Figure 4.6 illustrates an EV set. The solid line ABC represents the efficient set of action choices for the decision maker. The area below ABC includes other feasible choices which would be less preferred by all risk averse decision makers than some point on the line. These alternatives are less preferred because risk averse individuals, who have diminishing marginal utility for money, will prefer the probability distribution with the lowest variance for any given mean. Another way of defining what should be included in the efficient set is set forth by Meyer (1979) who states that if a group of decision makers face any given set of alternatives, an efficient set for that particular group of decision makers is any subset of the alternatives which contains every alternative which would be accepted by one or more of the decision makers. Meyer argues, however, that this latter definition results in an efficient set which is larger than necessary.

The individual of concern in Figure 4.6 has selected the action choice represented in terms of mean and variance at point B as his preferred action choice. Therefore it can be assumed that action choice B with mean $\bar{y}_B$ and variance $\bar{\sigma}_B^2$ maximizes his expected utility at a level which will be called k. This knowledge allows for the mapping of an isoexpected utility curve for the individual which describes all action choices whose combination of means and variances results in an expected utility of k for this decision maker. This isoexpected utility function is represented by the line DBE.

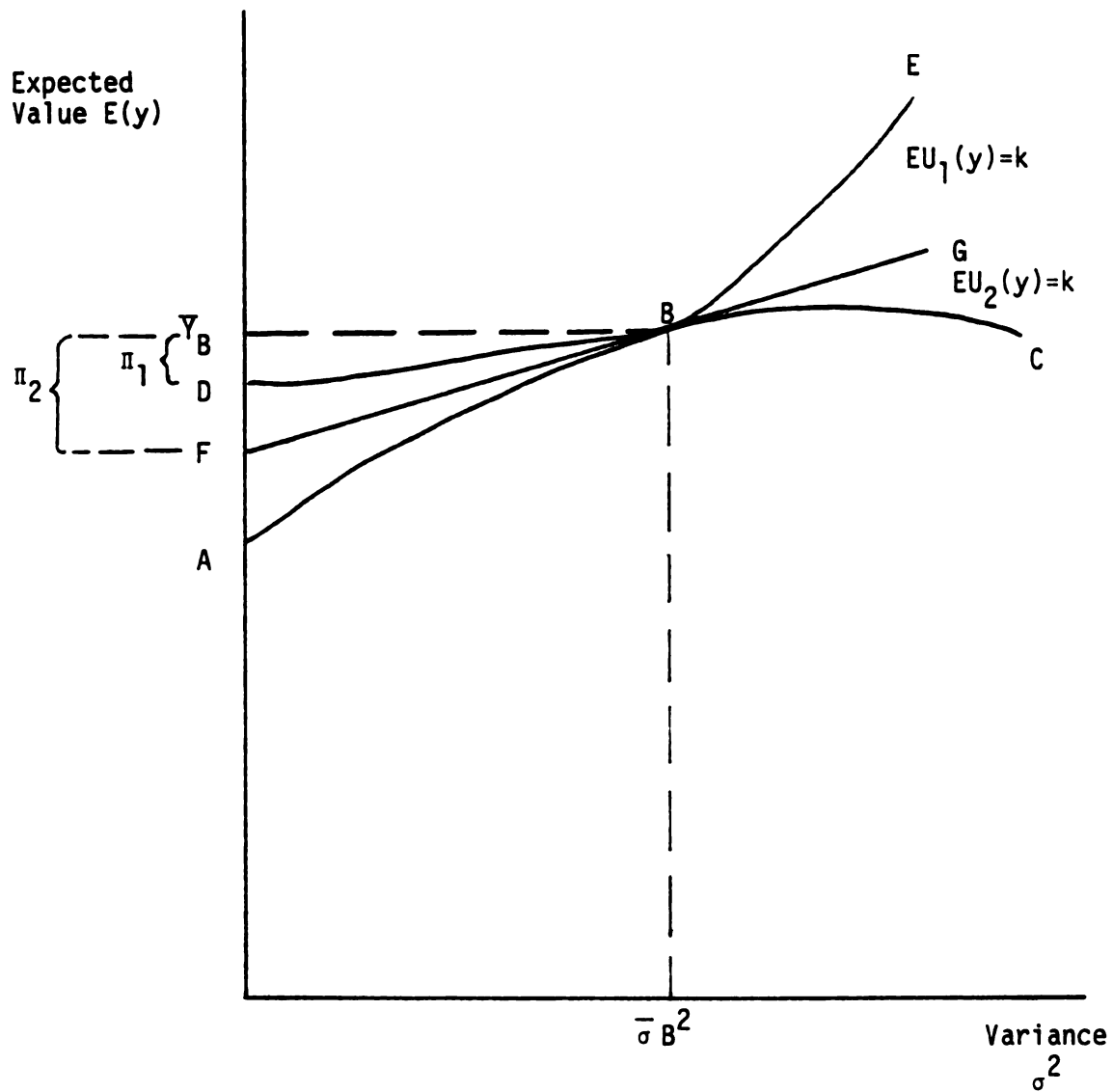


Figure 4.6. An Expected Value-Variance Efficient Choice Set With Isoexpected Utility Function for Two Individuals.

Individual one may not be the only decision maker to select B as his preferred action choice. Individual two also finds that B with a mean of $\bar{y}_B$ and variance σ_B^2 also maximizes his expected utility at a value of k. But because individual two has a different marginal utility for money than individual one, has isoexpected utility function for k shown in Figure 4.6 as the line FBG.

Ordering of individuals one and two by their degree of risk aversion can be accomplished by examining the slopes of their isoexpected utility lines and the risk premiums which they require. For individual one the intercept D defines an action choice with an expected utility of k which has zero variance. Therefore, D represents a certainty equivalent outcome noted as $\bar{y}_{CE,1}$. The slope of his isoexpected utility line can be defined as a constant, $\lambda/2$, times the variance σ^2 . This information can be used to define the expected value of the action choice at point B as

$$\bar{y}_B = y_{CE,1} + (\lambda \sigma_B^2)/2$$

This can be rearranged to obtain

$$\bar{y}_B - y_{CE,1} = (\lambda/2) \sigma_B^2$$

which, by definition is the risk premium. This can be measured directly from Figure 4.6 as

$$\pi_1 = \bar{y}_B - D$$

The slope is the coefficient of absolute risk aversion at $\bar{y}_B$.

The same procedure can be followed for individual two whose risk premium is

$$\pi_2 = \bar{y}_B - F$$

Because π_2 is greater than π_1 , individual two can be said to be more risk averse than individual one. But, it must be remembered that both the risk premium and the coefficient of absolute risk aversion are only local measures. Therefore global inferences about risk attitude are not justifiable when this method is used.

The reliability of risk aversion measures derived from mean-variance tradeoffs has been questioned because the EV set may not be an unbiased estimator of the means and variances of probability distributions of action choices faced by decision makers. Use of this technique requires either that the probabilities associated with each action choice are normally distributed or that the decision maker has a quadratic utility function. While it is not difficult to obtain unbiased estimates of means and variances required to obtain an unbiased estimate of expected utility, the lack of bias only pertains to the initial probability distribution function. But plugging the initial unbiased estimators into either the functional form required for a normal distribution or a quadratic utility function will give you biased estimators.

Other Methods of Measuring Attitudes Towards Risk

All of the methods of determining attitudes towards risk discussed so far rely on the discovery of an individual's utility function over wealth or income or the development of an isoexpected utility function. In contrast to these methods is that used by the observed economic behavior approach which assumes that the degree of risk aversion manifested by individual farmers can be derived from the difference between their actual behavior and that which is considered to

be economically optimal. It is assumed that if the initial model accurately describes the farmers decision environment, then the difference between optimal input levels and those actually used by the farmer are caused by the farmers aversion to risk. The validity of the results obtained is conditional on how well the specified model describes the decision environment. This model will be discussed in greater detail within the context of its empirical application by Moscardi and de Janvry (1977) in Chapter VI.

While the observed economic behavior approach uses mathematical programming to derive numerical measures of farmers attitudes towards risk many programming models only seek to discover whether risk aversion of some type is needed as a constraint to accurately predict farmers choices. Examples of this approach can be found in the discussion of applications of the safety-first model in Chapter II.

Conclusions

Perhaps the most important conclusion to be drawn from this discussion of measures of attitudes towards risk is the caveat that they are in fact local measures and cannot justifiably be used to order individuals according to their attitudes towards risk "in the large." Despite this warning most empirical applications of the expected utility hypothesis and other models of decision making under uncertainty which derive local measures of attitudes towards risk employ them in generalized conclusions about risk attitudes of a population or the ordering of individuals within the population. Examples of this can be seen throughout the studies discussed in Chapters VI and VII.

CHAPTER V

DERIVING UTILITY FUNCTIONS

Most efforts to measure risk attitudes within an expected utility framework require that a utility function be determined for each member of the sample. Several simplifying assumptions are commonly employed in this process. In this chapter, methods for eliciting utility functions, determination of their functional form, and the validity of common simplifying assumptions will be examined.

Methods for Directly Eliciting Utility Functions

In the directly elicited utility approach (DEU), a respondents utility function is derived from his responses to a series of hypothetical gambles. Although the structure of the gamble varies with the method used, the basic concept remains the same. The measurement of an individual's preferences requires the assumption that he can identify the most and least favorable outcomes of any action choice. These extreme outcomes are then used to construct a series of gambles over the relevant range. By adjusting either the value of the outcome or its probability of occurrence, a point of indifference between two gambles can be obtained. After a sufficient number of indifference points are obtained, a utility function can be derived using either statistical or graphical methods. Three game structures have been devised for directly eliciting utility functions: the Standard Reference Contract or von Neuman-Morgenstern model; the Equally Likely

Risky Prospects with a Certainty Equivalent, or modified von Neuman-Morgenstern model; and the Equally Likely but Risky Outcomes, or Ramsey model.

Using the Standard Reference Contract method the analyst finds the best and worst possible outcomes facing the decision maker and assigns arbitrary utility values to them. Probability values which sum to one are chosen and assigned to the outcomes of the gamble and the respondent is asked how much he would pay to play the resulting lottery. Once this indifference level of income is found, its utility measure is obtained by setting it equal to the expected utility of the gamble. Utility values for other levels of wealth are found by varying the probabilities in the lottery.

Three specific criticisms have been directed at this model. First, if the individual has a utility or disutility for gambling his response will be biased by the fact that he is given a choice between the outcome of a gamble and a certain event. Secondly, this technique assumes that the individual's perception of the probabilities of the two events in the gamble occurring (his subjective probabilities) are identical to the assigned objective probabilities.¹ Third,

¹The term 'objective probability' may be misleading as all measures of probability involve a degree of subjective judgement and none can be objectively ascertained with certainty. In the case of empirical establishment of the probability the heads will occur on the flip of a coin we can only assert that as N , the number of flips of the coin, goes to infinity, the variance from .5 will tend towards zero. Subjective judgement is involved in determining that the remaining variance is too small to be of concern. Nor can we prove analytically that the objective probability of receiving heads in a coin flip is exactly .5 since, as Gödel has pointed out, even a purely logical system is not entirely provable wholly within itself. (Johnson, 1982) Therefore 'objective probability' should be interpreted as either the probability presented in a given gamble or the probability within some subjective set confidence interval that an event will occur, and not as an empirically 'proven' or analytically 'true' probability.

biases may result from preferences for specific probabilities. Menger (1934) has argued that probabilities near one-half tend to be overvalued vis a vis probabilities near zero or one. Samuelson (1977) has stated that small probabilities tend to be overvalued.

The Equally Likely Risk Prospects with a Certainty Equivalent (ELCE) method was designed to overcome biases due to preferences for specific probabilities by assigning "ethically neutral" or equally likely probabilities to outcomes. Although this method overcomes biases due to probability preferences it is still subject to the biases which may arise from attitudes towards gambling or from divergence between subjective and objective probabilities. Scandizzo and Dillon (1979) have criticized the use of equal probabilities since "in a simple two-alternative bet, variance is completely confused with range, and skewness is completely confounded with the relative values of the probabilities, it is clear that a risky prospect has to have both unequal outcomes and unequal probabilities to display the minimum characteristics of randomness required to produce a subject's reaction."

The Equally Likely but Risky Outcomes (ELRO) method also uses neutral probabilities but reduces biases due to utility or disutility for gambling by presenting the subject with a choice of two gambles instead of a gamble and a sure outcome. In this model, the individual is presented with a .5 chance of winning "a" and a .5 chance of winning "c". He is then presented with an alternative gamble with only one of the two outcomes, a .5 probability of winning "b" specified. The respondent then selects a level of outcome "d" which would be required before he were indifferent between the two gambles. At the chosen level for "d"

$$U(A) + U(C) = U(B) + U(D)$$

and the utility interval "a" to "b" equals the utility interval "c" to "d". Additional games are then played which result in points of equally spaced utility until a complete utility function is developed over the relevant range of outcomes.

Officer and Halter (1978) tested the predictions made from utility functions elicited using these three methods against the actual fodder reserve plans used by five farmers in New South Wales, Australia. The mean and variance of the actual fodder reserve program used by each farmer was determined as were the mean and variance of twelve alternative reserve programs. The expected utility of each fodder reserve program was estimated using the costs of fodder reserve programs ranging from zero to twelve months of reserve and the three utility functions derived for each farmer. The utility functions developed for each farmer were not limited to a specific functional form but were selected on the basis of the highest R^2 value.¹ All of the functions were non-linear and indicated risk aversion. The fodder reserve program with the maximum expected utility was designated as the predicted decision for that utility function. The farmers' actual fodder reserve programs were compared to the fodder reserve choice predicted by the criterion of minimizing expected cost and each of the three utility functions. Error was measured as the difference between the predicted and actual months of fodder reserve held.

¹ R^2 is not a good criterion to use when selecting the proper functional form of the utility function because it does not compensate for varying degrees of freedom found in the linear and higher order equations. A more appropriate criterion is $\overline{R}^2$ which compensates for the differing degrees of freedom.

The average error of prediction using the utility function derived via the Standard Reference Contract method was 1.039 months of fodder reserve, while the average error using the ELRO method was .726 months of fodder reserve. The average error using the ELCE method was only .390 months. The criterion of minimizing expected cost resulted in an average error of .628 months of fodder reserve held.

One year later the farmers were reinterviewed and their utility functions were elicited using the ELCE and ELRO methods. They were also presented with their original fodder reserve program and that which was selected using the criterion of maximizing expected utility. Some of the respondents chose to alter their preferred fodder reserve programs to conform to the expected utility maximizing choice. It was found that the utility analysis using the ELRO method gave accurate predictions 76% of the time with an average error of .26 months of reserve held while the ELCE method resulted in an average error of .60. The criterion of minimizing expected costs gave accurate predictions only 58% of the time with an average error of .71.

Although none of the subjects showed any apparent utility or disutility for gambling, it is postulated that because a gambling bias may occur, the ELRO model is theoretically superior to the other two. But, because it involves significantly less work, the ELCE method may be more practicable.

Functional Form of the Utility Function

Individual utility functions are not theoretically restricted to one shape nor are they restricted to exhibiting a specific series of shapes such as the Friedman-Savage Utility function presented in

Chapter IX. Instead, the utility function may be linear throughout, or it may exhibit linear, concave and convex segments.

Empirical results have shown that individuals do not, in general have linear utility functions. Friedman and Savage's hypothesis of an "everymans utility function" has been challenged by results which show not only a wide variety of functional forms between studies, but different functional forms for individuals within the same sample. For example, Halter and Mason (1978) found that approximately one third of their sample had linear utility functions while the remaining two thirds were equally divided between exhibiting quadratic and cubic functional forms of utility functions. Binswanger (1978) found that all but one of 118 individuals had non-linear, risk averse utility functions which exhibited increasing partial risk aversion. While Francisco and Anderson (1972) found that utility functions were "S" shaped in 19 out of 21 cases, indicating risk aversion for relatively large gains and risk preference where large losses were concerned, they also found that participant's utility functions had inflection points at widely varying money levels which were not necessarily related to present wealth position.

Other studies, most notably Dillon and Scandizzo's work in northeast Brazil (1978), have shown the importance of the functional form of the utility function for the results obtained regarding attitudes towards risk. To test the hypothesis that farmers have different attitudes towards risk when subsistence is and is not assured, and that small owners and sharecroppers have different attitudes towards risk, Dillon and Scandizzo directly elicited the utility functions of small farmers in northeast Brazil. Instead of presenting the sixty-four sharecroppers and sixty-six small owners with hypothetical

gambles involving money outcomes, the gambles were framed within the standard reference contract model in terms of the likelihood of certain yields in numbers of years out of four. Two types of risky prospects were used, yielding two sets of responses for each group of farmers. One involved only payoffs above household subsistence requirements while the second included the possibility of not producing enough to meet subsistence needs.

Risk attitude coefficients were derived from mean-standard deviation, mean-variance, and exponential utility functions. These were specified, respectively, as:

$$U = E + \alpha V^{\frac{1}{2}}$$

$$U = E + \beta(E^2 + V)$$

$$U = \int_{-\infty}^{\infty} (1 - e^{-\gamma x})(1 - e^{-\gamma})^{-1} f(x) dx$$

where x is a risky prospect with probability distribution $f(x)$, mean E and variance V . For all three models, estimation of risk attitude coefficient was based on solution of the relationship that the utility of a risky prospect is equal to the utility of its certainty equivalent.

The authors found that conclusions about a populations risk attitudes are highly contingent upon the type of utility function fitted in a unidimensional utility context. With the mean-standard deviation model, small owners were more risk averse than sharecroppers and both groups were more risk averse when subsistence was a stake than when it was not. The mean-variance model does not support the hypothesis that owners are are risk averse than sharecroppers, although both groups are still more risk averse with subsistence at stake than when it is assured. The exponential form showed both groups to be risk averse, but with little difference between the groups or the

two situations.

For many commonly used utility functions, the properties of absolute and relative risk aversion are implicitly constrained by the choice of a utility function or by utilization of a methodology which requires the assumption of a specific utility function. Although not restricted on theoretical grounds, none of the common utility functions allow for both increasing and decreasing risk aversion albeit at different levels of wealth.

Table 5.1

Risk Aversion Coefficient Properties of Utility Functions*

Utility Function	Property of Absolute Risk Aversion Coefficient	Property of Relative Risk Aversion Coefficient
LINEAR	none	none
QUADRATIC	always increasing	always increasing
SEMILOG	always decreasing	constant
LOG LINEAR	always decreasing	constant
EXPONENTIAL	constant	always increasing

*Adapted from Lin, Gabriel and Sonka, 1981.

Since the development of the Bernoullian utility function for money, the issue of its proper functional form has been debated but not resolved. Early theorists and practitioners preferred the quadratic form of the utility function,

$$U = a + bW + cW^2 \quad \text{where } b, c > 0$$

because, if properly constrained, this function conforms to the risk averters requirement of a positively sloping concave function. It is also easy to use since, when combined with linear profit functions,

it generates quadratic expected utility functions which are easily maximized with currently available programming routines. The quadratic form is also easily fitted by OLS to utility questionnaire data (Buccola and French, 1978).

Criticism of the quadratic form of the utility function began with Arrow and Pratt's identification of an absolute risk aversion coefficient. If the decision maker is more willing to accept a fixed gamble as his wealth increases, the absolute risk aversion coefficient would decline with increases in wealth. The intuitively appealing description of behavior is not possible using quadratic utility functions which show that risk aversion increases rather than decreases with wealth.

The semilog form of the utility function has been proposed as an alternative which is more acceptable according to the hypothesis of declining absolute risk aversion. Unfortunately, it has no tractable solution other than the use of the Taylor Expansion with its associated error term. For empirical research, this is an important disadvantage which often overrides the theoretical advantage of its property of declining absolute risk aversion.

Buccola and French (1978) explore the use of an exponential utility function as an alternative to the quadratic or semilog functions and then compare the predictive ability of the exponential model to one using a quadratic function for two producers. Grower number one's responses to a Standard Reference Contract DEU procedure approximate an exponential shape. Grower number two's responses more nearly suggest a cubic function. Because of a commitment to increasing absolute risk aversion, his utility function is also fit using an exponential form. Quadratic functions are also fit to the data for

both respondents.

In both cases, the quadratic function was more concave than the corresponding best-fit exponential function. As money values increase, the quadratic approaches the exponential from below, crosses it, and then approaches the exponential again at high money values. In both cases, the absolute risk aversion coefficients under the quadratic specification are lower than those under the exponential specification below the point at which the two functions intersect. The growers coefficients are equal at or near the intersection, and the quadratics coefficient of absolute risk aversion rises above the exponential beyond the point of intersection.

In a research context much of choice behavior under uncertainty is characterized by the absolute risk aversion coefficient. Given the results of Buccola and French's study, researchers need to be wary not only of the utility functional form employed, but also of the feasible expected profit range of the set of risky prospects considered. Exponential and quadratic forms predicted similar choice behavior for expected profit range near the intersection of the functions, but highly divergent behavior elsewhere.

A Generalized Form of Utility Functions

Recent developments in the area of transformation of variables suggest that the appropriate degree of nonlinearity in a utility function does not require a priori assumption but can be specified by sample observations. This can be accomplished through the use of a generalized functional form,

$$1. \quad \frac{U^\lambda - 1}{\lambda} = \alpha + B \frac{M^\lambda - 1}{\lambda}$$

with an associated risk aversion coefficient

$$2. \quad r(M) = \frac{U''}{U'} = -(\lambda-1) \left(\frac{1}{M} - \frac{1}{U} - \frac{\partial U}{\partial M} \right)$$

where λ is the transformation parameter, U is utility, and M is monetary income or wealth.

$$3. \quad U_i^* = B_0 + B_1 M_i^* + B_2 M_i^{2*} \text{ where } U_i^* = \frac{U_i^\lambda - 1}{\lambda}$$

$$M_i^* = \frac{M_i^\lambda - 1}{\lambda} \text{ and}$$

$$M_i^{2*} = \frac{M_i^{2\lambda} - 1}{\lambda}$$

(Lin and Chang, 1978).

If λ equals one, equation (1) and (3) are the same as linear and polynomial functions respectively. When λ approaches zero, equation (1) is equivalent to a log-linear form. In general, different degrees of curvature of the utility function can be represented through different values of λ . Therefore, the general functional forms provide greater flexibility in the degree and type of nonlinearity than either linear or polynomial functions. It is also possible to transform only U or M so that the generalized equation is equivalent to a semilog form when λ approaches 0.

Lin and Chang (1978) use the generalized form to determine whether the Bernoullian utility maximization hypothesis could have predicted a farmers production decision better than that reported by Lin, Dean, and Moore (1974) if a better functional specification had been adopted. From the six farmers studied by Lin, Dean and Moore, one was chosen for which lexicographic utility maximization, predicted actual behavior better than Bernoullian utility or profit maximization, both of which had done equally poorly.

Using the data from the previous study the generalized form was fit using a series of λ 's and a maximum likelihood technique was used to select the best value of λ . In this case a λ of $-.70$ was determined to be the maximum likelihood estimate of the Bernoullian utility function. The farm plan choice predicted using the new specification of the utility function corresponded to the actual farm plan used by the farmer which neither the lexicographic nor the expected profit maximization model was capable of predicting in this case.

The Effect of Flexibility of Functional Form and Magnitude of Possible Outcomes on Utility Function Estimation

Despite the fact that utility functions are not theoretically restricted to exhibiting only increasing or decreasing first derivatives throughout their range, most applications of the EUH reviewed assign such a restriction to each individual's utility function. The use of an inflexible functional form and the range of prospects over which the utility function is taken can have a major impact on the outcomes of the analysis.

It is not unreasonable to imagine that individuals will exhibit utility functions of different shapes for prospects involving gains above current wealth and those involving losses. Many studies only examine situations where either small gains or small losses are possible. Even those studies which allow for situations where both gains and losses are possible only allow a utility function with either increasing or decreasing marginal utility.

Consider an individual who, unknown to the researcher, has a Friedman-Savage form utility function as shown in Figure 5.1. If the individual's utility function is fit with a single inflexible

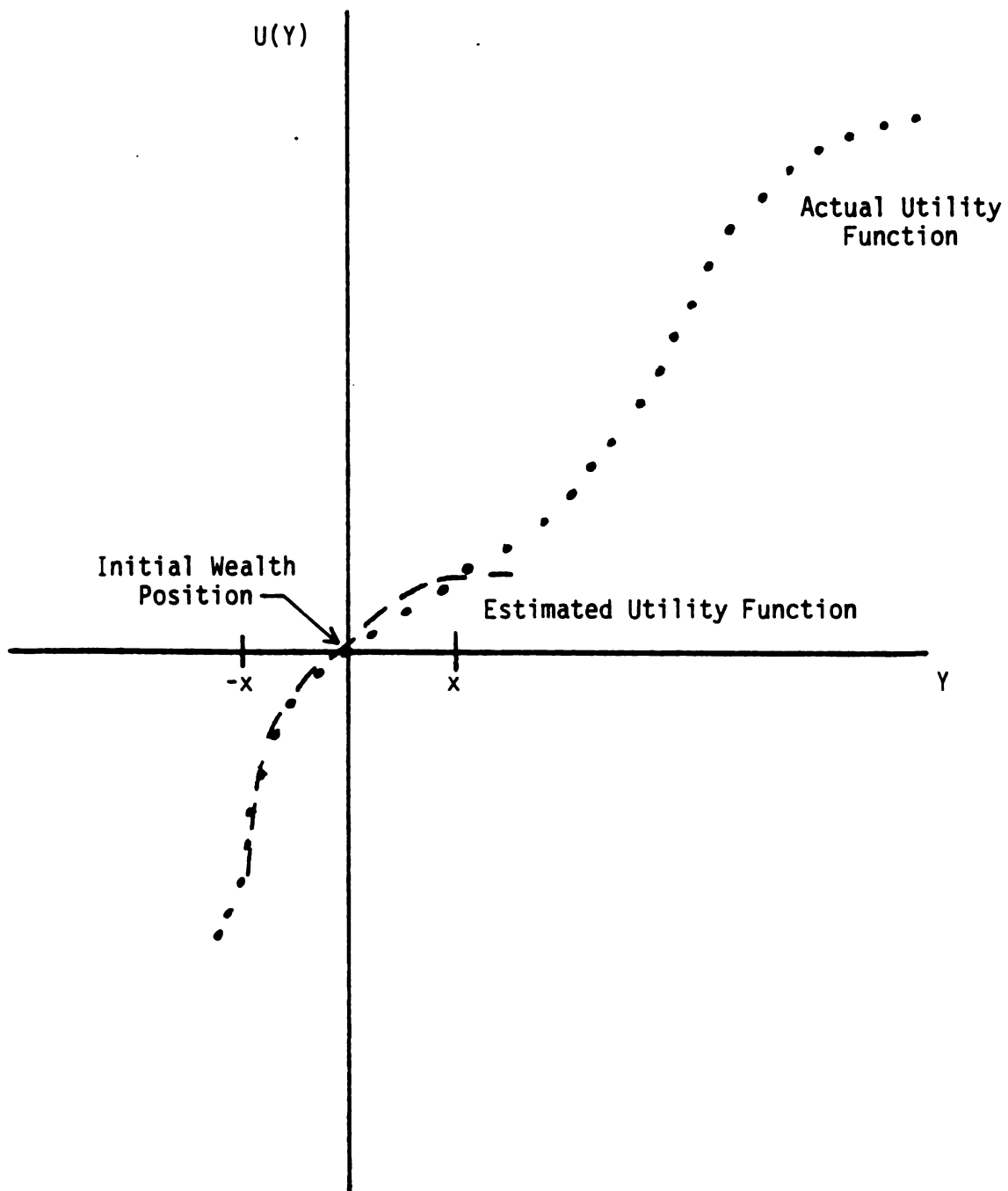


Figure 5.1. An example of the Effect of Flexibility of Functional Form and Magnitude of Possible Outcomes on Utility Function Estimation.

functional form over a small, symmetrical range of gains and losses ($-x$ to x), he will appear to be risk averse over the entire range.

Johnson (1983) has argued quite convincingly that the restrictions of an inflexible functional form utility function and narrow range of prospects are responsible for the generally accepted assumption that farmers are risk averse. An accurate mapping of an individual's utility function requires both that the range of prospects considered includes gains and losses of a size large enough to alter the individual's socio-economic status, and allowance for both increasing and decreasing marginal utility over the range of prospects. Both of these are necessary if any inflection points in an individual's utility function are to be reflected in the functions fitted. Results from fitting functions without inflection points cannot be taken as evidence that such points do not exist.

Arguments of the Utility Function

Following Bernoulli, utility has been measured over wealth or income holding everything else constant. More recently, economists and psychologists have argued that the traditional unidimensional utility function does not adequately capture the complexity of human cognition or the variability of attributes within a population. Although this argument is, in many respects, a sound one, attempting to incorporate multidimensional utility analysis into an expected utility framework opens a Pandora's box of methodological problems ranging from measurement of individual utility to comparisons of utility between individuals.

One of the first models which explicitly incorporated multi-attribute utility functions was lexicographic utility maximization

(see Chapter II). This model has a distinct advantage in that it allows for a hierarchy of wants which are not restricted to those which can be defined in monetary terms. The attendant disadvantage, however, is that it is nearly impossible to make any interpersonal comparison of utility as no two individuals can be assumed to exhibit the same hierarchical ordering of preferences.

Later, Kahneman and Tversky (1979) argued the necessity of including subjective probability or decision weights into the determination of expected utility. Rather than attempting to hold the influence of probabilities constant they propose an explicit form for its inclusion. Their proposed model is multiplicative; probabilities are weighted by a function V and outcomes by a utility function U . The resulting ordering index model can be written as

$$\text{maximize } EU(y+w)v(F(y+w))$$

Rather than proposing methods to measure the new function V , they suggest instead that it is a standard function across individuals, even though it is not well behaved near the endpoints. In some respects this assumption undermines the initial intent of including decision weights as an argument which would account for the variation among individuals.

Although Prospect Theory may not provide an effective mechanism for incorporating subjective probabilities or decision weights into the utility function, there is strong evidence that subjective probabilities are an important factor in determining preference orderings. Davidson, Suppes, and Siegel (1957) have shown that individuals subjective probabilities do not necessarily conform with objective probabilities even in relatively simple situations such as the flip of a coin. Haneman and Farnsworth (1980) have shown the effect of

differing subjective probability distributions on the pest management decisions made by forty-four cotton growers in the San Joaquin Valley in California. They argue that cotton growers' choice of IPM or conventional pest management strategies is based not on differences in risk preferences but on different subjective probability distributions for the outcomes of each action. It was found that there was no difference in the distribution of risk preferences between IPM and nonIPM users. But while each group's subjective probability distribution of yields and profits was correct for their own method, it underestimated the expected value of the other method. Given the subjective probability distributions for partial profits under both control strategies, the current strategy employed was superior to the alternative for 35 of the 44 growers using either an expected profit or an expected utility maximizing decision criterion.

The discrepancy between subjective and objective probabilities may be due, in part, to individuals ability to revise probabilities "accurately" compared to revised estimates obtained using Bayes Theorem. Francisco and Anderson (1972) tested Australian farmers' ability to fully use new information related to the price of wool, lamb markings as a percentage of ewes joined, and annual rainfall in inches. Information utilization and probability revisions were calculated using the Phillips-Edwards accuracy ratio of:

$$\text{accuracy ratio} = \frac{\text{Observed log likelihood ratio}}{\text{Bayesian log likelihood ratio}}$$

where the log likelihood ratio is the difference between the observed log posterior odds and observed log prior odds. The accuracy ratio equals one when subjective revision is identical to the Bayesian revision. In all of the tested cases, the accuracy ratio was less than 0.55. This implies that even when participants are given what

could be considered to be adequate information regarding the objective probabilities it is unlikely that their subjective probabilities will be identical to the objective ones. Since accuracy ratios vary among individuals, each person in a sample will revise probabilities differently and therefore will be responding to a different gamble than everyone else even if you present them all with identical objective probabilities.

Janis and Mann (1976) argue that many decisions are made under high levels of stress which influence the decision makers behavior. They describe five different coping models used by individuals depending on the level of stress to which they are subject. In the unconflicted adherence model the risks associated with maintaining the status quo are small. As a result, there is no consideration given to alternative action choices and no attempt is made to change. In the unconflicted change model the risk associated with not changing is high while the stress associated with the change is low. The action choice selected is the one which is most highly recommended and alternative choices are not explored or considered. The defensive avoidance model is characterized by high levels of stress. The decision maker attempts to shift responsibility, procrastinate, and remain inattentive to new information. Because the decision maker does not believe that a better course of action is available, he fails to examine alternatives. High stress levels also characterize the hypervigilance model in which the decision maker siezes on hastily contrived solutions overlooking the full set of consequences because of his excitement. In contrast to these four models, the vigilance model is the one followed by a EUH rational man. Under moderate stress levels, the decision maker carefully assimilates and weighs information regarding

possible action choices and appraises each choice before making a decision.

Another study proposing still different axioms of rational behavior is Tamerin and Resnik's study of cigarette smokers (1972). In contrast to risk takers who bear risks because of potential monetary rewards, the risks taken by smokers or other substance abusers can be described as impulsive. This type of risk taking appears to exhibit the absence of a rational evaluation process and fails to conform with the EUH model. Consequently, a more complicated utility model is needed with psychological arguments to account for pleasure obtained from activities in which the objective risks are exceedingly high.

In order to explain the deviations from "rational" expected utility maximizing behavior which can be explained via a unidimensional utility function over money, several new arguments must be added to the utility function. Only a few additional arguments have been mentioned; there are doubtlessly numerous others. The resultant utility measure would be a function of income or wealth, probabilities, stress levels, pleasure, and satisfaction of nonpecuniary wants. Although understanding their influence on the formation of preferences may be possible, given the state of the art of decision analysis, researchers do not yet have the tools to formally incorporate them into expected utility analysis.

Conclusions

The single argument utility function provides the fundamental tool of the expected utility hypothesis which in turn is the basis for much of the disciplinary work on uncertainty today. But questions about its derivation and the arguments included are causing some economists to reexamine its unconditional acceptance in use. Still, the

expected utility hypothesis is considered by many to be the best available tool for understanding the effect of uncertainty on economic choices.

One of the fundamental assumptions of utility function derivations which has been questioned is that individuals can accurately reduce their utility for wealth in terms of a single, precise number. Second is the question of whether a utility function derived in a contrived choice situation can be used to accurately predict real world situations. Third, and perhaps most important, is the debate over what arguments need to be included in the utility function. The logic of the argument that factors such as attitude towards gambling, subjective probability or decision weights, stress levels, and bounded rationality should be included as arguments in the utility function must be weighed against the costs of foregoing the use of the EUH as a tool while new methods for their measurement and incorporation into utility functions are developed. The last major question is what functional form the utility function should exhibit. It has been shown that the functional form assumed has important implications not only for the action choices predicted but also the attitude towards risk attributed to the decision maker. This final point is discussed in greater detail in Chapter IX.

The studies reviewed in Chapter VI as a whole assume away these questions. In examining the results of these studies as well as those presented in Chapter VII it is important to bear in mind the questions raised in this chapter and Chapter IV.

CHAPTER VI

EMPIRICAL MEASUREMENT OF FARMERS' ATTITUDE TOWARDS RISK

During the past three decades, numerous field studies have been carried out which measure farmers' attitudes towards risk within the context of expected utility and safety-first models. Risk attitudes have been determined through the use of a variety of techniques. The interviewing method derives risk attitude coefficients from utility techniques described in the first part of Chapter V. The experimental approach, which assumes a particular functional form of the utility function for all members of the population, uses choices between sets of gambles with real payoffs to determine the individual's local attitude towards risk. In contrast to these two approaches, the observed economic behavior approach does not require the direct participation of the sample population. The risk attitude coefficient is determined by examining the difference between optimal and observed levels of input use. Yet another approach is to use risk premiums to derive risk attitude coefficients through mathematical programming techniques.

All of these approaches embody assumptions regarding the validity of a hypothesis, initial conditions, and auxiliary assumptions. With only a few exceptions, the studies do not incorporate tests of these assumptions; none meet both conditions one and two of a test of a hypothesis outlined in Chapter II. In this review of the literature on the measurement of attitudes towards risk, particular attention will be paid to the specification of initial conditions (i.e., the

choice set employed) and the validity of auxiliary assumptions (i.e., that the utility function is measured accurately).

The Interviewing Approach

In Halter and Mason's (1974), and Whittaker and Winter's (1979), studies of the risk attitudes of 44 Oregon grass seed farmers it was assumed that decision makers select action choices according to an expected utility model. Initial conditions and auxiliary assumptions were that the farmers' income reflects the outcome of a choice of preferred farm plan, that the actual farm plan is identical to the preferred farm plan, that the utility function can be measured accurately using the Equally Likely but Risky Outcomes model, and that subjective probabilities are identical to objective probabilities.

As was noted in an earlier discussion of this study, it was found that equal proportions of the group exhibited linear, quadratic, and cubic functional forms of utility functions. When the Arrow-Pratt measure of absolute risk aversion was evaluated at each farmers' 1973 gross income level, equiproportional groups of farmers were risk averse, risk loving, and risk neutral. Halter and Mason do not specify the range of coefficients found, but comments by Whittaker and Winter indicate that it was $+0.40$, implying slight aversion to risk.

Whittaker and Winter attempted to replicate Halter and Mason's study three years later. The authors do not indicate whether individuals were restricted to the same functional form of the utility function as was fit in 1973, nor do they indicate the distribution of functional forms or risk attitude coefficients. They do state that the average absolute risk attitude coefficient, measured at each farmers own 1976 gross income level, was -0.29 implying a slight

preference for risk.

The shift in the average absolute risk attitude coefficient between 1973 and 1976 raises questions about the validity of the auxiliary assumption employed. Without more information than that provided by the researchers, discussion of this question becomes speculative in nature. The shift in the average risk coefficient could be the result of interviewer bias, changes in the functional form fit for each farmer's utility function, or may provide strong support for the hypothesis that attitudes towards risk are not invariant over time.

The possibility of interviewer bias resulting in significantly different utility functions was supported by Binswanger (1980) in a study in rural India. Binswanger divided his sample in half and had each subsample interviewed in opposite order by two teams of trained interviewers. He found that in each village, the same team of interviewers classified the respondents as more risk averse than did the other set of interviewers, regardless of which team had surveyed that village first. Those differences were statistically significant, often resulting in the reclassification of the respondent from risk preferring or risk neutral to extremely risk averse.

Without knowing whether the utility function fit to the 1976 data was restricted to the same functional form used in 1973 one could also speculate that the change in risk attitude coefficients was a result of the use of a different functional form and not of a shift in preferences. For example, if the same individual had a fitted utility function which was quadratic in one year and cubic in another, even if their income did not change, their evaluated risk attitude coefficient could change dramatically.

Utility of Income

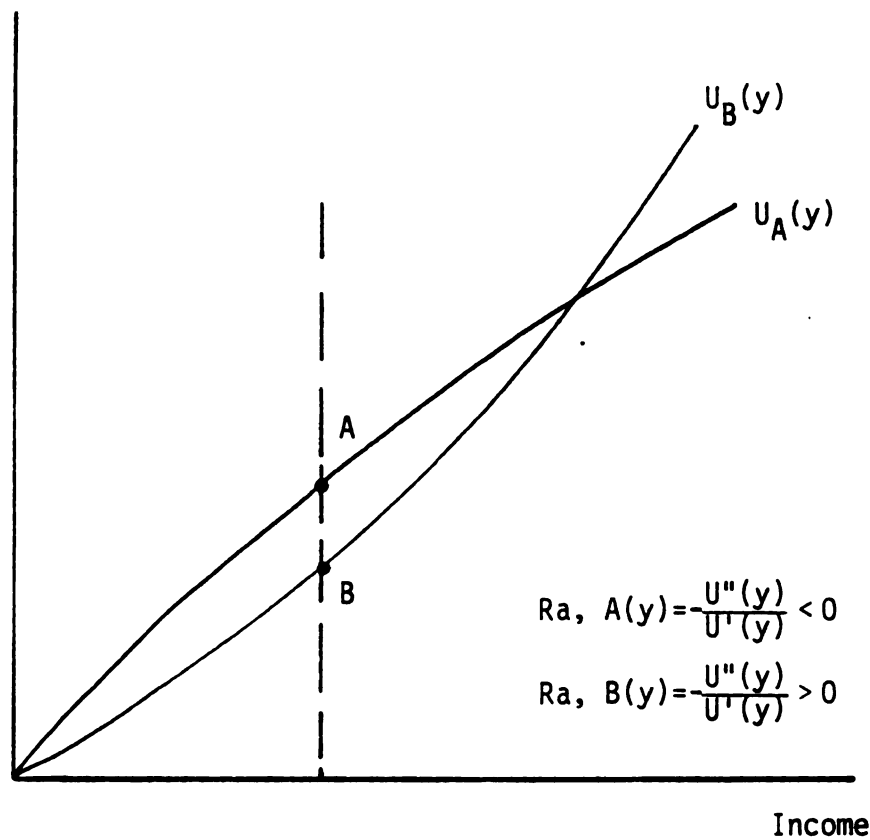


Figure 6.1. Effect of a Change in Functional Form of the Utility Function on the Coefficient of Absolute Risk Aversion

Although Halter and Mason and Whittaker and Winter were able to produce a numerical measure of attitudes towards risk, their studies add little to our understanding of decision making under uncertainty. Because the Arrow-Pratt coefficient was taken at each farmer's own gross income level, interpersonal comparisons of risk attitude are only comparisons of present attitude towards risk. Except for farmers with linear utility functions, the coefficients do not even provide a general ranking of risk attitudes. If two farmers shared an identical utility function such as the one shown in Figure 6.2, but had different incomes in 1973, one might incorrectly conclude that Farmer A was more risk averse than Farmer B, even though the farmers would have the same absolute risk aversion coefficient for any given level of income.

In a study of risk attitudes of farmers in northeast Brazil (discussed in detail in Chapter V) Dillon and Scandizzo (1978) employed many of the same initial conditions and auxiliary assumptions used by Halter and Mason and Whittaker and Winter. In the course of their research, Dillon and Scandizzo tested some assumptions while leaving others unvalidated. To ensure that attitudes towards gambling and subjective probabilities for yields would not bias results within the sample, it was ascertained that both sharecroppers and small owners in the sample were able to nominate yield probabilities as chances out of ten and had quite similar attitudes towards gambling and subjective probability distributions for yields. Two assumptions that were not tested and which may be critical in a developing country context are that farmers choices can be modelled via unidimensional utility functions with an argument in monetary units and that there is perfect substitution between cash and the market value of

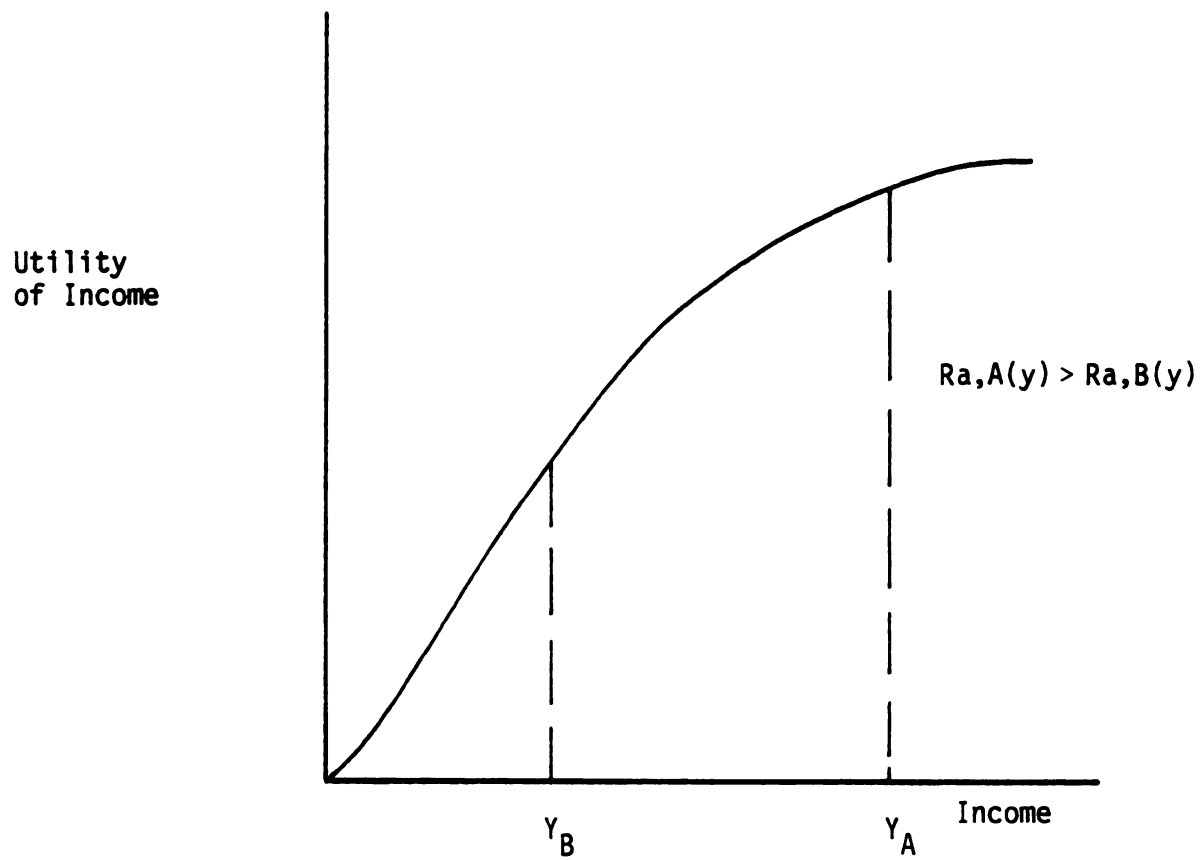


Figure 6.2. Effect of Different Income Levels in Risk Attitude Coefficients of Two Individuals Who Share the Same Utility Function

subsistence.

When risk attitude coefficients were derived from mean-standard deviation, mean-variance, and exponential utility functions, it was found that conclusions regarding risk attitudes are highly dependent upon the functional form of the utility function which is used. Dillon and Scandizzo also found that in an expected utility context the distribution of peasant risk aversion coefficients is diverse and not necessarily well represented by an average population value.

The Experimental Approach

Results of studies employing interviewing methods have been questioned because of the hypothetical nature of the games which respondents are asked to play. Although Dillon and Scandizzo's method of using gambles framed in terms of actual farm yields reduced the level of abstraction faced by the respondent, they were still hypothetical gambles. It has been argued that the responses given to such gambles may not be the same which would be given if the outcomes were real. In order to reduce the distortions which may arise from the use of directly elicited utility methods, Binswanger determined the risk attitudes of 330 Indian villagers using gambles with real payoffs.

Binswanger's first step was not to derive a utility function using DEU techniques. Instead he assumed a constant partial risk aversion utility function of the form

$$U = M(1-S)^{1-S}$$

where M is the certainty equivalent of a new prospect and S is the partial risk aversion coefficient which is, theoretically, fixed for each individual regardless of the level of payoff.

Individuals were asked to select a preferred gamble from a set of eight. The games were structured in a mean-variance framework with higher expected returns obtainable at the cost of higher variances. The worst possible outcome of any game was a zero gain and subjects were not faced with any budget constraints. Farmers partial risk aversion coefficients were derived from their preference ranking of alternative gambles. To simulate actual decision making processes individuals were given several days to discuss the choice of gambles with relatives and friends before being required to state their preferences.

Among the assumptions made at the outset of the study were that decision makers select action choices according to the expected utility model, that all individuals exhibit constant partial risk aversion, and that preference rankings of alternative real gambles accurately reflect farmers actual preferences.

Several reliability tests were conducted with the participants. It was found that behavior with gift money did not differ from behavior when gambling with own money at low game levels or one half and five rupees. The second test determined that after individuals became familiar with the game they could predict in a hypothetical situation how they would play an actual gamble. Although this proved to be the case when moving from the five rupee to the fifty rupee game level, amounts of money which are within the typical level of transaction carried out by villagers, one should be extremely cautious in assuming that this will hold in a move from the fifty to the five hundred rupee game as the latter represents a real windfall gain for the average villager. Binswanger was also able to show that there was no automatic tendency to select alternatives in the center of the distribution

of gambles.

The result of actual games played at the half rupee, five rupee, and fifty rupee levels, and a hypothetical game played at the five hundred rupee level, showed that at low game levels the distribution of partial risk aversion coefficients was fairly evenly spread from risk neutrality to intermediate risk aversion. As the game levels rose, the distribution shifted to the right and became more peaked, showing higher degrees of risk aversion. For individuals with initially low risk aversion, their risk aversion coefficient tended to rise rapidly for games beyond trivial levels. For individuals who initially had moderate levels of risk aversion, the level increased slowly or remained constant as the game level rose. The results violate the theoretical assumption that partial risk aversion will remain constant regardless of the level of payoff involved (Zeckhauser and Keeler, 1970).

Interpreted in an expected utility framework, the evidence suggests that all but one of the individuals had nonlinear risk averse utility functions which exhibit increasing partial risk aversion. This conflicts with one of the study's initial assumptions -- that all individuals have a constant partial risk aversion utility function -- and raises doubts regarding the validity of the methods used.

In essence, Binswanger has assumed initially what he later tries to measure. In using only one parameter to describe a utility function, Binswanger's approach is analogous to describing a production function by observing the level of inputs which a farmer employs on one field. If this approach is valid, then the assumed utility function described by the empirically obtained parameter can be used to predict the actual choices made by the decision maker. None of the

studies which use this method have verified the results by testing the assumed utility functions' ability to predict the preferred choice from another choice set.

Grisley and Kellogg (1980) used the methods proposed by Binswanger to derive the partial risk aversion coefficients of forty farmers from two widely separated villages in the Chaing Mai Valley of Thailand and test the hypothesis of increasing partial risk aversion. The subjects were offered opportunities to participate in five games that each included eleven alternatives. Each game was a multiple of three of the preceding games, implying that there was both an increase in risk and an increase in wealth for each individual alternative across the five games. If individuals were increasingly partial risk averse they would initially prefer more risky alternatives, but select less risky alternatives as risk increased in successive games.

The hypothesis of continuously increasing partial risk aversion was not supported by the results. Increasing partial risk aversion was evident over games two, three, and four, but decreasing partial risk aversion occurred in the ranges of games one to two and from game four to five. It can be speculated that the lower levels of partial risk aversion found in these two ranges is a function of the level of payoffs involved. In the first case, the monetary payoff was of a trivial nature. In game five the lowest payoff was of greater magnitude than the average amount of cash held in many households. Thus, even the minimum amount that could be won represented a significant gain and may have induced farmers to bear greater risks.

Although the experimental method does have the advantage of being able to observe real choices and gives the farmer time to reflect, it shares many of the problems of hypothetical questioning

techniques. Davidson, Suppes, and Siegel (1957) found in laboratory experiments that using a flip of a coin to determine the outcome of the gamble (the technique used by both of the experimental studies) did not eliminate the problem of subjective probability biases as not all participants had subjective probabilities of one-half for each side of the coin. In addition, utility or disutility for gambling may bias results because participants are given the option of receiving a fixed amount instead of participating in a gamble. Thus, they have a choice between a gamble and a sure outcome, as in the equally likely risky prospects with a certainty equivalent technique. If learning does occur as the series of gambles progresses, as has been suggested by Binswanger, the choice to not participate in some gambles will leave some subjects with lower levels of learning.

In deriving partial risk aversion coefficients it is assumed that the participant maintains the same wealth level throughout the series of gambles. If he plays each gamble, however, his wealth position will change substantially within a brief period of time. Mosteller and Nogee (1967) have reported that the amount of money which an individual has before him, such as the winnings from a previous gamble, will affect his decisions. In both studies it is impossible to lose over the series of games and the average return is greater than most participants' monthly income. Knowles (1980) believes that this and other factors lead the participant to treat the money as "funny money" and not as real wagers.

The Observed Economic Behavior Approach

Both the directly elicited utility and experimental approaches require active farmer participation in some type of game or gamble

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to derive a measure of attitude towards risk. In the observed economic behavior approach it is assumed that the degree of risk aversion manifested by individual farmers can be derived from the gap between their actual behavior and that which is considered to be economically optimal. The validity of the results is conditional on how well the specified model describes peasant behavior. To determine that the observed economic behavior is consistent with initial conditions, auxiliary assumptions and the model of decision making used requires information about the action choices facing the decision maker, probabilities associated with each action choice, and the decision maker's preference function. For complex decisions, acquiring this information is both difficult and costly.

In determining the attitudes towards risk of forty-five farmers in Puebla, Mexico, Moscardi and deJanvry (1977) argue that given a production technology, the risk associated with production, and market conditions the observed level of factor use reveals the underlying degree of risk aversion. The authors begin with the safety first rule proposed by Katoaka and then, following Pyle and Turnovsky (1970), derive a certainty equivalent model by maximizing the upper bound of the disaster level given by Chebychev's inequality. In the resulting model,

$$\max V(\mu, \sigma) = \mu - K\sigma \text{ for } K=K(S)$$

where K is the marginal rate of substitution between expected net income and risk. K is a function of a vector of peasant household characteristics, S . In deriving the first order conditions from which each farmer's risk attitude, $K(S)$, is determined, a generalized power production function was used.

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decision-making process, the value of the risk aversion parameter can be deduced from the observed levels of products and inputs by solving

$$K(S) = \frac{1}{\theta} \left(1 - \frac{P_i X_i}{P_f i u_y} \right)$$

where P_i is the price of the i th input, X_i is the quantity of the i th input, f_i is the elasticity of production of the i th input, u_y is the mean output, and θ is a risk coefficient.

Because the risk aversion coefficient is treated as a residual and tends to include other sources of disparity between optimum and actual resource allocation in addition to the effect of attitudes towards risk, careful screening of data must be done to ensure that the measure K does not include the effects of constraints such as imperfect markets or capital availability.

The optimum level of fertilizer was the input used and was determined using results from twenty-five test plots supervised by CIMMYT. Nitrogen was selected as the relevant variable because it is agronomically the most important input for increasing yields in the area and is also the largest component of variable costs. The results of this procedure show a distribution of risk aversion which is highly skewed towards the risk averters and centered around $K=1.12$. A risk neutral farmer would have a K value of zero. To facilitate the use of discriminant analysis in a later portion of the study, K was truncated at 2. Approximately thirty percent of the respondents had a K value between 1.75 and 2.00.

Although the observed economic behavior approach is appealing because it does not require participation in a gaming scheme, the results are subject to error stemming from three sources. The accuracy

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of results is entirely conditional upon specification of a realistic economic optimum level of input use, development of a model which accurately portrays the farmers decision making processes, and screening of observed behavior to eliminate all sources of discrepancy, except risk attitude, between actual and observed behavior. In this study the economic optimum for each farmers field was calculated using a production function derived from results obtained on twenty-five test plots supervised by CIMMYT researchers. It is not uncommon to find that even under "optimum" conditions the level of inputs actually used and yields produced on farmers fields deviate significantly from those in research trials. Thus, the economic optimum specified using the experiment station production function may be unrealistic. It is also unlikely that the farmers decision making process is adequately described by a model which includes only the expected value of the marginal productivity of the input and the price of the input compounded by a risk factor. This incomplete model increases the necessity of screening observations to remove all factors other than risk which contribute to the discrepancy between actual and optimal factor use. Evidence that this has not been accomplished is seen when socio-economic factors are regressed against risk attitude coefficients. It was found that the lower the farmer's off-farm income and the less land under his control, the more risk averse the farmer. Binswanger and Sillers (unpublished), in a paper on credit constraints facing farmers, show that both of these factors are major constraints in receiving loans for inputs. Thus, a credit constraint, not attitude towards risk, may be the cause of lower levels of fertilizer application by low income small farmers.

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farmers preferred choice of plans. Officer and Halter (1980) and Lin, Dean, and Moore (1974) have shown that actual farm plans may not reflect true preferences because of factors constraining the opportunity set of farmers such that they do not contain the utility maximizing choice. In fact, for none of their respondents was their actual farm plan a member of their efficient set. These results should lead us to reconsider the results of observed economic behavior studies as well as safety first studies which assume that the farmers actual behavior reflects his preferred action choice. This problem can also arise in the reverse, as in the programming study by Brink and McCarl where the farmers actual cropping patterns were not present in their choice set.

The Interval Approach

Because of the limitations of local measures of attitudes towards risk and the difficulty of directly measuring the utility of income or wealth, King and Robison (1981) have developed a method of inferring a global risk aversion function from a measure of average risk aversion. This development is predicated upon the recognition that, over small ranges, an average risk aversion measure is a good measure of the actual Arrow-Pratt function of absolute risk aversion.

The model developed by King and Robison measures

$$E(U(\pi, \epsilon))$$

where ϵ is an error term resulting from the failure to measure or hold constant variables other than income or wealth which affect the utility function. Then using an efficiency criteria developed by Meyer which is consistent with the expected utility hypothesis, the authors measure an interval around risk preferences over an entire

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range of outcomes obtained by comparing carefully selected pairs of distributions.

This is a unique approach to risk attitude measurement as the measurements are only accurate in terms of quantifiable probability measures. The authors propose an interval measurement which allows for a tradeoff between Type I and Type II errors. Type I error is the rejection of the preferred choice from the choice set, while Type II error is the failure to correctly order pair-wise comparisons of action choices. Since the expected utility hypothesis employs a single argument utility function which discriminates on the basis of absolute differences in expected values of outcomes this approach has a great likelihood of committing a Type I error and very little likelihood of Type II error.

The interval measured by King and Robison can be of any shape or width. The larger the width the greater the likelihood of type II error (failure to order pairwise comparisons), and the smaller the type I error (rejection of the preferred action choice). Methods for determining the optimal interval width to minimize error still need to be developed.

To test this model a series of three questionnaires was administered to graduate students in agricultural economics at Michigan State University. The first questionnaire measured risk intervals of different widths at different income levels. The second questionnaire employed the equally likely with risky outcomes method (discussed in Chapter V) to derive utility functions. The third questionnaire presented decision makers with a series of choices between pairs of distributions.

In this study, the model predicted correct choices 65% of the

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time, yielding a 35% type I error. It also ordered choices correctly 100% of the time for a zero type II error. The largest interval width predicted correct choices 98% of the time while the smallest interval used predicted choices correctly 75% of the time. The largest interval ordered choices correctly 9% of the time (91% Type II error) and the smallest ordered them 91% of the time (9% type II error).

Given the difficulties involved in measuring utility functions directly this may become an accepted method for measuring risk preferences. It remains to be seen how the interval approach will perform when applied in actual choice situations.

The Mathematical Programming Approach

Bond and Wonder (1980) used a combination of directly elicited utility and mathematical programming techniques to derive risk attitude measures for a sample of Australian farmers. Assuming that farmers select action choices according to the expected utility model, Bond and Wonder used the Standard Reference Contract technique to determine the risk premium for income required by 217 farmers who regularly participate in the annual Australian Agricultural and Grazing Industry Survey. The risk premium was used to derive a risk attitude coefficient for each farmer through the use of mathematical programming models whose objective function directly employ the variance or standard deviation of returns. For example, the certainty equivalent of a range of uncertain income levels can be written into an objective function as:

$$X_0 = X^* + \frac{1}{2}V[X][U''(X^*)/U'(X^*)]$$

where X^* is the certainty equivalent, $V[X]$ is the variance of the

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risky prospect X , and $U'(X)$ and $U''(X)$ are the first and second derivatives of the utility function evaluated at the point X^* .

The standard deviation or the variance can be employed directly yielding objective functions of the forms

$$X_0 = X^* \theta (V[X])^{\frac{1}{2}}$$

$$X_0 = X^* + AV[X]$$

Solving for the risk coefficients θ and A results in

$$\theta = \frac{1}{2} (V[X])^{\frac{1}{2}} [U''(X^*) / U'(X^*)]$$

$$A = \frac{1}{2} [U''(X^*) / U'(X^*)]$$

Farmers were described as risk averse, risk neutral, or risk preferring depending on whether their risk premium was positive, zero or negative. Farmers who initially displayed risk aversion but switched over to risk preferring responses for later gambles were characterized as being averse to preference. Respondents who vacillated between risk preference and aversion were not classified. This category included almost twenty-five percent of the respondents. The responses to the risk attitude questionnaire are shown below.

Table 6.1

Classification of Farmers by Attitude Towards Risk

Risk Attitude	Frequency
Aversion	77
Preference	25
Neutrality	33
Averse to preference	29
Other	53

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Estimates of the risk premium and risk attitude coefficients suggested that, on average, there is only a 'moderate' degree of risk aversion in the rural sector but that attitudes towards risk vary markedly between individuals.

Although this method of estimating risk attitudes is appealing in its apparent simplicity, Drynan (1981) has shown that it is not possible to meaningfully estimate the risk premium, $\emptyset$, and A parameters within the context of expected utility analysis. This is due, partially, to the fact that the risk premium and Bond and Wonder's estimates of $\emptyset$, as measures of explicit risk attitudes, all depend on the variances of the risks used in measuring these attitudes. Thus the measurement is not independent of the measuring tool. In so far as the authors define A as one-half the negative value of the Arrow-Pratt absolute risk aversion coefficient at X^* , A does measure local risk attitude. But the risk premium and $\emptyset$ are not constants, even locally; they vary with risk itself.

Drynan also raises questions regarding the validity of the procedures used because of the values which were obtained for $\emptyset$ and A. Because of the estimation procedures used, the estimates of $\emptyset$ and A should be linear transformations of the risk premium. In addition, coefficients of variation in responses should be constant apart from sign for a given risk. The cumulative distribution functions of the measures are also related for a given risk and should be identical except for the scale of the horizontal axis. None of these conditions hold in the results presented by Bond and Wonder.

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Conclusions

Conventional wisdom holds that farmers are generally risk averse. The evidence presented in this chapter is not in total support of that contention. In fact, farmers appear to share the whole spectrum of attitudes towards risk, from risk loving to risk aversity.

It is difficult to reach more specific conclusions from the evidence presented because the studies and their results are not easily compared. Almost every study which has attempted to measure farmers attitudes towards risk has used a slightly different method and employed different initial conditions and auxiliary assumptions than its cohorts. Given questions regarding the validity of many initial conditions and auxiliary assumptions it is difficult to determine which of the methods gives the most reliable result. The results obtained are also subject to question in light of Johnson's argument that a utility function can be mapped accurately only if two conditions are met: the range of prospects considered must include gains and losses or changes in the level of income both of a magnitude which would alter the individuals' socioeconomic status, and allowance for both increasing and decreasing marginal utility over the range of prospects. Examination of Table 6.2 reveals that none of the studies reviewed met both of these conditions.

The process of verification is further complicated by the fact that the numerical measures of risk attitude, such as the Arrow Pratt coefficient of absolute risk aversion and the "k" value determined in observed economic behavior studies, are not reducible to one standard measure. Different studies may also be measuring different types of risk aversion. Berry (1979) and Huysam (1978) argue that an individual's attitude towards risk is composed of an inherent attitude

Table 6.2
Magnitude of Gains, Losses, or Changes
in Income and Flexibility of Functional Form
of the Utility Function Used in Nine Studies

Were the outcomes of the game framed in terms of gains and losses? Were they of significant magnitude to change the equation fitted to exhibit

Table 6.2

	Were the outcomes of the game framed in terms of one period gains and/or losses or varying levels of income?	Were they of significant magnitude to change the individual's socio-economic status? ¹	Was it possible for the equation fitted to exhibit a combination of increasing and decreasing marginal utility?
Binswanger	one period gains	no	no
Bond and Wonder	gains and losses in income	yes	no
Brink and McCarl	NA	NA	NA
Dillon and Scandizzo	gains and losses in income	yes (losses) no (gains)	no
Grisley and Kellogg	one period gains	no	no
Halter and Mason	gains and losses in income	yes	no
Moscardi and de Janvry	one period gains	no	no
Officer and Halter	one period gains and losses	no	no
Whittaker and Winter	gains and losses in income	yes	no

¹Examples of gains and losses deemed significant enough to change and individuals socio-economic status include gains large enough to allow a landless peasant to purchase land or a farmer to buy another farm and losses which would result in bankruptcy or failure to meet subsistence requirements.

towards risk which is not a consequence of economic variables or constraints, and induced risk aversion which is income or wealth determined. Observed economic behavior studies of risk attitude measure both inherent and induced risk aversion while the other methods may or may not include both. Chapter VII examines the proposition that risk attitudes are closely linked with wealth and other socioeconomic variables.

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CHAPTER VII

CORRELATIONS BETWEEN RISK ATTITUDES AND SOCIOECONOMIC VARIABLES

In addition to deriving a numerical measure of attitudes toward risk, several researchers have made an effort to correlate risk coefficients with a variety of socioeconomic variables. The conflicting results which they obtain may be due to the different methods they used to derive risk coefficients, the fact that they consider quite different sets of socioeconomic variables, and the different settings in which the research was conducted. In this brief discussion, their results will be presented with the purpose of finding areas of consistency.

In their studies of Oregon grass seed farmers, Halter and Mason entered eleven farm and decision maker characteristics into a step-wise regression with risk attitude as the dependent variable. Three variables, percent of land owned, educational level, and age were used in a second step-wise regression which included the linear and quadratic terms of the variables as well as their linear interaction terms. The results of the final regression are shown in Table 7.1 along with the results obtained by Whittaker and Winter when they repeated the study in 1976.

Examination of Table 7.1 shows that the sign of every estimated coefficient changed between 1973 and 1976. It seems highly unlikely that the relationship between risk attitude coefficients and socioeconomic variables could have changed so much in only three years. To test the hypothesis that a change in income was responsible for

Table 7.1
Estimated Coefficients and Standard Errors Associated with Pratt's Absolute Risk Aversion Coefficients

Dependent Variable	A Education	B Age	C % of Acreage Owned	A ²	AxC	AxB	Constant	R ²
1973 Pratt Coefficient	-3.065 (2.393)	-.2304 (1.011)	1.566 (.0429)	-0.0449 (0.0143)	0.8631 (0.3278)	.0274 (.3085)	1.231 (6.961)	.413
1976 Pratt Coefficient	3.802 (1.081)	.5569 (.5468)	-.1257 (.0194)	.0380 (.00645)	-.8044 (.148)	-.1377 (.1394)	-4.329 (3.144)	.709

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the change in Pratt coefficients between the two studies, the change in the coefficient was regressed on the change in income. The R^2 was only .002 and the estimated coefficient was one third the size of its standard error. Therefore, the change which is observed must have been related to a change in some socioeconomic variable which was not included in the model. Since neither set of authors include in their reports the eight socioeconomic variables which were rejected from the model on the basis of Halter and Mason's first step-wise regression, it is impossible to determine whether one, or a combination of these variables contributed to the results. A later study in the same region by Mason and Halter showed that acres of grass seed farmed was positively correlated to increases in risk aversion.

When Dillon and Scandizzo determined risk attitude coefficients of a group of small owners and sharecroppers in northeast Brazil, they found that the estimated coefficients were not normally distributed. This suggests that the socioeconomic characteristics of farm households, which were also not normally distributed, may account for some of the variation within each tenure group. Four socioeconomic variables for which data was readily available were used to test this hypothesis. These included the farmers age, income, household size, and ethical attitude towards betting. Utility free and utility specific regression models were developed in a linear form relating the risk premium requested by the i -th individual to the risk of the prospect presented to him in the experiment, socioeconomic variables, and an additive random disturbance. The utility free model was run twice, once without restrictions and once with a zero order restriction placed on the socioeconomic variables. A second set of models differs

from the first in that the measure of risk used was the variance minus the squared certainty equivalent. In a quadratic utility framework, this is equal to the risk premium divided by the risk aversion coefficient. The set of regressions was run in the unrestricted and restricted forms. The unrestricted equations provide marginal measures of risk aversion while the restricted forms provide average measures.

As in the case of the individual data, major differences exist between the values of the parameters measured when subsistence (income required to maintain the farming unit intact) was and was not at risk. For sharecroppers, these differences extend to the entire estimated equation. For small owners, however, the estimated marginal risk aversion parameters under the two sets of circumstances are not significantly different. For both owners and sharecroppers, an increase in the riskiness of the random prospect induces an increase in the required risk premium. A similar association with increasing risk aversion was found for variables of ethical beliefs against gambling, aging, and for owners, an increase in household size. In conformity with Arrow's hypothesis of declining risk aversion with increasing wealth, increases in income were associated with a fall in the requested risk premium. For both tenure groups in both situations, larger risk premiums are required as risk increases.

Moscardi and de Janvry used three classes of variables to define the socioeconomic characteristics of the peasant households in their sample in Pueblo, Mexico. The first class of variables were related to the nature of the household and included family size, and age and years of schooling of the household head. The total amount of land under its control and the level of off-farm income were used to represent the income generating opportunities of the peasant household.

Only one variable was used to define access to public institutions, membership in a "solidarity group". These groups were created in conjunction with the Pueblo Project to allow peasants access to credit not as individuals but as members of a group of five to twenty members.

Discriminant analysis was used to test the hypothesis that a systematic relationship exists between attitudes toward risk and the socioeconomic characteristics of peasant households. Of the total number of observations assigned to each group on the basis of low, intermediate or high risk aversion coefficients, approximately 84% remained in their original group. No reclassification occurred between the extreme groups. It was found that higher degrees of risk aversion were positively correlated with age and negatively correlated with schooling, family size, off-farm income, land under control, and membership in a solidarity group. The results support the hypothesis that the risk bearing capacity of peasants can be explained in part by their socioeconomic characteristics. Particularly significant for that purpose are the extent of land under control, off-farm income, and membership in a solidarity group.

When Binswanger regressed eleven socioeconomic and structural characteristics in the partial risk aversion coefficients derived for peasants in rural India, he got some surprising and some expected results. To ensure that neither sex nor village membership affected the distributions, he first determined that estimated coefficients did not change significantly for males or females or across villages. One of the most surprising results of the regression analysis was the weakness of the relationship between physical assets, measured as the gross sales value of those assets, and risk aversion, especially given the strong effect that game size had on risk attitudes. The

sign of the coefficient of wealth was consistently negative, but not always statistically significant. Wealth had little impact on behavior at the Rs 50 game level, an amount commensurate with monthly wage levels or small agricultural investments.

Higher levels of risk aversion were associated with low levels of education although the effect was not a strong one. When two variables correlated with schooling, salary income and a progressive farmer dummy were suppressed, schooling had a much stronger effect. Past experiences with playing the gambles, or luck, was highly correlated with risk attitude, with success in prior games negatively correlated to increased risk aversion. The effect of "luck" did not wear off rapidly, but did tend to decrease as the stakes rose.

Increasing risk aversion was positively correlated with age at the Rs .50 and Rs 5 income levels but the two were negatively correlated at higher game levels. This result was unexpected as was the consistent result that risk aversion was not smaller for families with fewer dependents. As in the results published by Dillon and Scandizzo, tenants were shown to be less risk averse than landlords at low game levels. A negative correlation between risk aversion and transfers received supports the hypothesis that receiving income transfers reduces aversion to risk because they provide insurance against adversity.

Binswanger concludes from these results that the difference in investment behavior observed among farmers facing similar technologies and risks cannot be explained primarily by inherent risk attitudes, but instead are induced by the existence of differing constraint sets.

As part of a study on risk efficient fertilizer application rates for farmers in Brazil, Crocomo regressed the socioeconomic variables of age, education, family size, tenure arrangement, income, size of farm, and contact with sources of information against risk aversion coefficients for 118 farmers. The only significant parameter was the information index which was negatively correlated with increasing risk aversion. When a step-wise regression was run for all owners together, allowing for interaction terms, it was shown that increasing risk aversion was positively correlated with age, access to information, and an information-income interaction term. Increasing risk aversion was negatively correlated with increases in income which supports Arrow's hypothesis of decreasing absolute risk aversion with increasing wealth. Discriminant analysis showed that over 86% of the individuals were classified similarly by risk aversion coefficients and socioeconomic variables.

A summary of the findings of the studies discussed in this chapter is presented in Table 7.2. It is important to note that the relationships found between socioeconomic factors and attitudes toward risk are not consistent across studies.

Nevertheless, the finding that local measures of attitudes toward risk are highly correlated with socioeconomic characteristics in developing countries indicates that there may be an important distinction between that part of risk taking behavior which is innate to the individual (not a consequence of economic variables or constraints) and that which is income or wealth determined. The innate propensity or desire or willingness to bear risk may be called preferential risk aversion while wealth or income's affect on the ability to bear risk may be termed induced risk aversion.

Table 7.2
Relationship Between Socioeconomic Factors and Increasing Risk Aversity

Table 7.2

	Binswanger	Dillon and Scandizzo	Moscardi and de Janvry	Halter and Mason	Whittaker and Winter	Crocomo
Age	+ ^b	+	+	+	-	+
Years of Schooling	ns		-	+	-	ns
Size of Family		+ ^c	-			ns
Size of Land Holdings	-		-			
% of Holdings Owned	ns	+ ^d	ns	-	+	
Off Farm Income	-	- ^e	-			
Annual Income		- ^e				-
Solidarity Group Affiliation			-			
Luck ^a	-					
Ethical Belief Against Gambling		+				+
Information Access						

^aLuck is determined by previous winnings in one-period money gambles.

^bRisk aversion increased with age with low monetary gambles but decreased with age at higher levels of reward.

^cRisk aversion increased with size of family for small owners but not for sharecroppers when subsistence was at risk.

^dResults were highly dependent upon the functional form of the utility function used.

ns Tested but shown to be not statistically significant.

Blanks indicated factors not considered in the analysis.

Huysam argues that when profitable technology exists, all farmers are eager to innovate. Therefore, preferential attitudes toward risk can not account for differences in adoption. Rather, it is the degree of induced risk aversion which prevents small farmers from adopting new technology. The major policy implication that Huysam derives from this analysis is that removal of the disadvantages of small farmers requires institutional policies aimed at equalizing access to factor and product markets rather than some kind of intermediate low yielding technology. Underinvestment need not occur if agriculture is risky and farmers are risk averse. If they have effective mechanisms for self-insurance or risk diffusion, they may still invest up to the risk neutral optimum.

Berry echos Huysam's position in arguing that unproductive or unprogressive behavior by small-scale farmers in developing countries is not the result of unusual aversion to risk but is the result of a limited capacity to bear risk. Berry further argues that since risk entails potential cost, risk bearing, therefore, depends on access to resources with which to meet these costs, there is no inherent inconsistency between risk aversion and profit maximization. Studies which take into account all of the costs to the farmer of alternative courses of action, including the cost of risk, often find that poor farmers' behavior is consistent with profit maximization.

According to Berry, when access to formal risk-spreading institutions is limited, participation in certain informal institutions or social networks is used to increase an individual's claim on resources. It thus becomes worthwhile for the individual to maintain or improve their position in that group through patterns seen as wasteful. Market imperfections which limit the access of certain groups

to risk spreading institutions cause apparent risk averse behavior. Therefore, policies which reduce uncertainty by increasing farmers' information about opportunities and constraints without simultaneously improving their access to resources will not increase their capacity to bear risk.

CHAPTER VIII

UNIVERSALITY OF UTILITY FUNCTIONS AND RISK ATTITUDE COEFFICIENTS

Information regarding individuals' attitudes toward risk is often elicited for use in current and future personal and policy decisions. This chapter examines evidence which raises questions regarding the reliability for these purposes of utility functions and risk attitude coefficients derived using current practices. There is reasonable evidence that utility functions elicited from responses to hypothetical choices can be used to predict choices in other hypothetical situations. What has not been demonstrated is the ability to identify an actual choice set along with accurate subjective probabilities such that the expected utility hypothesis can be applied to actual choice conditions. There is also an increasing body of evidence which calls into question assumptions regarding the stability of preference over time, income, and situations, and our ability to rank individuals according to their derived risk attitude coefficients.

Applicability of Hypothetically Derived Utility Functions to Actual Choice Situations

Except in observed economic behavior studies, individuals' utility functions or risk attitude coefficients are determined within a contrived environment. The preferences exhibited within that environment may not accurately reflect the individuals' general preference. Mason (1972) and Roumasset (1978) have demonstrated that a utility function in one-period money, such as the gambling games used in

directed elicited utility techniques, may be viewed as an indirect utility function of consumption with short term borrowing and lending opportunities. As a result, an individual who is risk neutral with respect to their lifetime utility function may exhibit an apparently risk-averse or risk preferring indirect utility function for one-period money because of capital market imperfections. Therefore, the attempt to separate attitudes from constraints may be impossible using one period gambles.

An empirical example can be seen in the Officer and Halter test of DEU techniques discussed in Chapter V. The fodder reserve plans to which the predicted decisions were compared were substantially different in the first and second years. In the first year, actual fodder reserve programs were used as the standard for comparison, while in the second year, preferred fodder reserve plans were used. Lin, Dean, and Moore (1974) in a test of the predictive ability of the expected utility hypothesis, showed that actual farm plans may not reflect true preferences because of factors which constrain the actual opportunity set of farmers so that they do not contain their utility maximizing choice. In fact, for none of the respondents was the actual farm plan in the individual's efficient set.

In a study in the same region as that used by Officer and Halter, Officer, Halter and Dillon (1967) found that the ranking of farmers on the basis of their measured risk aversion was not consistent with all of the subjects managerial practices and the ranking of relative risk implied by the adoption of these specific practices. For example, a farmer who was relatively more risk averse than another may select "less risky" stocking rates but "more risky" levels of fodder reserve than his counterpart.

The Impact of Changing Wealth
Levels on Attitudes Towards Risk

The independence axiom in conjunction with the other axioms of expected utility theory implies that the individuals ranking of preferences corresponds to the expectation of a fixed utility function defined over final consequences or ultimate levels of wealth. Friedman and Savage, in estimating the utility function by fixing its endpoint values at two arbitrary wealth levels, indicate that the EUH would be violated if the use of another pair of wealth levels as reference points yielded a utility function differing in more than origin and unit of measure from the one initially obtained.

The procedure of integrating alternative gambles with initial wealth before ranking, referred to by Kahneman and Tversky (1979) as "asset integration", requires that when an individual is faced with alternative gambles expressed in terms of deviations from current wealth, he will chose the gamble whose distribution over ultimate wealth has the highest expected utility. Markowitz (1952) has noted, however, that the assumption that a utility function is defined over ultimate wealth level is not consistent with the observed tendency of individuals of all wealth levels to purchase insurance and lottery tickets. He hypothesized that changes in wealth cause the utility function to shift horizontally so as to keep the inflection point in a Friedman-Savage utility function at or near the current or usual level of wealth.

Experimental evidence also suggests that individual gambling behavior at different initial wealth levels is more indicative of a shifting utility function than of movements along a fixed utility function. Davidson, Suppes, and Seigel (1957) found that even when

participants' wealth levels had changed significantly during the period between experimental gambling situations they gave responses which were consistent with original game preferences, sometimes duplicating them exactly. Kahneman and Tversky have also concluded that the preference order of prospects is not greatly altered by variations in asset situations.

The Markowitz hypothesis of a shifting utility function implies that changes in initial wealth essentially cause the individual to go back and rerank the entire set of distributions over ultimate wealth levels. In the words of Eden (1979) this hypothesis, which asserts that preferences cannot be defined independently of the current consumption point, is "disturbing to economists who use the assumption of 'constant tastes' quite heavily . . . it is hard to see how positive economics can do without this assumption and it is almost impossible to think of welfare economics without it."

Intertemporal Consistency of Utility Functions

Markowitz's hypothesis regarding the non-fixity of utility over ultimate wealth levels also raises disturbing questions regarding the intertemporal validity of an individual's utility function. The hypothesis implies that regardless of current asset position, an individual would respond to a given gamble in exactly the same manner whenever it is presented to him. Empirical studies using farmers in Oregon and Michigan have shown that this is not the case. Halter and Mason (1974) used the ELCE method to determine the utility functions of forty-four Oregon grass seed farmers and found that approximately one third of them had linear, quadratic, and cubic utility

functions. When classified by their Arrow-Pratt coefficient of absolute risk aversion evaluated at the farmer's 1973 level of gross income, equi-proportional groups of farmers were risk averse, risk neutral and risk preferring. The average Arrow-Pratt coefficient for the group was +.40 implying a slight aversion to risk. Whittaker and Winter (1978) repeated the study with the sample in 1976. They found that the average Arrow-Pratt coefficient of absolute risk aversion evaluated at the farmer's 1976 level of gross income was -.29 implying a slight preference for risk. To test the hypothesis that the change in the average coefficient was caused by the change in income between 1973 and 1976, the change in the coefficient was regressed on the change in income for all of the observations. The R^2 value was only .002 and the estimated coefficient was only one third the size of its standard error. Therefore, the change in the Pratt coefficients of farmers between 1973 and 1976 must have been caused by some other factor.

Similarly when Love (1982) repeated the study done by King (1979) using a sample of Michigan farmers, he found that the intervals used to characterize utility functions using stochastic dominance with respect to a function had changed. When using discriminant analysis to classify farmers according to risk attitude, Love found that the same variables (such as assets, income, or age) could not be used for all classes of decision makers within one time period, or for one class in both time periods.

These conflicting results lead to the conclusion that the Markowitz model may be applicable only in situations when assets are the primary factor influencing decision making. An example of this is an active investor in the stock market whose asset position can

fluctuate dramatically in short periods of time and who immediately feels the impact of such fluctuations. But when dealing with farmers or other classes of decision makers whose assets are likely to remain stable over long periods of time, other factors may have a much larger influence on preferences and decision making behavior. For these decision makers, the hypothesis of asset integration may or may not hold; it is extremely difficult to validate the hypothesis. What is clear is that other factors influence preference rankings over time. In conclusion, Markowitz's hypothesis of non-integration of assets causing instability of preferences over ultimate wealth levels may be an appropriate model in some situations but does not necessarily imply intertemporal stability preferences for gains and losses because of changes in other factors which may influence decision making behavior.

Group Utility Functions

Despite the questions raised regarding the intertemporal validity of hypothetically derived utility functions and their applicability to real world choice situations, farmers' risk attitude coefficients have been used in the development of extension programs. Because of the difficulties inherent in tailoring extension advice to individual farmers on the basis of their attitude towards risk, Officer, Halter and Dillon (1967) tested the feasibility of making fodder reserve program recommendations on the basis of group utility functions. Assessment of the errors between the group recommendations and the farmers decisions (measured in terms of months of fodder reserve held) was used to determine the suitability of using a group utility function.

Predictions made using the methods of deriving the groups utility function by taking the average of the groups individual utility functions and taking the median utility function to represent the group as a whole were tested against the fodder reserve predictions made using individual utility functions and the criteria of cost minimization. The average error in predicting months of fodder reserve held by individuals using individual utility functions was only .26 months, and the average error using a cost minimization criteria was .71 months. The method of using a median utility function to represent the groups utility resulted in an average error of .64 months of fodder reserve held. The average utility function predicted fodder reserves held less accurately than any of the other three methods with an average error of .86 months. Although the median measure of a group utility function was far less accurate in its prediction than the use of individual utility functions, it still seems that a risk-oriented group utility function approach can provide better recommendations than a more traditional approach such as expected cost minimization which makes no allowance for risk.

Interpersonal Comparisons of Attitudes Toward Risk

The use of a utility function for making group decisions does not overcome problems of interpersonal comparisons of utility. Derived risk attitude coefficients are commonly used to rank individuals according to their degree of risk aversion. What is often overlooked is that a risk attitude coefficient such as the Arrow-Pratt absolute risk aversion coefficient is only a local measure of risk aversion. It does not necessarily follow that the same ranking of individuals

will be obtained if a local measure is taken at any other point on their utility functions. Assume that there are two individuals, A and B, whose utility functions are shown in Figure 8.1. If the individuals' risk aversion coefficients are taken at Y_1 , individual A will be more risk averse than individual B. When their risk aversion coefficients are taken at point Y_2 , however, the ordering is reversed and individual B is more risk averse than A. Thus, the ranking of individuals by a local risk aversion measure is highly dependent upon where that measure has been taken. Pratt (1964) has shown that one decision maker can be said to be more risk averse than another if, and only if, for every risk the amount for which he would exchange the risk is smaller than for any other decision maker. Therefore, adequate rankings of individuals according to their attitudes towards risk can only be made if we know their risk aversion in the large, over their entire utility function.

Conclusions

The major thrust of this chapter has been to reemphasize the point made in Chapter IV, that local measures of attitude towards risk cannot be generalized for use in global comparisons. Not only must concern be voiced over generalizations for distributions with dispersion beyond the local bounds, but also for the consistency of utility functions and risk attitude coefficients over changing levels of wealth and time. In light of the findings that utility functions and their associated risk attitude measures are very time, wealth level, and context specific the usefulness of studies which attempt to precisely measure attitudes may diminish.

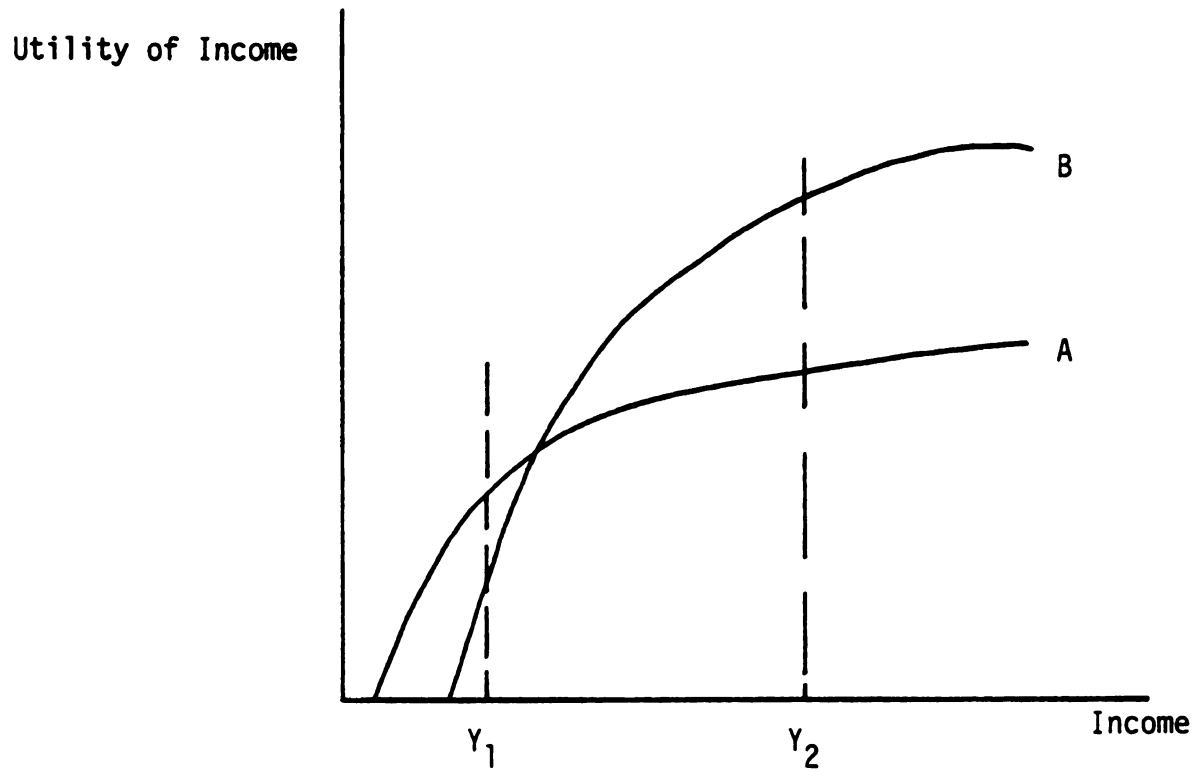


Figure 8.1. Ranking of Individuals According to Their Risk Attitude Coefficients

SECTION FOUR

LOOKING AHEAD

The analysis presented in Sections Two and Three provides overwhelming evidence of the need for further research in decision theory and its applications. In Chapter IX, several theoretical extensions which have been developed to overcome deficiencies in the expected utility hypothesis are presented. Chapter X suggests directions for future research and reviews what has been learned in this paper about state of the art decision theory's ability to explain and predict farmer decision making behavior under uncertainty.

CHAPTER IX

EXTENSIONS OF THE EXPECTED UTILITY HYPOTHESIS

Tests of the EUH have focused on its ability to predict farmers preferred action choices. Tversky has argued that in view of the extreme generality of the model on the one hand, and the experimental limitations on the other, the basic question is not whether the model can be accepted or rejected as a whole. Instead, the problem is to discover which of the assumptions of the model hold, or fail to hold, under various experimental conditions.

The three major assumptions of the EUH which concern us are that expected utility maximizers follow the four axioms of rational behavior defined in Chapter III (ordering, transitivity, substitution and certainty equivalents among choices), that utilities can be assigned to absolute states of wealth, and that judgments called for in an analysis can be represented accurately by a single, precise number.

Experimental evidence supports the contention that individuals' actions often do not conform with these fundamental assumptions of the EUH. Decision theorists have used this experimental evidence to develop new approaches to understanding decision processes within the general framework of expected utility analysis. Kahneman and Tversky's pioneering work on prospect theory is an attempt to resolve questions arising from the fact that individuals edit information before using it to choose the prospect with the highest value. Because

each individual will edit information in unique ways, apparent inconsistencies in preference ordering arise. In addition, Kahneman and Tversky argue that the decision weights which multiply the value of outcomes are determined by factors including, but not limited to, their attendant probabilities.

The independence axiom which underlies the EUH appears to be routinely violated by decision makers. Machina has shown, however, that despite inconsistencies between the independence axiom and actual behavior the basic concepts, tools and results of expected utility analysis are still applicable. The generalized form of expected utility analysis which he has developed does not require that the independence axiom hold. Instead, all that is required is an assumption of smoothness of preference and consistency in the shape of utility functions in a given region. An important implication of this weaker assumption is that the shape of the utility function for wealth is a complete characterization of risk aversion whether or not the individual is an expected utility maximizer.

Both of these extensions of the EUH maintain the assumption that individuals can accurately state their preferences in the form of a single number. Proponents of "fuzzy set theory" argue that uncertainty due to randomness and uncertainty due to imprecision and vagueness are both present in decision making. These distinct qualities must be modeled in different ways, the former using probability theory and the latter using fuzzy set theory. Fuzzy set theory provides a means of quantifying the degree of imprecision associated with any input into the decision process through the use of membership functions. The degree of uncertainty or "fuzz" related to an action choice is, therefore, a function of the fuzziness of the inputs.

Prospect Theory

In the remainder of this chapter, the three extensions of the expected utility hypothesis will be reviewed in more detail beginning with prospect theory. Following Bernoulli, it has generally been assumed that utilities are assigned to states of wealth. Kahneman and Tversky depart from this tradition and analyze choices in terms of changes in wealth rather than states of wealth. They reject the assumption of classical analysis that preferences reflect a comprehensive view of the options available to the decision maker. Kahneman and Tversky propose instead that people commonly adopt a limited view of the outcomes of decisions; they identify consequences as gains or losses relative to a neutral point. This can lead to inconsistent choices regarding the same objective consequences because they can be evaluated in more than one way depending upon the reference point with which the outcomes are compared.

In developing prospect theory, Kahneman and Tversky cite several violations of the axioms of the EUH. One of these is framing, the effects arising when the same alternatives are evaluated in relation to different points of reference. Framing effects in consumer behavior may be particularly pronounced in situations which have a single dimension of cost and several dimensions of benefit.

In the EUH, the utilities of outcomes are weighted by their probabilities. Kahneman and Tversky hold that the decision weights that multiply the value of outcomes do not coincide with the attendant probabilities. Instead, low probabilities are commonly overweighted while intermediate and high probabilities are underweighted relative to certainty. The underweighting of intermediate and high probabilities reduces the attractiveness of possible gains relative to sure

ones and reduces the threat of possible losses relative to sure ones. This "certainty effect" leads to violation of the substitution axiom. In prospect theory an individual's outcome weighting mechanism is represented by a value function. Risk aversion or seeking is explained by the curvature of this function which is usually concave for gains and convex for losses.

The shape of the value function is explained by the "reflection effect" whereby the preferences expressed for negative prospects are the mirror image of those for positive prospects. In other words, the reflection of prospects around zero reverses the preference ordering. As a result, risk aversion in the positive domain is accompanied by risk seeking in the negative domain. In conjunction with the certainty effect this leads to risk seeking preference for a loss that is probable over a smaller loss that is certain. This seems to eliminate aversion to variability, at least with respect to losses, as a plausible explanation of behavior. In addition, the function for losses is much steeper than that for gains. If given an equal probability of loosing \$X or gaining some amount, individuals usually demand that the potential gains be a multiple of \$X before they will engage in the gamble.

To simplify choices, individuals often disregard components that are shared by all prospects under consideration and focus on their differences. This "isolation effect" may produce inconsistent preferences since a pair of prospects can be decomposed in many ways and the different decompositions may lead to different preference orderings.

Prospect theory distinguished two phases in the choice process. In an initial editing phase, a preliminary analysis of the offered

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prospects is carried out, often yielding a simpler representation of the prospects. The second phase is one in which the edited prospect with the highest value is chosen. Editing involves several separate actions including coding, where gains and losses are assessed relative to some neutral reference point, combining, where the range of prospects is reduced by combining the probabilities associated with identical outcomes, segregating, where the risky component of a prospect is separated from the riskless component, simplifying, where extremely unlikely outcomes are discarded and other outcomes are rounded, and dominance, where dominated outcomes are rejected.

Many of the apparent inconsistencies in preference ordering result from editing. In the evaluation stage a decision weight is associated with each probability affecting the impact of probability on the overall value of the prospect. The resulting value is not a probability measure and the summation of the values is typically less than unity. Using the value function, a weight is assigned to each outcome which reflects the subjective value of that outcome. The resulting set is a measure of the values of deviations from the reference point, or the expected gains or losses associated with each prospect.

Although the evaluation procedure suggested by prospect theory is procedurally similar to that used in expected utility analysis, the two processes are qualitatively different. Prospect theory seeks to explicitly incorporate the subjective impact of probabilities into the utility analysis through the specification of a value function for each individual. The theory also seeks to explain the reasons for apparent inconsistencies found in individual preferences. This descriptive model of preference formation also presents challenges

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to the theory of rational choice because it is far from clear whether the effects of decision weights, reference points, and framing should be treated as errors or biases, or whether they should be accepted as valid elements of human experience.

Generalized Expected Utility Analysis

Experimental evidence has shown that the independence axiom of the EUH is systematically violated by phenomena such as the St. Petersburg Paradox and the Allais Paradox. Machina argues that despite these violations, the basic concepts, tools, and results of expected utility analysis are still applicable because they are not dependent upon the independence axiom. They can also be derived from a weaker assumption of smoothness of preferences over alternative probability distributions.

The role of the other axioms of expected utility theory, which amount to the assumptions of completeness and continuity of preferences, are essential to establish the existence of a continuous preference function over probability distributions in much the same way as is done in standard consumer theory. It is the independence axiom which gives the EUH its empirical content by imposing a restriction on the functional form of the preference function. The independence axiom implies that the preference function may be represented as the expectation with respect to the given distribution of a fixed function defined over the set of possible outcomes. In other words, the preference function is constrained to be a linear function over the set of distributions of outcomes, or, as commonly phrased, "linear in the probabilities". For the independence axiom to hold, the local utility functions for all distributions in the range of prospects

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must be identical. This is often not the case, as will be shown below. This restriction does not apply if we use a generalized form of expected utility analysis proposed by Machina.

Violations of the independence axiom can be demonstrated using the Friedman-Savage utility function. Based on their observations that the willingness of persons of all income levels to buy insurance is extensive and that the willingness of individuals to purchase lottery tickets, or engage in similar forms of gambling is also extensive, Friedman and Savage proposed that there is a generalized form of a von Neumann-Morgenstern utility function held by most people (see Figure 9.1). The utility function is concave and implies risk aversion at low income levels, linear and locally risk neutral at the inflection point, and convex and locally risk loving at high income levels relative to current income. Individuals will be unlikely to take unfair odds in insurance or gambling in amounts close to their initial wealth position given their hypothesized constant marginal utility for money in this range. Given the chance of significant gains, however, the individual will participate in gambles with unfair odds. The individual will take equally unfair odds for much less in losses than in gains in an attempt to preserve the resources which he holds.

One implication about human behavior stemming from the assumption of a Friedman-Savage utility function is that people will tend to prefer positively skewed distributions, with larger tails to the right, to distributions which are negatively skewed, with larger tails to the left (Markowitz, 1952). There is evidence to suggest that a preference for positive skewness and a relative preference for risk

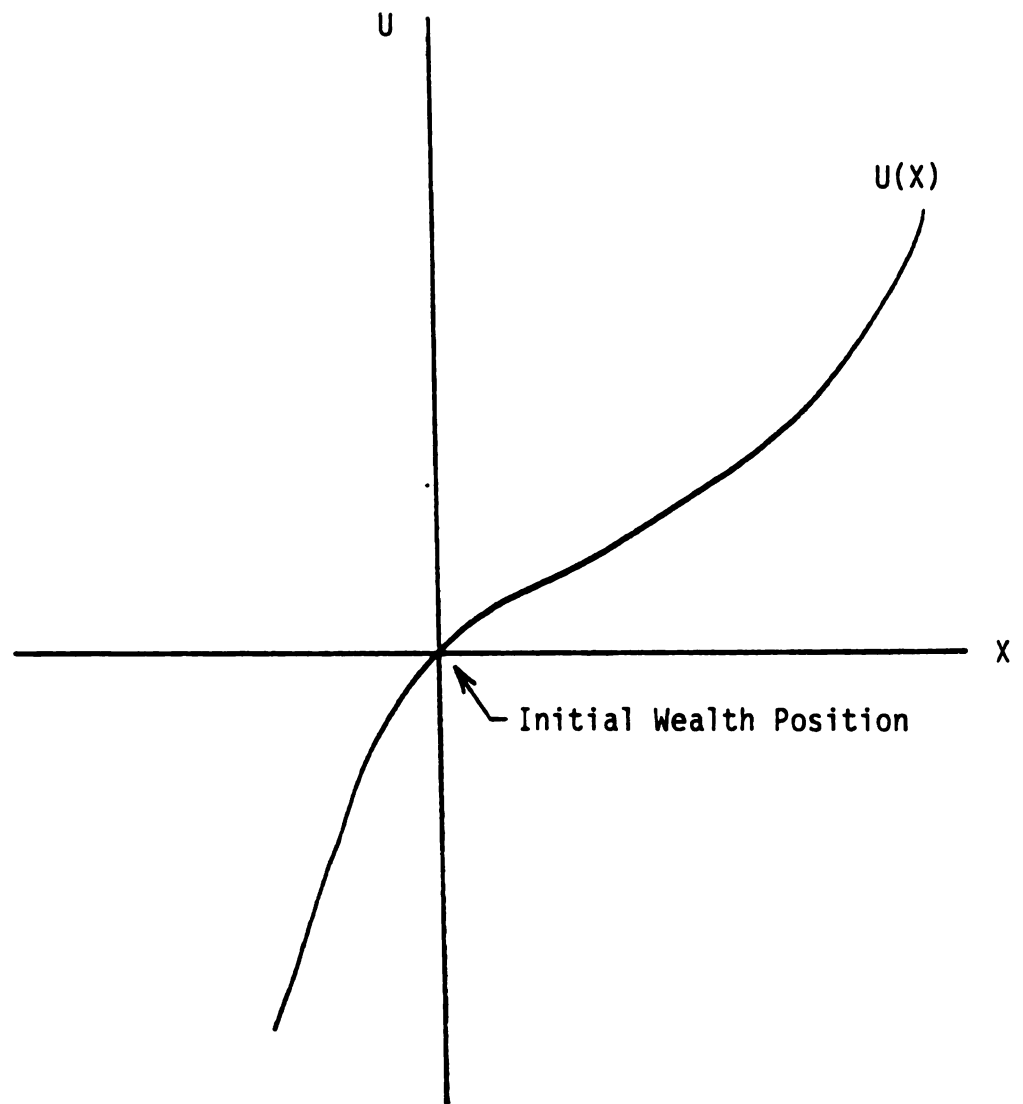


Figure 9.1. Friedman-Savage Utility Function

which increases in the upper rather than the lower tails of distributions are also exhibited by global risk averters whose utility functions do not conform to the Friedman-Savage form.

With the later discovery by Markowitz, and Friedman and Savage that the amount an individual would pay for a $1/n$ chance of winning $\$nZ$ is an eventually declining function of n , Friedman and Savage modified their utility function to include a terminal concave section. This modified Friedman-Savage utility function is shown in Figure 9.2.

Objections were also raised to the original Friedman-Savage form because of the typical response of individuals to a certain type of gamble, known as the St. Petersburg Paradox. The paradox stemmed from the observation that an individual typically would never forego a significant amount of wealth to engage in a gamble which offered a payoff of $\$2^i$ with probability 2^{-i} even though the expected winnings from this gamble are infinite. But the Friedman-Savage function which is consistent with the restrictions of the independence axiom shows, unrealistically, that an individual would take this gamble. The Friedman-Savage form of the utility function is not the only one which suffers from this shortcoming. Menger has shown that whenever the utility function is unbounded, gambles with infinite certainty equivalents can be constructed. Arrow demonstrated that individuals with unbounded utility must violate the continuity and transitivity axioms as well as the independence axiom. By bounding the utility function, as is done in the modified Friedman-Savage utility function, the degree of risk aversion is no longer monotonic with respect to outcomes.

A third objection to the Friedman-Savage utility function, and one which clearly demonstrates systematic violation of the

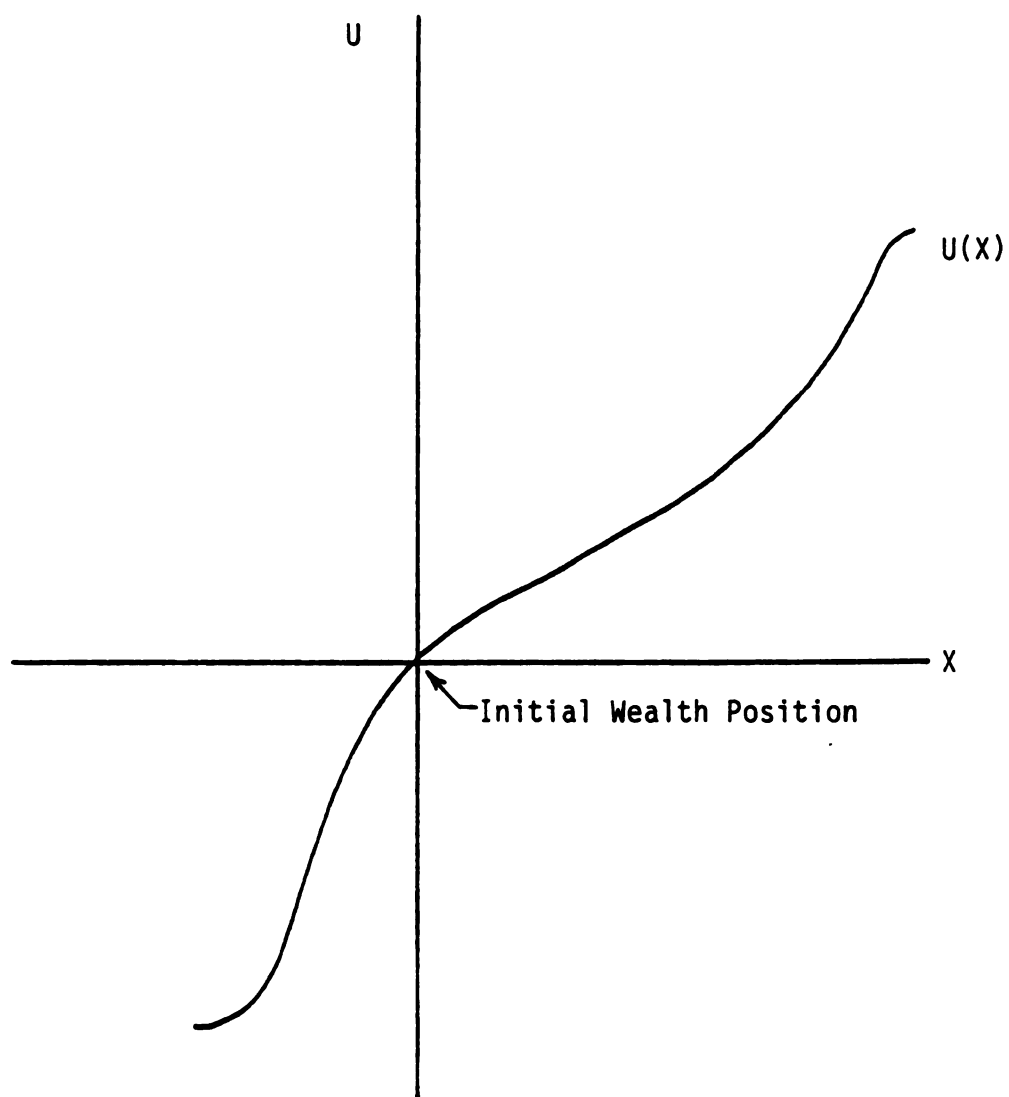


Figure 9.2. Modified Friedman-Savage Utility Function

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independence axiom, comes in the form of the Allais Paradox (1979). The paradox is that individuals systematically rank a stochastically dominating pair of prospects according to a utility function which is more risk averse than the one used to rank a stochastically dominated pair. This is clearly a violation of the independence axiom.

The Allais Paradox can also be used to demonstrate another violation of the independence axiom in that individuals have been found to be oversensitive to changes in the probabilities of low probability, outlying events. This violation has been analyzed by Machina (1981), Kahneman and Tversky (1979), Hagen (1979), and MacCrimmon and Larsson (1979). To compensate for the violation of the independence axiom stemming from oversensitivity to certain probabilities, both psychologists and economists have suggested the use of subjective expected utility models. (See Prospect Theory above.) Although these models allow for a relatively straightforward estimation of the individuals relative sensitivity to changes in low versus high probabilities, Machina argues that they exhibit many undesirable properties. Once the measure of subjective probability is non-linear, behavior is no longer characterized by the shape of the utility function alone and the main results of expected utility theory, such as the characterization of risk aversion by the concavity of the utility function, no longer apply. Subjective expected utility models are also incapable of incorporating the property of monotonicity. This necessarily results in cases where an individual maximizing with a non-linear preference function will prefer some distribution to ones that stochastically dominate them. Similarly, no subjective expected utility maximizer can exhibit general risk aversion even over restricted ranges of possible outcomes (Grether and Plott, 1979).

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A possible objection to this and other criticisms of EUH models is that when individuals are shown how their choices violate the independence axiom, they then alter their preference so as to conform with it. While this is strong testimony to the normative appeal of the axiom, it is irrelevant to the positive theory of behavior towards risk.

The generalized form of expected utility analysis proposed by Machina does not require that the independence axiom hold. In addition, it leads to results consistent with the Allais Paradox and the St. Petersburg Paradox without requiring the use of subjective probability models. Using local utility functions which display the appropriate qualitative property (e.g., risk aversion) for every local function in a region, the preference function will display the corresponding behavioral property throughout the region. This will occur even if the local utility functions are not the same, or in other words, the individual is not an expected utility maximizer. An important implication of this weaker assumption of smooth preferences is that the concavity of a cardinal function of wealth is a complete characterization of risk aversion in the sense that any risk averter must possess concave local utility functions whether or not he or she is an expected utility maximizer. Thus, the researcher who would like to drop the restrictions of the EUH and study the nature of general risk aversion can apparently still work completely within the framework of expected utility analysis.

Fuzzy Set Theory

Central to the paradigm of decision analysis using the expected utility analysis is the often unstated assumption that each of the judgments called for in an analysis can be represented accurately by a single, precise number. Thus, the EUH only addresses uncertainty due to randomness and not uncertainty due to vagueness or imprecision. Much of the unease exhibited by potential users of the tools of decision analysis stems from concern about their ability to provide sufficiently precise inputs regarding probabilities and utility to receive reliable answers. Watson, Weiss and Donnel (1979) argue that probabilities and utilities can inherently only be represented by somewhat rough sets of numbers. Their "fuzzy decision analysis" method is motivated by the need to handle the imprecision accompanying the judgmental inputs to decision analysis in a systematic and self-consistent manner.

Zadeh (1965), one of the first to argue for a new fuzzy approach to systems analysis and decision making under uncertainty, holds that imprecision and uncertainty are distinct qualities which must be modeled in different ways, the former using fuzzy set theory and the latter using probability theory. Fuzzy set theory is therefore, not an alternative to probability theory and the EUH, but a parallel calculus to be used to handle the imprecision inherent in human cognitive processes. The central concept in fuzzy set theory is the membership function which numerically represents the degree to which an element belongs to a set. The function is valued between zero and one and is assessed subjectively with small values representing a low degree of membership in the set and high values representing a high degree

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of membership. In other words, the statement that "it will probably rain tomorrow" would have a higher degree of membership in a set regarding likelihood of rain than the statement "it might rain tomorrow". Often the values used to represent degrees of membership in a set are not elicited directly. Instead, they are taken from curves drawn by individuals to represent their degrees of belief that an event will occur.

The calculus of fuzzy sets is based on three propositions to which numbers indicating membership should conform. These propositions are analogous to those used in conventional set theory and include:

1. The degree to which X belongs to set A and to set B is equal to the smaller of the individual degrees of membership.
2. The degree to which X belongs to either A or set B is equal to the larger of the individual degrees of membership.
3. The degree to which X belongs to (not A) is one minus the degree to which X belongs to A .

The calculations involved in the decision analysis can be considered to be a functional relationship between the inputs regarding probabilities and utilities and the output of the analysis in the form of the expected utility of an action. The three relationships cited above are used to deduce the "fuzz" on the output given the fuzziness of the inputs.¹

As with conventional utility analysis, probability distributions may be generated which characterize the range of possible outcomes for each action choice. Whereas the distributions obtained from

¹For particulars of the mathematical methods used, see Watson, Weiss and Donnell (1979) and Freeling, (1980).

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conventional analysis are taken to be the true distributions, in fuzzy set theory the extent to which the distribution of inputs, probabilities, and utilities implies an action choice is only as large as the least level of implication for each set. Unless one distribution clearly dominates another, it cannot be said to indicate the preferred action choice. To determine the preferred action choice when two sets overlap, one must determine the extent to which one set is preferred over the other through the use of Zadeh's fuzzy calculus.

There remain questions regarding the axiomatization of a fuzzy set calculus which can be used to elicit membership functions. Experimental evidence does show, however, that individuals are able to draw curves or probability distributions to represent their perceived imprecision regarding degrees of belief such as "better than ever," "pretty likely," or "about X%." The precise shapes of these distributions are somewhat arbitrary, but this fact does not affect the inferences which can be drawn from fuzzy set analysis as it is the general shape of the distributions that matter.

Conclusions

Although these theoretical extensions of the expected utility hypothesis are a step forward, their development to this point has left several important questions unanswered. Two of the most important questions are whether preferences can be measured in the context of any of the models, and whether they can be used as the basis for developing analytical models in the same way the expected utility hypothesis has been used. Lastly, concern has been expressed as to whether the extensions' need for costly, more complicated modes of

analyses will be justified by a commensurate increase in predictive accuracy.

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CHAPTER X

CONCLUSIONS

The previous nine chapters have pointed out many of the strengths and weaknesses in decision theory as it stands today. In this, the final chapter, conclusions regarding the verification of the models presented and the adequacy of the tools used in determining individuals' attitudes towards risk are summarized. Suggestions for areas for future research and their complementarities follow. The chapter and the paper conclude with a review of the four steps which were followed in meeting the initial goal of determining the adequacy of state of the art decision theory and its applications in explaining and predicting farmer decision making under uncertainty.

Verification of a Model of Decision Making Under Uncertainty

Neither the safety-first nor expected utility models succeeded in meeting criterion one and two for a test of a hypothesis which were set forth in the introduction to Section Two. In fact, the safety-first model has not been subjected to a comprehensive test using Gieres' criterion in any of the studies which could be found for review. Furthermore, there is no definitive support for the basic hypothesis that attitudes towards risk, or concern about avoiding a disaster level of returns, affect farmer investment or cropping decisions. Despite this lack of verification, the safety-first

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approach maintains its intuitive appeal as a descriptive explanation of farmer behavior, especially in developing countries where no safety net exists and returns below those required for subsistence can have consequences far more permanent than bankruptcy. As will be discussed in greater detail in the following section, certain aspects of the safety-first approach may contribute to the development of a descriptive understanding of the factors which affect farmer decision making behavior.

Although safety-first models and the expected utility hypothesis have been treated as separate and distinct models in this paper, Pyle and Turnovsky (1970) have demonstrated that, under certain restrictive conditions, some safety-first models can be deduced from the expected utility hypothesis. Although this link is a useful one, it also raises the spector that many of the weaknesses of the expected utility hypotheses which have been noted will also surface with new and more rigorous tests and applications of the safety-first models.

What are some of the problems which have been encountered with the expected utility hypothesis as a theory of decision making behavior under uncertainty? Three of the major assumptions underlying the expected utility hypothesis are: that utility maximizers follow the four axioms of rational behavior defined in Chapter III, that utilities can be assigned to absolute states of wealth, and that statements called for in an analysis can be represented by a single, precise number. In Chapter IX it was seen that experimental evidence supports the contention that individual actions do not conform with these fundamental assumptions. Although theoretical extensions of the expected utility hypothesis have been developed to partially overcome these deficiencies, several important questions remain unanswered, including

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whether the extensions' need for costly, more complicated methods of analysis will be justified through a commensurate increase in predictive accuracy.

This question is especially disturbing in light of the issues raised in Chapter VIII regarding the adequacy of methods which have already been developed for use in application of the naive expected utility model. The greatest stumbling blocks which remain are development of means for: easily measuring subjective probabilities, incorporating a decision maker's confidence in his probability measures into the decision analysis, eliciting utility functions in real choice situations, ascertaining measures of global risk aversion and aggregation of individuals' utility functions, measuring multi-argument utility functions, and separating the causes and effects of innate and induced risk aversion.

Despite these unanswered questions, the expected utility hypotheses remains the most widely accepted and used model of decision making under uncertainty. It is, according to Hey (1979), the basis of at least 95 percent of disciplinary models in risk analysis including the literature applicable to farmers in developed and developing countries.

Directions for Future Research

When looking towards future developments in the field of decision theory, one is struck by the seemingly conflicting priorities. On one hand there is a clear need for further development and testing of a model of decision making behavior and methods for its application which will yield accurate measurement of risk attitudes and predictions. This requires overcoming many of the stumbling blocks cited

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On the other hand, there is an immediate need, especially in the developing country context, for learning more about general attitudes towards risk and, perhaps more importantly, determination of the factors which contribute to seemingly risk averse or risk loving behavior by agricultural producers. Answering these questions may not require the antecedent development of methods for accurately measuring attitudes towards risk. A more useful approach for these purposes may be to concentrate on the use of mathematical programming models such as the one developed by Low which was discussed in Chapter II. Of course, special attention must be given to specification of objective functions and constraints in the model. An interdisciplinary approach utilizing the skills of economists, anthropologists, sociologists, and agricultural scientists is recommended for this task. The appropriateness of contributions to be made by other disciplines is suggested by the work of Huysam and Berry cited in Chapter VII.

Despite the apparent conflict between these two needs, research toward the development of an improved rigorous model of decision making under uncertainty and development of a descriptive understanding of general risk attitudes and the factors which influence their development are, in fact, complementary. Disciplinary research on the development of better models will allow for more accurate measurement of attitudes towards risk and increased predictive powers for individual decision makers and formation of appropriate policies in both the developed and developing economies. But, this flow of useful information is not one way. Multidisciplinary research conducted to develop a descriptive understanding of general risk attitudes and

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the factors which influence their formation can provide useful knowledge to disciplinary researchers. Three specific areas are those of differentiating between innate and induced risk aversion, ascertaining decision makers' confidence in their probability estimates, and determining appropriate arguments to include in the utility function.

Because of the complementarities which exist between the two research thrusts, simultaneous research and open and frequent communication between researchers involved in each research area needs to be encouraged.

Conclusion

In Chapter I it was proposed that the degree to which state of the art decision theory and its applications could explain and predict farmers' decision making behavior under uncertainty could be determined by a careful examination and critique of decision theory from an economist's perspective. It was further proposed that this goal could be attained through the completion of four steps. In Section One the foundation for the remaining steps was laid through an exploration of risk and uncertainty and a description of decision problems under uncertainty.

Section Two was comprised of an exposition of two of the major models of decision making under uncertainty and their test. Chapter II focused on safety-first type models and the question of whether attitudes towards risk affect cropping decisions when examined within a safety-first framework. Chapter III examined the expected utility hypothesis and reviewed two tests of this hypothesis. It was found that neither the safety-first models nor the expected utility hypothesis were able to meet both conditions one and two of a test of a

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hypothesis set forth in the introduction to Section Two.

Section Three focused on applications of the two models discussed in Section Two. Following a discussion of alternative measures of local attitudes towards risk, Chapter IV concluded with the caveat that all of the methods described resulted in measurement of risk attitudes "in all small" and could not be justifiably employed in inferring general conclusions about risk attitudes of a population or the ordering of individuals according to preference within the population. Chapter V examined several of the methods used to empirically determine utility functions of individuals within an expected utility framework. The influences of the specified form of a utility function on the risk attitude measure taken from it was also discussed. The chapter also raised questions regarding the validity of unidimensional or one argument utility function and presented a case for the inclusion of independent factors in addition to wealth in the utility function. Chapter VI built upon the preceding chapters and reviewed the methods used and conclusions reached in many applied studies which measure farmers' attitudes towards risk as a means of understanding their decision making behavior under uncertainty. It was found that the studies presented conflicting evidence about the distribution of risk attitudes within and between populations. Because of their different methods used to determine risk attitudes and different assumptions employed, it is impossible to determine whether the discrepancies found are a result of actual differences or the methods employed in measurement. Chapter VII extended the discussion of the previous chapter and summarized the results of research which correlates attitudes towards risk with a wide variety of socio-economic

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variables. The relationships found between socio-economic factors and attitudes towards risk were not consistent across studies. This may be due, in part, to the fact that each study used a different set of socio-economic variables. Another factor affecting the results may be that, as in the previous groups of studies, different assumptions and methods were used in determining the populations' risk attitudes. Nevertheless, the finding that local measures of attitudes towards risk are highly correlated with socio-economic characteristics of farmers is a significant one. It may point to an important distinction which can be made between that part of risk taking behavior which is innate to the individual and that which is induced by income, wealth, or other socio-economic factors. The chapter concluded with a discussion of the implications of this distinction for policy formation and development of new technology in a developing country context. Section Three concluded with a chapter on the universality of utility functions and risk attitude coefficients. In this chapter it was found that the results obtained in the applied studies reviewed in Chapters VI and VII all share one major flaw; they attempt to order individuals according to risk attitude using local measures of attitudes toward risk. It was argued that this procedure can not give valid results because there is strong evidence that preferences are not stable over time, income, and situations. In addition, orderings based on local risk attitude coefficients are seen to be highly dependent upon the specific income level at which the measure is taken. Chapter VIII also questioned the reliability of applying utility functions derived using the current practice of constructing hypothetical choice situations to the prediction of real world choices. Because

of these important flaws in current practices, the usefulness of studies which attempt to precisely measure attitudes towards risk is drastically reduced.

Section Four reviewed recent developments in decision theory which may partially overcome some of its deficiencies and set forth recommendations for future research. Chapter IX explored the possible contributions of prospect theory, generalized expected utility analysis, and fuzzy set theory towards filling the gaps in the expected utility hypothesis which emerged when experimental evidence showed that several of the hypotheses' fundamental assumptions did not hold. Although these theoretical extensions are undoubtedly a step forward, none of them have been developed to the point to which it can be determined if preferences can be measured within the context of the model or whether they can be used as the basis for developing analytical models such as those developed using the expected utility hypothesis. Because of their lack of testing it has yet to be determined if any of the models significantly improve decision theory's predictive power in actual choice situations.

Chapter X has proposed a two-pronged agenda for future research with one area of emphasis on disciplinary research in decision theory with special attention to developing methods for applying the theory in real world choice situations. The second, complementary thrust is towards developing a descriptive understanding of the factors which influence the formation of risk attitudes and their effect on decision making behavior of farmers in developing countries.

Chapter X concludes with an assessment of the papers' contribution to determining the degree to which state of the art decision

theory and its applications can explain and predict farmers' decision making behavior under uncertainty. What has been determined is that, although the safety-first and expected utility hypothesis provide useful theoretical frameworks for developing a conceptual understanding of farmer decision making behavior under uncertainty, they fail to be adequate in the explanation and prediction of behavior for two reasons. First, neither model meets conditions one and two of a test of a theoretical hypothesis, and therefore, cannot be treated as verified. Secondly, experimental evidence has shown that many of the tools used in the application of the theories to actual choice situations are deficient and may result in conflicting or misleading conclusions.

Despite the lack of conclusive evidence in support of state of the art decision models, the expected utility hypothesis remains the basis for most of the disciplinary work in decision making under uncertainty today. There are enough questions about decision theory raised in this paper and elsewhere to predict that the field will experience constant, and possibly, radical changes in the approaches used for some time to come.

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