# Some Estimates of Farmers' Utility Functions

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Abstract

Utility functions for 13 Minnesota farmers are estimated from their responses to hypothetical decision problems under uncertainty. The results furnish strong evidence of risk aversion and of decreasing absolute risk aversion as wealth increases. Of several forms of functions studied, the best fits were clearly obtained using a Sum of Constant Absolute Risk aversion (SCAR) function

$$\psi(y) = -e^{-\lambda_1 y} - \beta e^{-\lambda_2 y}$$

where y represents a prospective gain in wealth, $\lambda_1$ represents the upper bound of absolute risk aversion, $\lambda_2$ the lower bound, and $\beta$ is a weighting parameter. Approximate medians for the estimated parameters (with gain in \$ thousands) are $\lambda_1 = .1$, $\lambda_2 = .003$, and $\beta = 50$. Suggestions for improvements in interviewing and in statistical techniques are developed.

Key Words

Key words include utility, Bayesian, farmers, uncertainty, risk aversion, decision theory, and cattle.

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# Some Estimates of Farmers' Utility Functions

Clifford Hildreth and Glenn J. Knowles*

## I. Description of the Study

A study of farmers' utility functions and expectation formation was undertaken by the authors in the fall of 1976. Its purposes were to aid in the assessment of the relevance of Bayesian decision theory to production and marketing decisions on farms and to develop information about farmer utility functions and expectation formation that would be necessary in applying the theory.

The study was conducted in cooperation with the Economic Research Service, USDA, and the Southwestern Minnesota Farm Management Association. Interviews of about an hour each were held with 13 farm operators, selected from the Association's membership, on four occasions from November, 1976 to December, 1977. In the first interview the general nature of the study was explained and participation solicited. Those who agreed were asked general questions about the organization of their farms, their typical production and marketing procedures, and their plans for the coming season.

The second visit (March, 1977) related to possible changes in plans and practices and to the farmer's expectations about prices in the coming marketing period. Such questions continued in the third meetings (July, 1977). Changes in expectations were discussed.

The farms had been selected to represent established farmers conducting commercially significant operations. Only members who had joined the Association before 1973 and had at least $400,000 cumulated gross farm sales in a three-year period (1973-75) were considered.

Cattle feeding is the region's principal enterprise. To insure that feeders were well represented, farms on which cattle sales accounted for at least 75 percent of cash receipts were separated. To insure inclusion of farms with important grain marketing problems, those on which corn accounted for at least 25 percent of gross receipts were also separated.

Seven farms were selected from each group in cooperation with the Association's extension agent. This selection was based on his impressions of the adequacy of records and the likelihood of obtaining careful responses in interviews. Thirteen farmers agreed to participate in the study.

The respondents were very busy people and quite a few interviews were interrupted or shortened by pressing business. In particular, the third visits came after a rainy spring had delayed planting. Three respondents could not be available and several interviews were quite short. This resulted in much less exploration of expectations than had been planned. Our impressions from these discussions of expectations are briefly noted in Appendix II.

In the fourth interview (December, 1977) each panelist was asked what his decisions would be in certain hypothetical situations involving financial uncertainty. Responses to these questions were the basis for estimates of farmer utility functions reported in Section IV. Problems encountered in formulating questions and interviewing are described in Section II. Section III concerns some properties of the responses. Estimates of farmer utility functions are given in Section IV followed by a brief review of results in Section V.

Appendix I sketches some earlier empirical studies of utility. Appendix II gives a brief account of the authors' interviews related to expectations. Data used in the analyses of Section IV are tabulated in Appendix III.

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## II. Interviewing

The authors have assumed throughout that carefully considered choices under uncertainty approximately satisfy Bayesian consistency and, therefore, have an approximate expected utility representation.[1/] This is not firmly established and various contrary views have been advanced. (See e.g., Schoemaker [31], also Appendix I, p. 66). The question is difficult to resolve because actions can be interpreted in many ways. Strict consistency, and sometimes even approximate consistency, requires careful calculations by the decision-maker, so in practice errors must be expected. Also, actions that appear inconsistent by one formulation of a decision problem may be consistent when a different framework is used, e.g., a multivariate instead of a univariate utility function. It seems to us reasonable to continue to explore the implications of expected utility models both theoretically and empirically and to let an eventual judgement rest on the extent to which researchers believe the models have resulted in improved understanding.

Someone studying behavior under uncertainty can, in principle, obtain observations in three ways. One can observe real-life decision-making, one can conduct experiments which pose contrived decision problems, or one can ask respondents to report decisions they would make in hypothetical situations. All present serious inherent difficulties.

In a Bayesian interpretation of real-life decisions, the investigator must know the decision-maker's relevant subjective probabilities (be they explicit or implicit) and must know quite a bit about the whole array of contingencies faced by the decision-maker rather that just those contingencies immediately affected by the observed decisions.[2/] A random variable representing the array of possibly relevant contingencies is sometimes called the initial prospect and is discussed further on pages 3 and 4.

An experiment usually involves alternative chance rewards of modest value. This means that any incidental motivation--for example, the subject might feel a desire to impress the investigator, a desire to confuse the investigator, or a desire to vent some immediate frustration--may easily influence or even dominate his behavior. Even if no extraneous influences are present, the contrived problem of modest consequences may not call forth a very careful calculation. Investigators try, of course, to minimize such interferences but how successfully this is done is hard to judge.

In the present study, hypothetical questions seemed the only practical possibility. Using hypothetical questions poses some of the above difficulties and also raises an obvious question as to whether or not reported choices are necessarily those that would actually be invoked if the circumstances were real. We believe our respondents answered conscientiously, but anyone who has changed one's mind once or several times in an important decision will recognize that a reported inclination based on a few moments reflection about a hypothetical question is not necessarily what the party would do if the described circumstances were really faced. Some of our conjectures about how this may have affected the interviews reported here are discussed in Section V.

Naturally, we wished to formulate a hypothetical situation that would yield as reliable responses as we could obtain. It seemed desirable to recognize the following criteria:

1. The situation should concern a serious matter to justify and hopefully stimulate a careful calculation.

2. It should have sufficient plausibility to not invite quick dismissal.

3. The chance aspect should arise as naturally as possible to avoid the complication of feelings respondents might have against contrived or casino-like gambling.

4. The probabilities involved should arise in a way that the respondent will accept them without second-guessing.

5. Unless the investigator is in a position to assess all contingencies faced by the respondent, the hypothetical contingency posed should be statistically independent of the real-life chances that the respondent already faces.

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1/ For development of consistency axioms and resulting expected utility representation, see Fishburn [7], [8] or DeGroot [5], Chapters 6,7.

2/ See Knowles [24], Appendix 2.1 for an agricultural example.

The need for (5) arises from the fact that if prospective gains or losses resulting from an immediate decision are related to gains or losses already in the decision-maker's prospect, then the nature of the relationships must be known to correctly interpret the decision. A simple illustration is given below. Prospective gains or losses not affected by the current decision have been called random initial wealth [22] or the current (or initial) prospect [14], [17], [24].

Example:

Let $\phi(x)$ be utility of wealth, the utility experienced by a subject if he knows his wealth at some future time will be x. Let X be a random variable whose values are the possible amounts that the subject might realize at the future time if he follows his present plans and fulfills his present commitments. Assuming no changes, the subject's expected utility is $E\phi(X)$ and X is called his initial prospect. If he undertakes new plans, commitments, and/or investments (or modifies old ones), he will have a new prospect Z and a new expected utility $E\phi(Z)$.

Y = Z-X is the modification in his prospect and is called his venture. If he is considering new plans, commitments, and/or investments he has a choice of modifications or ventures and his decision problem is

$$(2.1)\quad \max_{Y\varepsilon \mathcal{Y}} E\mathcal{Y}(X + Y)$$

where $\mathcal{Y}$ is the family of possible ventures.

For any choice of Y, (under certain regularity conditions, see Ash [1], Ch. 3) the resulting expected utility may be written

$$(2.2)\quad E\phi(X+Y) = \int\int \phi(x+y)dF_{X/Y=y}(x)dF_Y(y).$$

It is to be expected that drawing inferences about properties of $\phi$ from observed choices of Y will generally be complicated by dependence of choice on the joint distributions of X with the eligible Y's.

If X is independent of Y for $Y\varepsilon\mathcal{Y}$, matters are simpler, then $F_{X/Y=y}=F_X$ and one may define

$$(2.3)\quad \psi(y) = E\phi(X+y) = \int \phi(x+y)dF_X(x)$$

as utility of gain. Gain is defined as the increment (positive or negative) of future wealth that is due to modification of the initial prospect. Expected utility corresponding to a venture Y is then $E\phi(X+Y)=E\Psi(Y)$ and the decision problem may be stated

$$(2.4)\quad \max_{Y\varepsilon} E\Psi(Y).\mathcal{Y}$$

Inferences about $\psi$ from observed choices are more readily obtained and some important properties of $\Psi$, $\phi$ are closely related.3/ Neglect of the initial prospect if it is not independent of the ventures will typically lead to misinterpretations. This is illustrated below for a highly simplified case in which the researcher's assumption about the form of the utility function is exactly right and the subject's response is exact. Errors will be taken into account in Section III.

Suppose the subject has constant absolute risk aversion.4/ His utility of wealth function may be written, Pratt [29],

$$(2.5)\quad \phi(x) = -e^{-\lambda x} \quad \lambda>0$$

3/ See Hildreth [14], pp. 102-104.

4/ Absolute risk aversion is defined $r(x) = \frac{-\phi''(x)}{\phi'(x)}$ for utility of wealth function $\mathcal{Y}(x)$ or $\rho(y) = -\frac{\Psi''(y)}{\Psi'(y)}$ for utility of gain function.

and with initial prospect X, utility of gain is

$$(2.6)\quad -Ee^{-\lambda(X+y)} = -(Ee^{-\lambda X})e^{-\lambda y}.$$

Since utility functions are determined to positive linear transformations we may take

$$(2.7)\quad \Psi(y) = -e^{-\lambda y}.$$

An investigator wants to determine $\lambda$, the coefficient of (absolute) risk aversion. He asks the subject for the cash equivalent v of a chance to receive y if an unbiased coin shows heads. Since the toss of a coin is independent of the subject's initial prospect, v satisfies

$$(2.8)\quad \begin{aligned} &.5\,\Psi(0) + .5\Psi(y) = \Psi(v) \\ &-.5 - .5e^{-\lambda y} = -e^{-\lambda v} \\ &v = -\lambda^{-1} \log\,(.5 + .5e^{\lambda y}). \end{aligned}$$

Knowing v and y but not $\lambda$, the investigator solves (perhaps by an iteration)

$$(2.9)\quad e^{-\lambda v} - .5e^{-\lambda y} = .5 \text{ and obtains the correct value of } \lambda.$$

Note that $\lambda = 0$ always solves (2.9). This solution is not of interest since it permits any response v.

Suppose the subject is a farmer and he/she and the researcher agree that the chance of a freeze within the week is 50-50. The researcher asks the cash equivalent v of a chance to receive y if it freezes and proceeds to determine $\lambda$ in the same manner as with the coin toss. This will yield the correct value if the farmer has no prior stake in the possibility of a freeze and thus determines v as with a coin toss. Suppose, however, that the farmer has a berry crop worth z that will be lost if there is freeze.

Let W represent the farmer's initial prospect except for the berry crop and assume W is independent of a possible freeze. v will then satisfy

$$(2.10)\quad .5E\phi(W+z) + .5E\phi(W+y) = .5E\phi(W+z+v) + .5E\phi(W+v).$$

Before considering the venture the farmer's expected utility is $.5E\phi(W+z) + .5E\phi(W)$. If he receives v in cash expected utility becomes rhs, of (2.10); if he receives y contingent on freeze, expected utility becomes lhs. Rewriting the equality with $\phi(t) = e^{-\lambda t}$ yields

$$(2.11)\quad \begin{aligned} &(Ee^{-\lambda W})\,(e^{-\lambda y} + e^{-\lambda z}) = (Ee^{-\lambda W})\,(e^{-\lambda z}e^{-\lambda x} + e^{-\lambda v}) \\ &x = -\lambda^{-1}\,[\log\,(e^{-\lambda y} + e^{-\lambda z}) - \log\,(1 + e^{-\lambda z})] \end{aligned}$$

If the investigator knows that the initial prospect consists of a contingency, (z if it doesn't freeze, 0 if it does), and some contingencies, W, independent of freezing; he can obtain the correct $\lambda$ by solving

$$(2.12)\quad e^{-\lambda v}\,(1 + e^{-\lambda z}) - e^{-\lambda y} - e^{-\lambda z} = 0$$

However, if he ignores the initial prospect and solves (2.9) he will clearly be misled.

The reader can readily verify that with true $\lambda = .02$; a researcher who applied (2.9) instead of (2.12) would obtain the following incorrect values $\tilde{\lambda}$ in the indicated circumstances.

| Case | z | y | v | $\tilde{\lambda}$ |
|---|---|---|---|---|
| 1 | 10 | 1 | .547 | -.38 |
| 2 | 1 | 10 | 4.800 | .016 |
| 3 | 10 | 10 | 5.250 | -.020 |

To a careless investigator the farmer appears less risk averse than he really is because the venture involving y has some insurance value for the farmer, and this is not recognized by the researcher. In fact, in circumstances 1 and 3, the farmer appears to prefer risk unless his/her initial prospect is taken into account. If the researcher's proposal has been to make y contingent on absence of a freeze, the $\tilde{\lambda}$ calculated from (2.9) would lie above the true value.

The example cited above has been highly simplified but the existence of initial prospect bias is more general. It is seen from equation (2.2) that whenever $F_{X/Y=y}$ differs from $F_X$, interpretations of choices of ventures without accounting for the initial prospect will, except for rare accidents, be misleading.

In the present study, a major purpose of the background questions of the first two visits was to see how much could be learned about the panelists' initial prospects. If these could be ascertained reliably and accurately, the investigators could have based their subsequent utility analyses on observed actual decisions and/or hypothetical decisions with known relations to the initial prospects. However, it was judged that the resources of this study would not permit sufficiently accurate observation of initial prospects. Therefore, questioning for utility analysis was based on a hypothetical question believed to be independent of the initial prospects.

Condition (5), page 2, was imposed along with the other desiderata. After some consideration, the following situation was posed to introduce alternative choices.

> "Suppose a cancer vaccine has been discovered and the principal source is a particular gland of a few cattle. An animal that might furnish the needed antibodies has an enlarged gland at the base of the neck. A veterinary technician has visited your farm and found one steer with the enlarged gland. However, experience has shown that only half of the animals with the enlarged gland have the desired antibodies so there is a 50-50 chance that your steer will prove useful. The technician has arranged to return to perform a conclusive test. If positive (the steer is useful) he will pay you current market price plus $3,000 for the steer. If negative he will leave the steer unharmed to be marketed with the others. As an alternative to the above arrangement, he is willing to pay you current market price plus $1,000 to buy the steer outright and perform the test at his own facilities.
>
> Would you prefer to sell the steer at market plus $1,000 or take a 50-50 chance on receiving market plus $3,000?"

Upon receiving the answer, the interviewer adjusted the $1,000 sure return up or down until an amount was reached which the respondent indicated was about equally desirable to a 50-50 chance of $3,000. This was recorded and the $3,000 contingent amount was changed. A new certainty equivalent was located. Certainty equivalents corresponding to seven gambles of this kind were obtained in a personal interview (the fourth of those sketched in Section I) and a postcard requesting five additional comparisons was left for the respondent to mail.

As each interview progressed, the hypothetical example faded naturally into the background and some respondents tended to say, "You want to know how much cash I would take in preference to a 50-50 chance of getting y dollars. Well ...." The interviewers did form the impression, however, that the example helped set the tone in most cases. It is believed to have helped the panel visualize a naturally arising gamble, important but substantially unrelated to their current production and marketing decisions.

Questions, like the above, in which the respondent indicates a cash amount x that is indicated to be equivalent in his preferences to a 50-50 chance of receiving $y_1$ or $y_2$, are sometimes called Von Neumann-Morgenstern questions and are denoted by V in our tabulations. In most cases, $y_1$ was set at zero. Near the end of the V questioning, a variation was introduced which supposed that the farmer could have a conclusive test performed for a $200 fee and would receive $8,000 if the animal were useful. This was a V question with $y_1 = -200$, $y_2 = \$7,800$ and was the only question in that particular interview in which a contingency involving possible loss to the farmer was used. If x is treated as an expected response, the utility of gain function satisfies

(2.13) $.5\Psi(y_1) + .5\,\Psi(y_2) = \Psi(x).$

The example on page 3 involves a V question with $y_1 = 0$.

A few days after the personal interviews were completed, the panelists were contacted by phone and asked a question of essentially the form[5/], "What is the most you would just be willing to pay for a 50-50 chance of winning z dollars?" An answer of x indicated that a 50-50 chance of netting -x or z-x was approximately as desirable as doing nothing, thus leaving the initial prospect unchanged. This type of question was called lottery ticket and designated by L.

Of five farmers, Mr. Knowles asked additional questions of a form suggested by Frank Ramsey [30]. These R questions were either included after V questions or involved an additional visit. As used in these cases,[6/] the question involves giving the respondent three numbers $y_1$, $y_2$, z and asking him to designate an x such that a 50-50 chance of receiving $y_1$ or $y_2$ just as attractive as a 50-50 chance of receiving z or x (any of the numbers may be either positive or negative).

The answer to an L question may be interpreted as an assertion by the respondent that his utility of gain function satisfies

$$(2.14) \quad .5\Psi(-x) + .5\,\Psi(z-x) = \Psi(0)$$

For an R question the implicit restriction is

$$(2.15) \quad .5\,\Psi(y_1) + .5\,\Psi(y_2) = .5\,\Psi(z) + .5\,\Psi(x)$$

For each type of question, the respondent is saying that he is indifferent between a gamble whose utility is represented by the left hand side of the appropriate equation, (2.13) to (2.15), and the gamble (possibly a sure thing regarded as a degenerate gamble) whose utility appears on the right. If the response x is such that the actuarial value of the two gambles are equal, the response is said to be risk neutral and is the response to be expected if the subject has linear utility. For the question types V, L, R, the risk neutral responses are respectively $x = 1/2(y_1 + y_2)$, $x = \frac{z}{2}$, and $x = y_1 + y_2 - z$.

For any particular question and response one may associate a coefficient of absolute risk aversion in a natural way. One may obtain a constant absolute risk aversion utility function, $\Psi(t) = -e^{-\lambda t}$, that exactly fits the one observation. One then associates the resulting value of $\lambda$ with the response. When this is done a response will be said to be risk averse (or to indicate risk aversion) if $\lambda>0$, and to be a risk preference response if $\lambda<0$.

For V, L, R questions, this means substituting $-e^{-\lambda t}$ for $\Psi(t)$ in (2.13) to (2.15) respectively and solving the resulting equations for $\lambda$. After minor simplifications one has

$$(2.16) \quad e^{-\lambda x} - .5e^{-\lambda y_1} - .5e^{-\lambda y_2} = 0$$

$$(2.17) \quad .5e^{\lambda x} + .5e^{-\lambda(z-x)} - 1 = 0$$

$$(2.18) \quad e^{-\lambda x} + e^{-\lambda z} - e^{-\lambda y_1} - e^{-\lambda y_2} = 0$$

$\lambda = 0$ is always a trivial solution and is the only solution when the response is risk neutral. In other cases, one is interested in a non-zero solution.[7/]

For risk neutral and risk averse responses, calculated values of $\lambda$ are tabulated in Appendix III and shown on the charts of Section III which follows. These are used in some preliminary inspections of the data.

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5/ The exact phrasing depended on what had seemed to be effective in earlier talks with each particular farmer.

6/ See Knowles [24], Chapter IV.

7/ The possibility of multiple non-zero solutions has not yet been completely investigated. In the process of obtaining solutions in this study, it was verified in each case that the function is monotonic in $\lambda$ in the vicinity of the solution so another solution would have to be a different order of magnitude. Monte Carlo experiments were also conducted. The left-hand sides of (2.16) to (2.18) were plotted for $-2S \lambda \leq 6$ using 38 representative combinations of values of the stakes $(y_1, y\_, X, Z)$. These also gave no indications of multiple non-zero solutions.

## III. Responses: Some Preliminary Considerations

Economists have generally assumed that utility of wealth functions exhibit positive and decreasing absolute risk aversion.[1/] The authors believe (see appendix to Hildreth [15]) that business decisions will typically reflect these properties and have based the analysis reported in Section IV on such assumptions.

Positive absolute risk aversion implies a strictly concave utility function which would not explain gambling at unfair odds, something frequently observed. Of various explanations, two particularly appeal to us. One is that many gamblers derive utility from being in a gambling situation - like some people derive utility from drugs. To fully analyze such behavior requires a multivariate utility function whose arguments include variables reflecting gambling experiences as well as the money outcome (see Smith [32], also Newsweek, April 10, 1972).

The other instance is one in which the individual recognizes a dominant need for a quick increase in wealth, and this outweighs potential consequences of possible losses of greater actuarial value. The decision-maker is desperate to achieve a particular objective or avoid a particular catastrophe and either requires increased wealth.

The authors doubted that the chosen panelists faced either situation. The doubts were confirmed by early interviews.

It also seemed desirable to use the calculated risk aversion coefficients described in Section II as a check on these assumptions. First, consider the assumption of positive absolute risk aversion. Of the 286 total responses elicited, 155 were risk averse, 93 were risk neutral, and 38 were risk preferring.

At first glance, this doesn't seem strong confirmation of risk aversion. However, connecting the types of response with circumstances in which each was received conveys a somewhat different impression.

Theorists have typically assumed that gambles for small stakes are decided on actuarial value, i.e., exhibit risk neutrality, provided the decision-maker is not influenced by non-monetary aspects of the gamble - where it is held, with whom associated, how it is perceived by others, etc.

This seems reasonable to us. In fact, our interviews combined with introspection and other discussions lead us to believe that many people naturally think first in terms of actuarial value (as nearly as they can ascertain it) and then modify the indicated behavior if an adequate reason appears. An adequate reason might be diminishing marginal utility of wealth, in which case a risk averse response occurs. For this to be an adequate reason, a non-negligible sum must be involved. Other adequate reasons might be incidental, non-financial aspects (such as those mentioned above) of an envisioned venture. These could produce either apparently risk averse or apparently risk preference actions or responses. A complete understanding of these cases would require a multivariate utility function which incorporated the decision-maker's evaluations of non-financial considerations.

Another set of possible reasons for revising actions based on actuarial values of prospective ventures are the relations of the prospective venture to the decision-maker's other contingencies (initial prospect) as illustrated in Section II.

Of course, reasons for deviating from actuarial or risk neutral behavior may occur in various combinations. In real life the resulting calculations of expected utility may be complicated and involve quite a bit of internal utility searching, information gathering and processing, and expectation formation. These procedures are not psychologically cost free and if one does an actuarial value assessment and believes other considerations are of secondary magnitude (in their effect on utility) then one may as well make the risk neutral choice. Expected utility theory does not take account of calculation costs so one may expect deviations from theoretical solutions and observed behavior when economizing on calculation costs has been a factor.

It seems reasonable to expect that willingness to do careful calculations will be less with hypothetical questions than with real world decisions. We conjecture that examination of real world decisions, taking account of initial prospects and, where necessary, non-financial considerations would reveal a smaller proportion of risk neutral and risk preference decisions than resulted in this study.

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1/ Leigh Tesfatsion has shown that decreasing absolute risk aversion for utility of wealth implies decreasing absolute risk aversion for utility of gain. See Hildreth [14], Proposition 6.

In our interviews, risk neutral and risk preference responses tended to occur early in the interviewing. In the early stages, V questions were being asked, possible gains were relatively small, and there was only one question involving a possible loss (of only $200) for the farmer.

As interviewing progressed, possible losses were included in most questions, the sums involved became larger, and the respondents seemed to become more at home with hypothetical questions. All of these factors may well have contributed to the steady elimination of risk preference and risk neutral responses. Hopefully, the later responses involved more careful internal calculations.

Some notion of the extent of these effects is given in Table 1, which shows the number of risk averse (A), risk neutral (N), and risk preference (P) responses to each type of question in the entire set of data.

Table 1. Risk Status and Type of Question
(numbers of responses)

| | Risk Status | | | |
|---|---|---|---|---|
| | A | N | P | |
| Question Type | | | | |
| V | 79 | 70 | 37 | 186 |
| L | 42 | 4 | 1 | 47 |
| R | 34 | 19 | 0 | 53 |
| | 155 | 93 | 38 | 286 |

All of L questions and most R questions involved possible loss to the respondents. L questions generally involved substantially larger sums of money than V or R. Thirty-six of 47 L questions involved possible gains of $10,000 or more, compared with 85 of 198 for V and 6 of 43 for R. V questions were asked in the first visit in which hypothetical choices were posed, most L questions were asked in later phone contacts, and most R questions in a subsequent visit. The null hypotheses of independence between risk status and question type is rejected at the .0001 level by the usual $\chi^2$ test.

In Appendix III, respondents with 75 percent or more cash returns from beef are listed $B_1$ to $B_7$. Those with 25 percent or more returns from corn were originally designated $C_1$ to $C_7$. $C_4$ declined to participate and $C_3$ discontinued farming during the study. $C_5$ and $C_6$ involved father-son partnerships and the authors questioned whichever partner was available. $C_{5f}$ identifies the father's responses on farm $C_5$ and $C_{5s}$ the son's. Both were available on the final visit and they chose to answer jointly. These responses are designated $C_{5fs}$. $C_{6f}$ and $C_{6s}$ identify father and son, respectively, on farm $C_6$.

$B_3$ was asked 11 R questions and all responses were risk neutral. The interviewer reported that these questions were asked after a number of V questions and that the respondent seemed impatient and not inclined to reflect on the questions. Except for these answers, there were only eight risk neutral responses to R questions.

It may also be worth observing that five respondents ($C_1$, $C_2$, $C_{6f}$, $C_{6s}$, $C_7$) account for 30 of the 38 risk preference answers. These respondents tended to give different answers to the same questions when some that had been asked in the initial interview were repeated on postcards (see V questions) and their responses included several violations of the sure thing principle (e.g., $C_1$, valued a .5 chance of 50 less than a .5 chance of 8, but later valued both at nothing). This suggests that the interviewers may not have succeeded in making questions clear in some of these cases.

$C_{6f}$ started with risk preferred answers, switched to risk averse and then mused, "I guess I just had an impulse to gamble when we started." He did not offer to go back and change answers so the originals were tabulated. $C_{6s}$ explained his high risk premium for a chance to win $3,000 by noting that he had a $3,000 payment due soon and wasn't quite that liquid, so winning that much would avoid the inconvenience of raising it some other way. Side remarks of the farmers were usually interesting to the authors and were not discouraged unless a large part of the intended interview seemed threatened.

The authors have the impression that many of the initial answers were dominated by comparisons of actuarial values and sometimes by associations of the postulated ventures with considerations not intended by the interviewers. $B_6$ initially gave risk preference answers and then asked to revise them. He said his first impulse was to accept a low price for his animal in order to further the research.

When assured that the hypothetical research was intended to go forward regardless of his decision, he changed to risk neutral answers.

In general, the interviewers tried hard not to guide answers and refrained from pointing out possible inconsistencies for this reason. Discussion of inconsistencies would also have used very scarce time. Panelists were permitted to reconsider and revise answers on their own initiative. The authors believe that discussions of inconsistencies with respondents can be useful, but the arrangements for the present study didn't seem to offer a good opportunity.

Another impression was that calculating by the respondents became more careful as questioning progressed. Thinking about the questions seemed to some extent cumulative. The possibility of large gains and the existence of possible losses also seemed to stimulate more considered responses from some panelists.

That size of gain and existence of possible loss are also associated with risk status is shown in Tables 2 and 3. Table 2 shows risk status of V questions for which largest possible gains were respectively $200, $8,000, and $20,000. Independence of status and largest gain is rejected at the .005 level.

Table 2. Risk Status and Size of Gain, V Questions
(numbers of responses)

| Largest Possible Gain ($000) | Risk Status A | N | P |
|---|---|---|---|
| .2 | 1 | 5 | 8 |
| 8 | 4 | 16 | 2 |
| 20 | 7 | 6 | 1 |

Table 3 was constructed by looking at responses of each panelist individually instead of looking at the whole pool of responses. For many panelists, one can form a simple rule that covers all or most of the responses. Sometimes the most effective rule is in terms of maximum stake (defined as the largest possible gain or loss in the question), sometimes in terms of whether or not a particular decision problem contemplates a possible loss. It would also be possible to construct fairly successful rules in terms of which questions came early in the interviewing. However, there was some variation in this from one interview to another that was not preserved in the records.

To briefly interpret statements of rules in the table, the first one says that $B_2$'s responses were risk neutral when the maximum stake was less than $20,000 and otherwise risk averse. The rule for $C_1$ says that his responses tended to be risk averse only when there was a possible loss or maximum stake was at least $15,000. Two of his 16 responses were inconsistent with this rule.

Before interviewing, the researchers expected quite a few, perhaps mostly, risk neutral answers to the $200 question and some of the others with low stakes. It was expected that risk averse answers would dominate when there was a stake of several thousand dollars or more. Instead, when a respondent seemed to be primarily motivated by size of stake the switching point was $5,000 to $50,000.

Taking the above evidence and other interviewing impressions into account, the authors believe that important business decisions will naturally bring forth more thorough calculations by entrepreneurial decision-makers and that risk aversion will be more persistent. Since a contribution to understanding important business decisions is viewed as the main purpose of the study, the statistical analysis of Section IV is based only on risk averse responses.

Returning to the other assumption common to most economic studies--decreasing absolute risk aversion--the data were again examined in a preliminary fashion. For this purpose some indicator of the general level of gain contemplated in a particular question was needed.

Each question posed in this study, and many of those posed in others, involved an assertion by the respondent that

$$\sum_1^m p_i \,\psi(y_i) \underset{-}{\sim} \sum_1^n q_j \,\psi(z_j)$$

where "$\underset{-}{\sim}$" is read "is about as desirable as."

Table 3. Rules Covering Individual Respondents*
(numbers refer to thousands of dollars)

| Respondent | Rule | Total Number of Responses | Number of Exceptions |
|---|---|---|---|
| $B_2$ | ms $\geq$ 20 $\Rightarrow$ A, ms < 20 $\Rightarrow$ N | 16 | 0 |
| $B_3$ | ms $\geq$ 40 $\Rightarrow$ A, ms < 40 $\Rightarrow$ N | 30 | 4 |
| $B_4$ | pl $\Leftrightarrow$ A | 13 | 0 |
| $B_5$ | All A | 26 | 2 |
| $B_6$ | pl $\Rightarrow$ A, not pl $\Rightarrow$ N | 22 | 2 |
| $B_7$ | (pl or ms $\geq$ 8) $\Leftrightarrow$ A | 21 | 1 |
| $C_1$ | (pl or ms $\geq$ 15) $\Leftrightarrow$ A | 16 | 2 |
| $C_{5f}$ | ms > 5 $\Leftrightarrow$ A | 15 | 2 |
| $C_{6f}$ | ms > 20 $\Rightarrow$ A, ms $\leq$ 20 $\Leftrightarrow$ P | 16 | 0 |
| $C_{6s}$ | (pl or ms $\geq$ 8) $\Leftrightarrow$ A | 16 | 2 |
| $C_7$ | ms < 8 $\Rightarrow$ P, 8 $\leq$ ms $\leq$ 50 $\Rightarrow$ N, ms > 50 $\Rightarrow$ A | 21 | 3 |

ms: maximum stake
pl: possible loss
A: risk averse response
N: risk neutral response
P: risk preferred response

* Responses of $B_1$, $C_2$ were less systematic in relation to ms, pl.

$\Sigma p_i y_i$ is the actuarial value of the possible outcomes in the mixture on the left and $\Sigma q_j z_j$ is the actuarial value of the possible outcomes of the venture on the right. The number used as an indicator is the simple average of the two actuarial values.

$$a = 1/2\ (\Sigma p_i y_i + \Sigma q_j z_j)$$

and thus represents the average level of possible gain contemplated by the respondent in answering a particular question. In our questions the p's and q's were either .5 or 1 and there were at most two possible outcomes of a venture. Hence, for a V question

$$a = 1/2\ (.5y_1 + .5y_2 + x)$$

and for L and R, respectively

$$a = 1/2\ (.5x + .5(z-x)) = .25z - .5x$$

$$a = 1/2\ (.5y_1 + .5y_2 + .5z + .5x) = .25(y_1 + y_2 + z + y)$$

Suppose a farmer's risk aversion does decrease with gain. Then his calculated $\lambda$'s for small values of a should be higher than $\lambda$'s for large a. Charts $B_1$ through $C_7$ which follow are scatter diagrams for $\lambda$ and a.

A few responses are omitted from the charts. $B_4$ was omitted because he had only two non-zero $\lambda$'s. On the second two L questions, $C_2$ said he wouldn't pay anything for the offered opportunities because it was too much like gambling. As noted earlier, $B_3$ was distracted and uncommunicative when visited with R questions. He replied quickly, apparently routinely, and seemed anxious for the interview to end. These 11 observations with $\lambda$=0 are not plotted.

Responses that indicated risk preference or risk neutrality are plotted along the a-axis in the charts. They are seen to be mostly associated with low a-values and with V questions. Recall that they were asked during the early part of the fourth interview which was the first time responses to hypothetical questions were requested.

Neglecting the entries on the a-axis, the downward drift of $\lambda$ as a increases is striking and persistent. It is evident on every chart. The data are certainly consistent with economists' conjecture of decreasing absolute risk aversion.

If one were to approximate points with a free hand curve (or perhaps two curves in cases like $B_2$, $C_{6f}$, $C_7$, where different questions elicited distinctly different respones) the curves would almost all be convex (note that arrangements like $C_7$, $C_{6f}$, $B_6$ look more convex when adjustments in scale are taken into account). This reinforces the notion that risk aversion probably remains positive, but downward sloping as gain becomes large and suggests that $\lambda(a)$ might typically be everywhere convex, at least for positive a, the only case for which our study furnishes data.

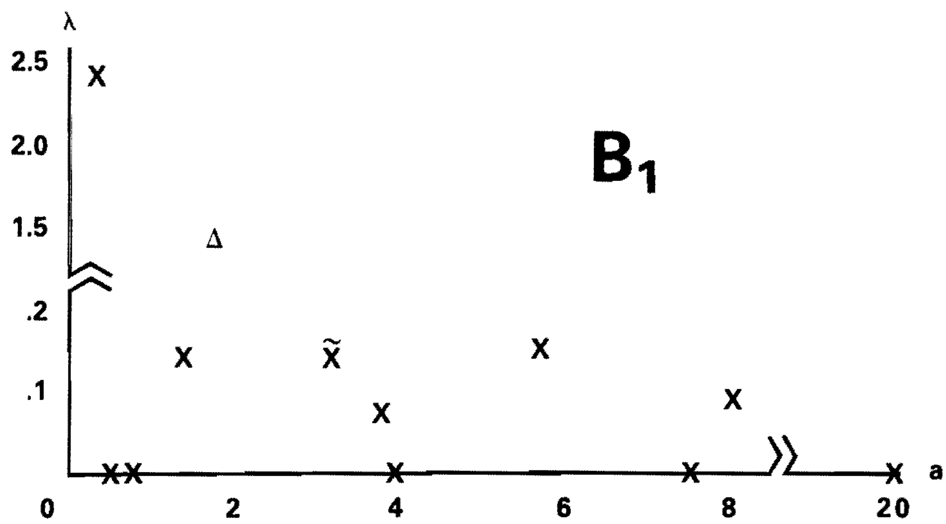
Considering that a is a makeshift statistic and that questioning was conducted in a difficult area, the scatter diagrams seem pretty smooth. The idea of smoothness will be reinforced by high correlation coefficients in the statistical analysis of the next section.

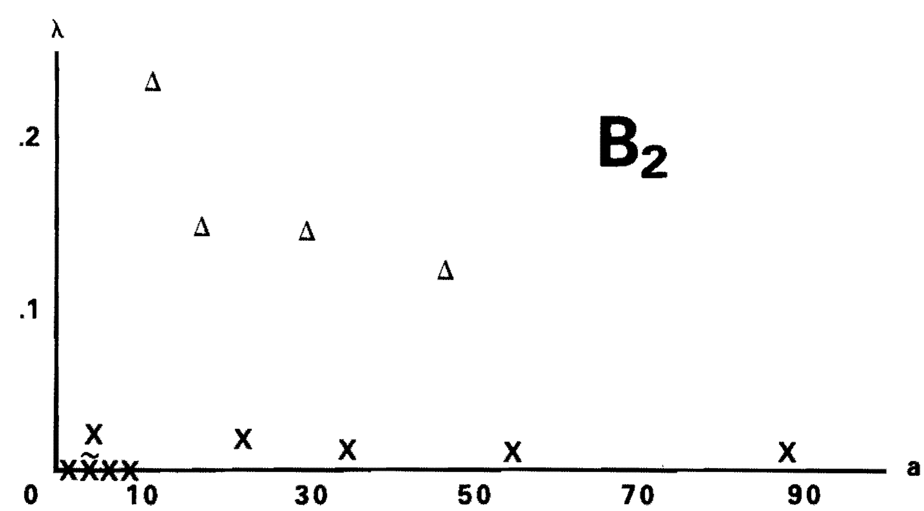
Some of the charts ($B_2$, $B_7$, $C_1$, $C_7$) show a distinct difference between risk aversion corresponding to V questions and risk aversion corresponding to L and/or R questions for comparable values of a. On other charts, question types look reasonably homogeneous. A possible explanation for differences is that most R and all L questions involve the possibility of loss or cost to the panelist while a possible loss is involved in only one V question (indicated $\tilde{x}$). Another possible explanation is that L and R questions were asked after V questions (the questions were asked in approximately the order they appear in Appendix III).

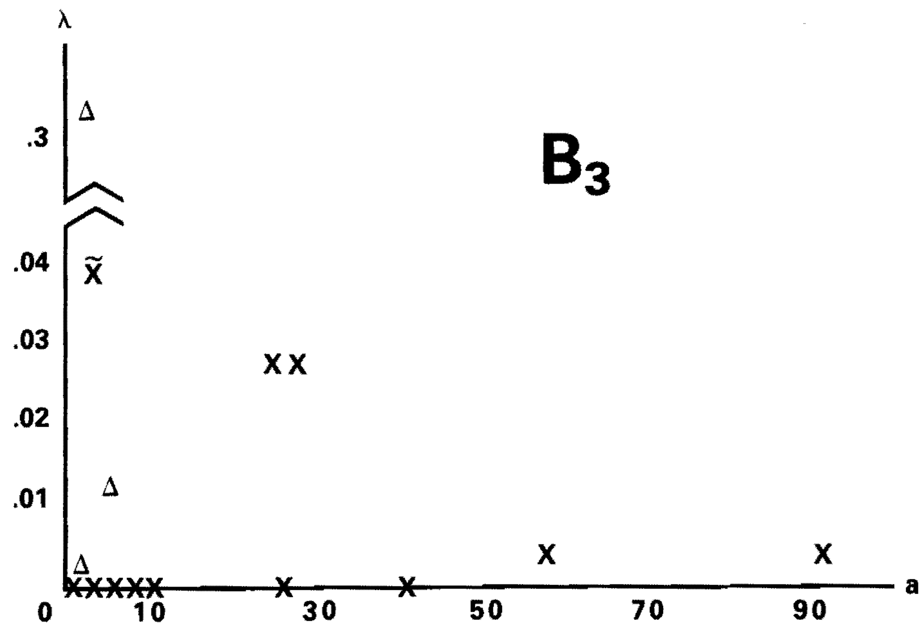
When V questions were planned, it was not known whether or not other questions would follow. If the initial questioning about hypothetical problems had seemed to disturb the panelists or to produce completely chaotic answers, the later phone and personal visits would not have been undertaken. In planning V questions, it was believed that questions not involving losses would be less troublesome at the outset, but one instance with a possible loss was included to see if this made a marked difference in responses. Would even a small possibility of loss stimulate more risk averse responses? Except for $B_6$ and perhaps $C_1$ this does not appear to be the case.

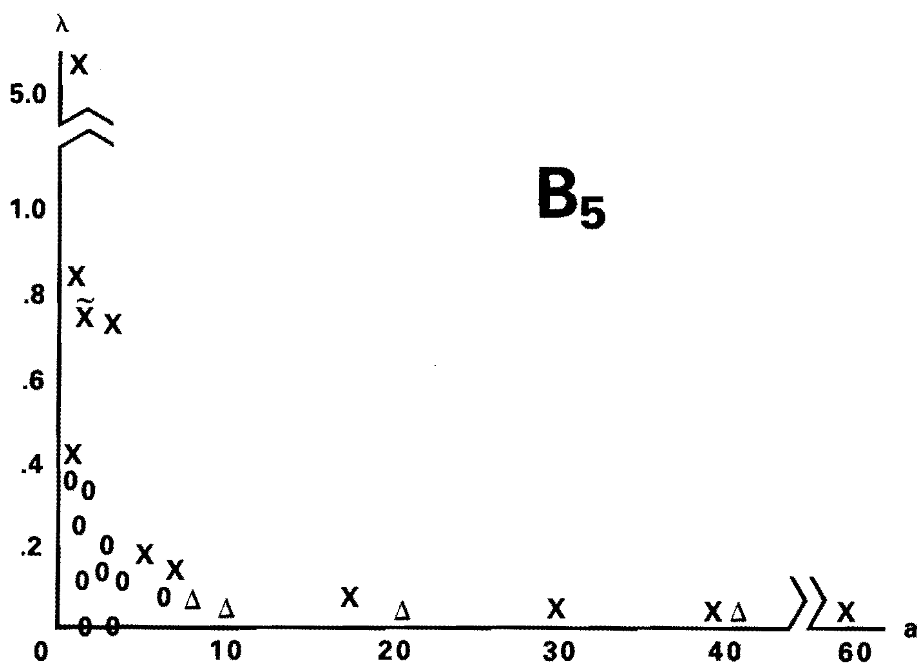
Charts of Risk Aversion Coefficients for Individual Observations

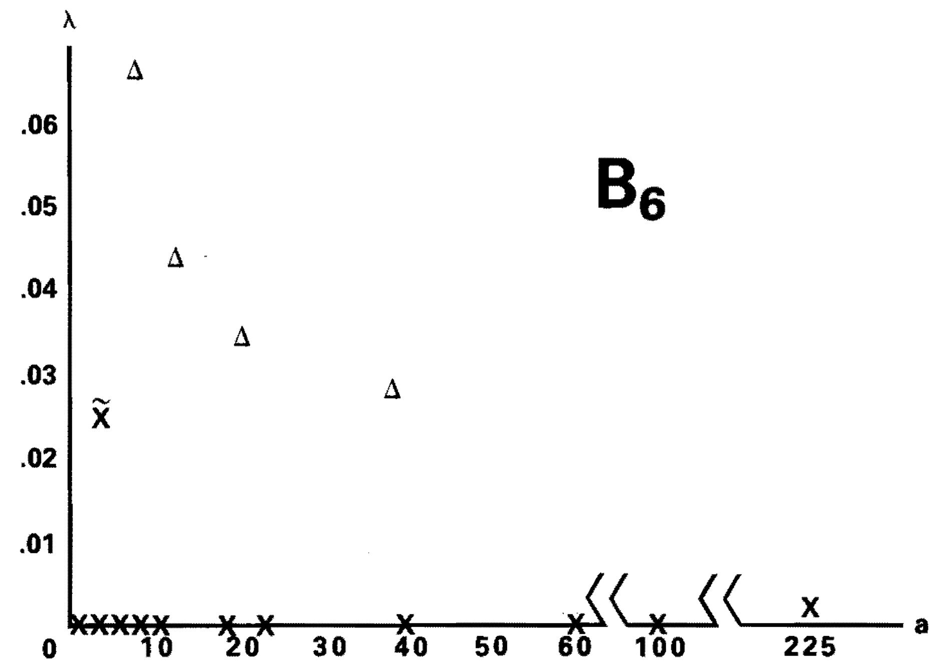
Question Types: x designates a V question, Δ an L question, 0 an R. $\tilde{x}$ is the only V involving a possible loss.

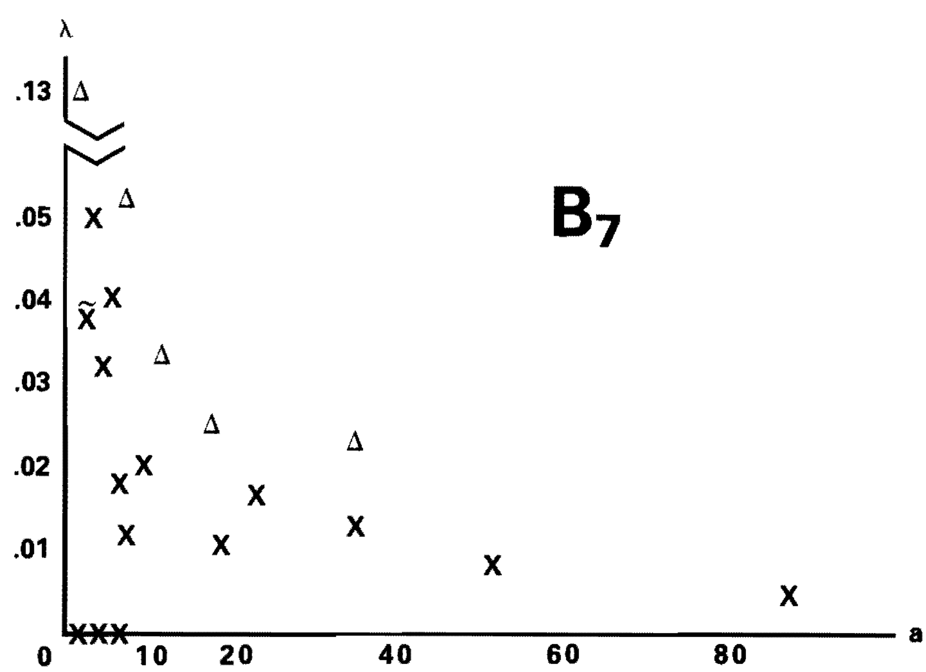



λ
.3
.04
.03
.02
.01
0
10
30
50
70
90
a
B3


λ
5.0
1.0
.8
.6
.4
.2
0
10
20
30
40
60
a
B5


λ
.06
.05
.04
.03
.02
.01
0
B6
10
20
30
40
50
60
100
225
a


λ
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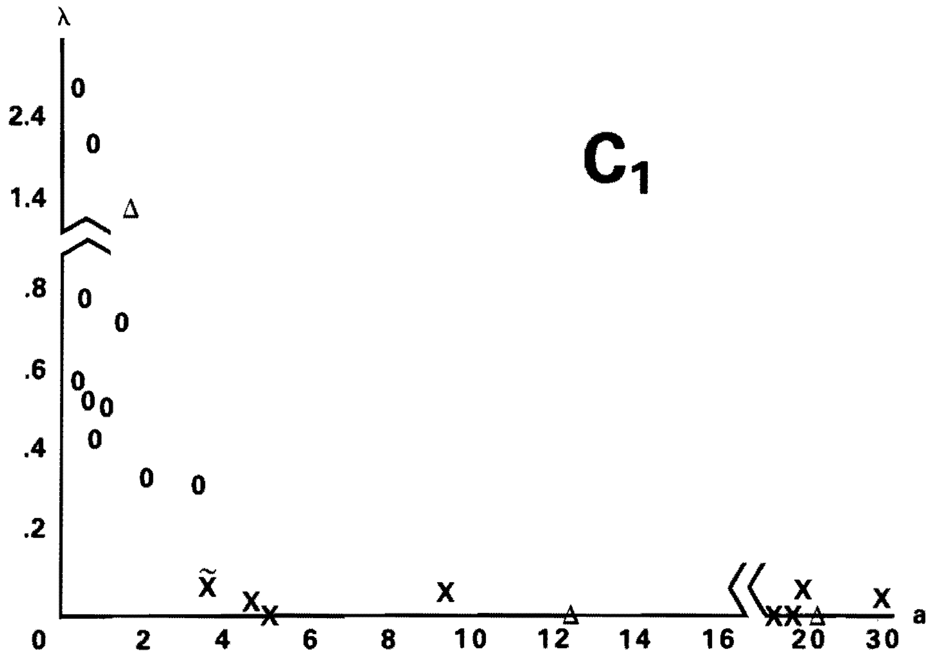
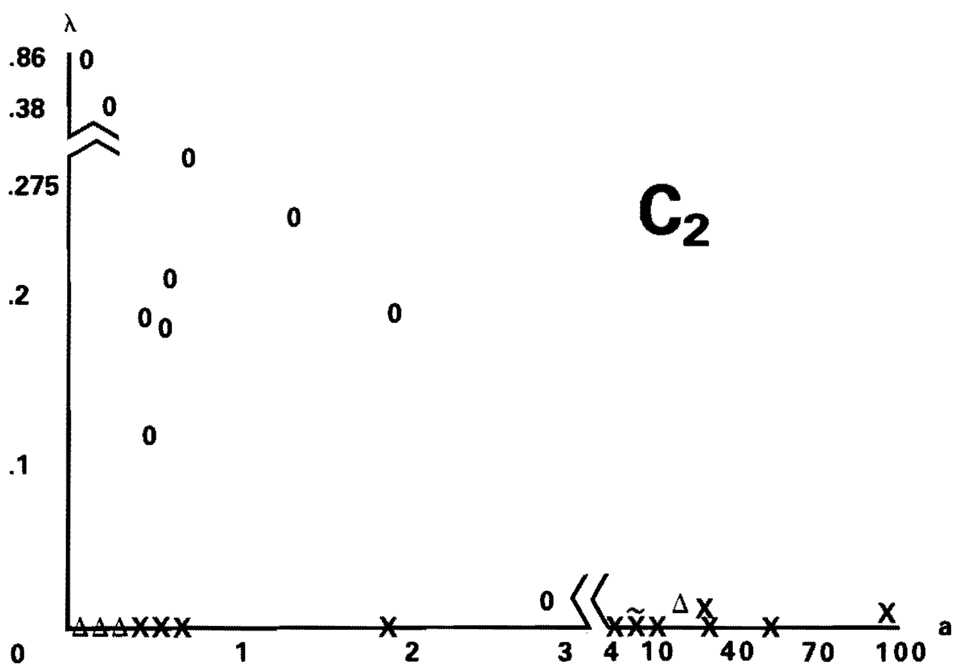
.05
.04
.03
.02
.01
0
B7
10
20
40
60
80
a


λ
2.4
1.4
.8
.6
.4
.2
0
C1
0 2 4 6 8 10 12 14 16 20 30
a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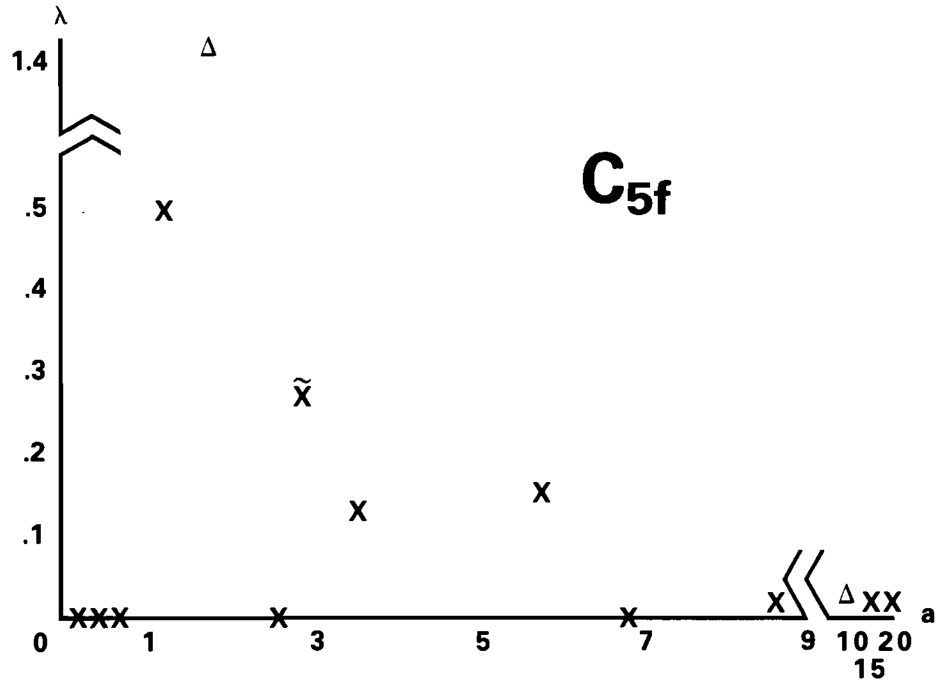
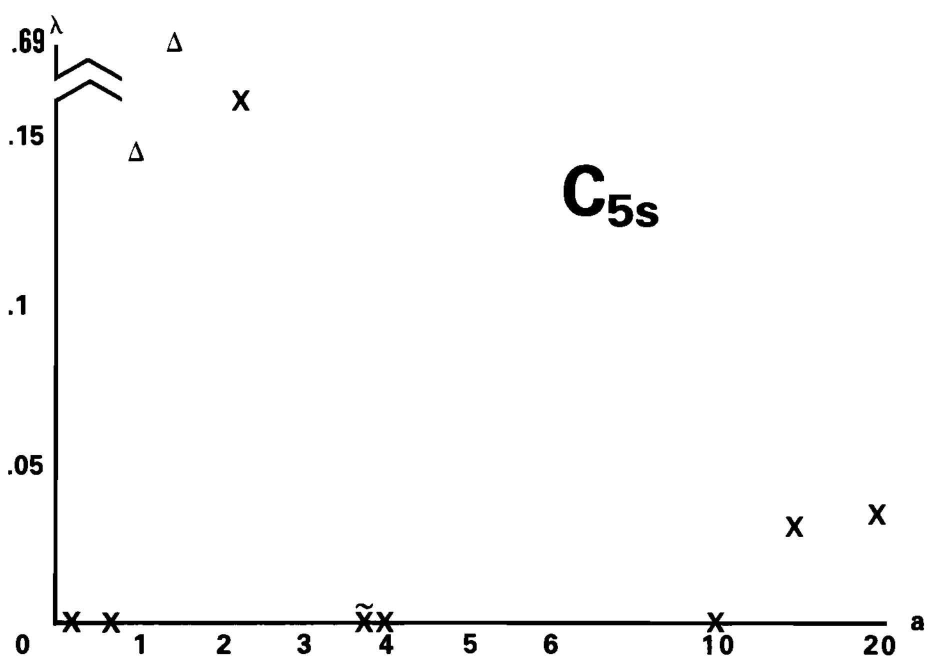
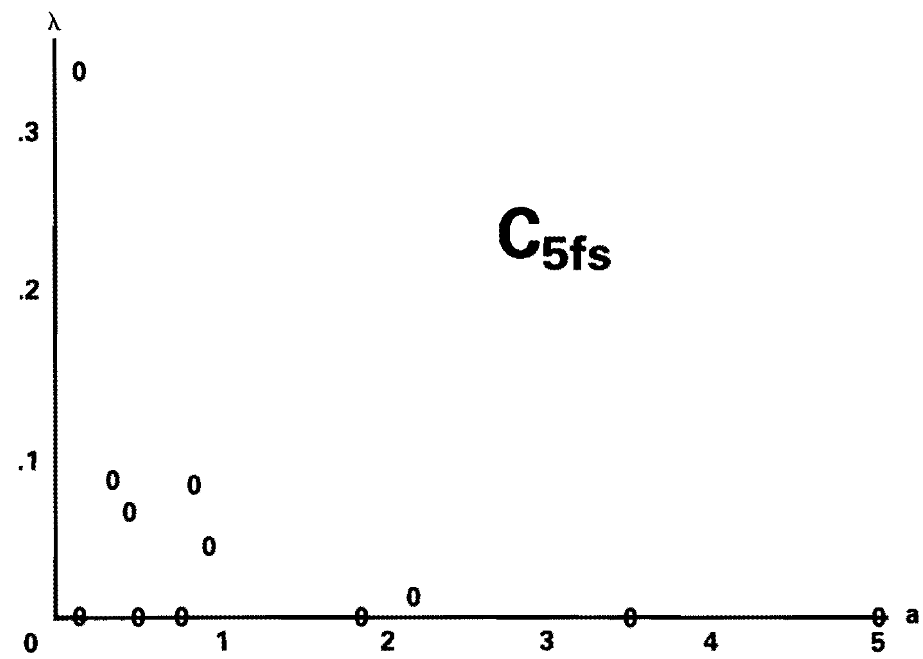
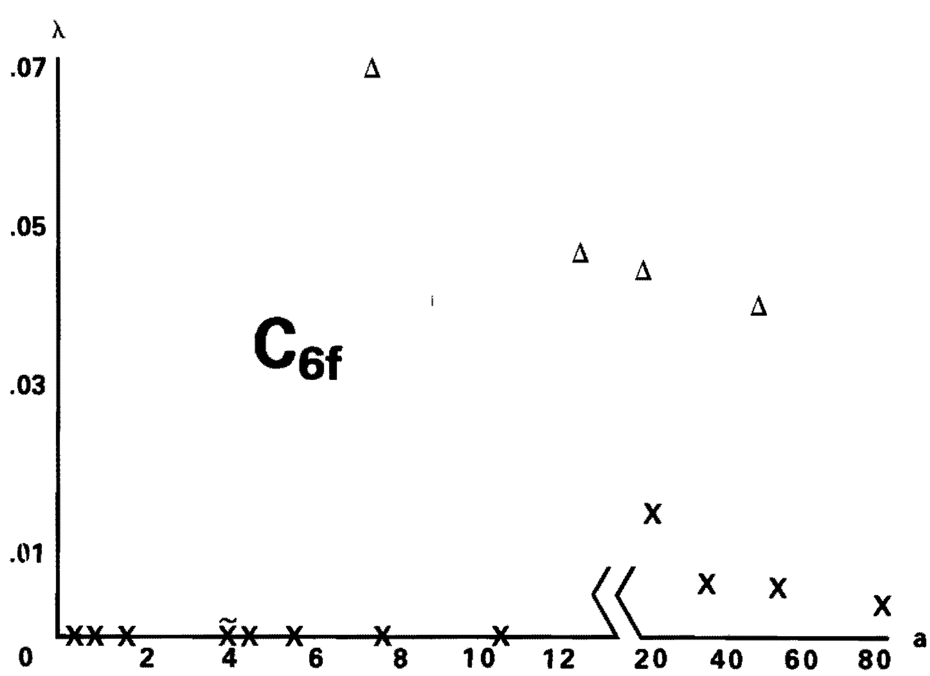
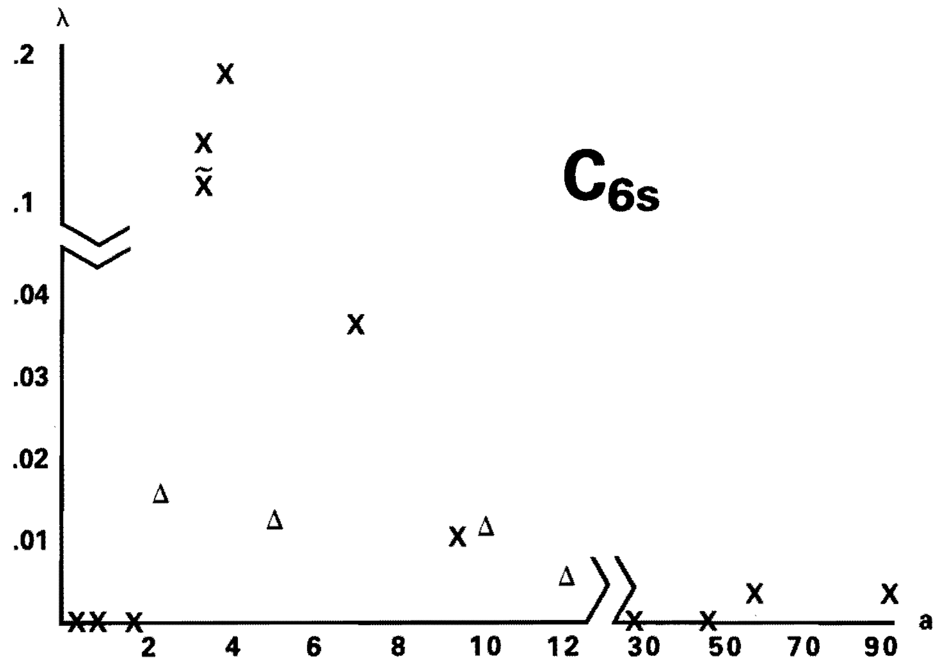
.275
.2
.1
0
C2
1 2 3 4 10 40 70 100
a

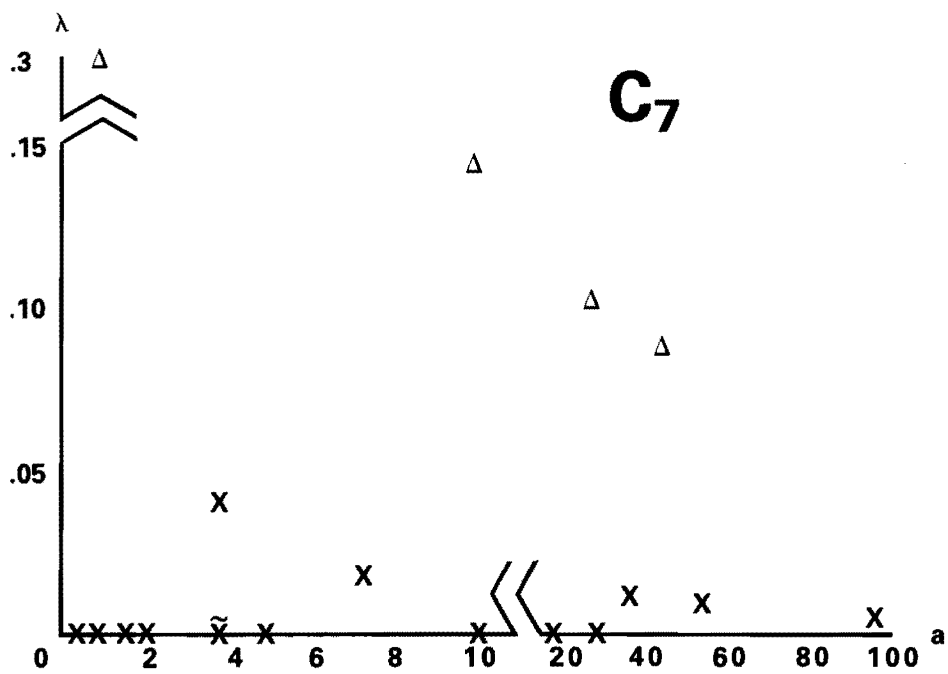

λ
1.4
.5
.4
.3
.2
.1
0
1
3
5
7
9
10
20
15
a
$C_{5f}$


λ
.69
.15
.1
.05
0
1
2
3
4
5
6
10
20
a
$C_{5s}$


λ
.3
.2
.1
0
1
2
3
4
5
a
$C_{5fs}$


λ
.07
.05
.03
.01
0
2
4
6
8
10
12
20
40
60
80
a
$C_{6f}$


λ
.2
.1
.04
.03
.02
.01
C6s
2
4
6
8
10
12
30
50
70
90
a


λ
.3
.15
.10
.05
0
C7
2
4
6
8
10
20
40
60
80
100
a

IV. Estimated Utility Functions

The estimates and tests reported here should be interpreted with some caution. Methods developed for linear statistical models have been applied to nonlinear relations. Heteroscedasticity of error terms has not been taken into account though Knowles ([24] pages 160-170) reports some evidence of this.

However, for most panelists the equation of principal interest fits sufficiently well and the associated tests are sufficiently decisive (see Tables 4-6) that it seems highly unlikely that biases due to nonlinearity or some inefficiency due to heteroscedasticity could materially change the general directions of the evidence furnished by the study. Some possibilities for developing improved methods are briefly outlined in Section V.

As noted earlier, Pratt ([29], page 130) showed that constant absolute risk aversion implies a utility function of the form

$$(4.1) \quad \psi(y) = -e^{-\lambda y} \quad \lambda>0$$

and that a linear combination of such functions with positive coefficients shows decreasing (but positive) absolute risk aversion.

$$(4.2) \quad \psi(y) = -\sum_{i=1}^{n} \beta_i e^{-\lambda_i y} \qquad \lambda_i>0,\ \beta_i>0.$$

For convenience, we refer to function like (4.1) as CAR and those like (4.2) as SCAR.

SCAR functions have a number of properties which make them promising for empirical work (see Hildreth [16], pp. 13-14; Tesfatsion [35]). The number of terms can be adjusted to accommodate data of varying complexity without disturbing properties of smoothness and positive, but decreasing, risk aversion. If utility of wealth is SCAR, then utility of gain is also SCAR and $\beta_i = \alpha_i Ee^{-\lambda_i X}$ where X is initial prospect, utility of gain is given by (4.2), and utility of wealth by

$$(4.3) \quad \phi(x) = -\sum_{1}^{n} \alpha_i e^{-\lambda_i x} \qquad \alpha_i>0, \lambda_i>0.$$

For SCAR functions, absolute risk aversion $\rho(y) = -\frac{\psi''(y)}{\psi'(y)}$ satisfies

$$(4.4) \quad \lim_{y\to\infty} \rho(y) = \min_{i=1..n} \{\lambda_i\}$$

$$\lim_{y\to-\infty} \rho(y) = \max_{i=1..n} \{\lambda_i\}$$

CAR and the two simplest versions of SCAR have been fitted to risk averse responses. $SCAR_1$ and $SCAR_2$ are defined by

$$(4.5) \quad \psi_1(y) = -e^{-\lambda_1 y} - e^{-\lambda_2 y}$$

$$\psi_2(y) = -e^{-\lambda_1 y} - \beta e^{-\lambda_2 y}$$

respectively.

CAR is the special case of $SCAR_2$, obtained by setting $\beta = 0$; $SCAR_1$ is the special case obtained by setting $\beta = 1$. For $SCAR_1$ and $SCAR_2$ we have ordered the terms so that $\lambda_1 > \lambda_2$. Thus, for $SCAR_2$, $\beta$ is the weight of the term with the smaller coefficient in the exponent. Estimated parameters for each of the three forms obtained by using all risk averse responses for each panelist are given in Table 4.

Each of the 13 clusters of calculated values in Table 4 pertains to a particular respondent. The numbers in parentheses beside the respondent identifications are the numbers of observations on which the respective calculations are based.

In each cluster, columns refer to the three alternative forms for the utility function, rows to calculated statistics. The first three rows are parameter estimates, the row labeled SSR shows the sum

Table 4. Estimates Based on All Risk Averse Responses*

| Respondent (number observations) | $B_1$(7) | | | $B_2$(9) | | | $B_3$(7) | | | $B_5$(24) | | | $B_6$(6) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Form Equation | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ |
| $\lambda_1$ | .12 | .17 | 6.3 | 0.19 | .030 | .50 | .0033 | .0041 | .052 | .035 | .048 | .048 | .0022 | .0029 | .092 |
| $\lambda_2$ | | .036 | .097 | | .0052 | .0035 | | .0011 | .0021 | | .021 | .018 | | .00069 | .0012 |
| $\beta$ | | | 44 | | | 38 | | | 72 | | | 85 | | | 42 |
| SSM | 26 | | | 5340 | | | 5583 | | | 1712 | | | 28,900 | | |
| SSR | 8.2 | 7.3 | 1.0 | 4450 | 3800 | 18 | 98 | 96 | 31 | 118 | 113 | 113 | 6393 | 6253 | 10 |
| $R^2$ | .69 | .72 | .96 | .17 | .289 | .997 | .98 | .98 | .994 | .93 | .93 | .93 | .78 | .78 | .9997 |
| Significance Level | .025 | .01 | | .0001 | .0001 | | .1 | .05 | | N | N | | .0001 | .0001 | |

| Respondent (number observations) | $B_7$(17) | | | $C_1$(16) | | | $C_2$(15) | | | $C_{5f}$(10) | | | $C_{5sf}$(6) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Form Equation | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ |
| $\lambda_1$ | .0128 | .0171 | .072 | .031 | .044 | 3.8 | .0043 | .0053 | .019 | .066 | .091 | .45 | .021 | .022 | .336 |
| $\lambda_2$ | | .0036 | .0029 | | .0084 | .031 | | .0013 | .000055 | | .017 | .028 | | .021 | .00082 |
| $\beta$ | | | 20 | | | 150 | | | 555 | | | 9.1 | | | 4160 |
| SSM | 5670 | | | 515 | | | 10,700 | | | 181 | | | 79 | | |
| SSR | 1490 | 1220 | 19 | 18 | 17 | 3.5 | 262 | 242 | 57 | 65 | 51 | 11 | 36 | 36 | 32 |
| $R^2$ | .74 | .79 | .997 | .97 | .97 | .992 | .98 | .98 | .995 | .64 | .72 | .94 | .54 | .54 | .59 |
| Significance Level | .0001 | .0001 | | .0001 | .0001 | | .001 | .0001 | | .005 | .005 | | N | N | |

| Respondent (number observations) | $C_{6f}$(8) | | | $C_{6s}$(11) | | | $C_7$(10) | | |
|---|---|---|---|---|---|---|---|---|---|
| Form Equation | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ |
| $\lambda_1$ | .014 | .019 | .16 | .0046 | .0057 | .016 | .019 | .027 | .57 |
| $\lambda_2$ | | .0038 | .0036 | | .0014 | .00021 | | .0050 | .0050 |
| $\beta$ | | | 47 | | | 100 | | | 126 |
| SSM | 3770 | | | 9040 | | | 5643 | | |
| SSR | 2770 | 2310 | 6 | 269 | 250 | 131 | 3950 | 3360 | 1.05 |
| $R^2$ | .29 | .39 | .998 | .97 | .97 | .986 | .30 | .40 | .9998 |
| Significance Level | .0001 | .0001 | | .1 | .05 | | .0001 | .0001 | |

N: Clearly nonsignificant

* Estimates based on data in thousands of dollars

of squares of residuals from each of the estimated utility functions. The entry just above the CAR-SSR cell is the sum of squares of deviations of responses from their mean. $R^2 = \frac{SSM-SSR}{SSM}$ is the multiple coefficient of determination.

The procedure for estimating $SCAR_2$ is sketched below. CAR and $SCAR_1$ are simpler special cases.

The sample consists of responses to a series of questions or trials, say $t = 1 \cdot\cdot T$. Suppose t is a V question. Let $w_t$ be the response that would be obtained if the panelist appraised his utilities perfectly, i.e., he responded without error. Then $w_t$ would satisfy

$$(4.6) \quad .5\psi(y_{1t}) + .5\psi(y_{2t}) = \psi(w_t)$$

For $SCAR_2$ this is

$$(4.7) \quad -.5\ [e^{-\lambda_1 y_{1t}} + \beta e^{-\lambda_2 y_{1t}}] - .5\ [e^{-\lambda_1 y_{2t}} + \beta e^{-\lambda_2 y_{2t}}] = -e^{-\lambda_1 w_t} - \beta e^{-\lambda_2 w_t}$$

or

$$e^{-\lambda_1 w_t} + \beta e^{-\lambda_2 w_t} = .5\ [e^{-\lambda_2 y_{1t}} + \beta e^{-\lambda_1 y_{2t}} + \beta e^{-\lambda_2 y_{2t}}]$$

For an L question the corresponding equation determining $w_t$ (derived from (2.14), p. 13) is

$$(4.8) \quad e^{\lambda_1 w_t} + e^{\lambda_2 w_t} + e^{-\lambda_1 (z_t - w_t)} + \beta e^{-\lambda_2 (z_2 - w_t)} = 2(1+\beta)$$

and for an R-question (see (2.15), p. 13).

$$(4.9) \quad e^{-\lambda_1 w_t} + \beta e^{-\lambda_2 w_t} = e^{-\lambda_1 y_{1t}} + \beta e^{-\lambda_2 y_{1t}} + e^{-\lambda_1 y_{2t}} + e^{-\lambda_1 y_{2t}} + \beta e^{-\lambda_2 y_{2t}} \quad -e^{-\lambda_1 z_t} - \beta e^{-\lambda_2 z_t}$$

Given $y_{1t}$, $y_{2t}$, and/or $z_t$ as specified in the question, the errorless response is a function of the parameters; write it $w_t(\lambda_1, \lambda_2, \beta)$. The observed response $x_t$ is an approximation to $w_t(\lambda_1, \lambda_2, \beta)$ so it seems reasonable to consider least-squares estimates of $\lambda_1$, $\lambda_2$, $\beta$, namely those which minimize

$$(4.10) \quad S(\lambda_1, \lambda_2, \beta) = \sum_{t=1}^{T} (x_t - w_t(\lambda_1, \lambda_2, \beta))^2.$$

In this study, for an initial parameter point, the $w_t$ were obtained from (4.7), (4.8), (4.9) by an interative procedure. $S(\lambda_1, \lambda_2, \beta)$ was then calculated and the gradient $(\frac{\partial S}{\partial \lambda_1}, \frac{\partial S}{\partial \lambda_2}, \frac{\partial S}{\partial \beta})$ was obtained by implicit differentiation. The new parameter point was then chosen by a version of Gauss-Newton embodied in the BMDP3R nonlinear regression package developed at the University of California, Los Angeles. $w_t$, S, and the gradient were obtained for the new parameters and the process was continued to convergence. The program was written by Lew Paper. If the errors $(x_t - w_t)$ can be regarded as independent drawings from a given normal population, the estimates are maximum likelihood.

From the SSR rows it is seen that, for most panelists, $SCAR_2$ gives a much better fit than CAR or $SCAR_1$. The statistical significance of the differences is crudely assessed in the last row of each cluster. The tabulated significance level in each CAR column is the highest significance level (lowest numerical value) at which the null hypothesis $H_o$: $\beta = 0$ is rejected using $SCAR_2$ as the maintained hypothesis. Significance levels tabulated in Graybill [3] were used with the F-test as developed for linear regression. Since $\beta = 0$ eliminates $\lambda_2$, F was assigned 2 and T-3 degrees of freedom when testing CAR. For testing $SCAR_1$ against $SCAR_2$, the null hypothesis was $H_o$: $\beta = 1$ and $F_{1,T-3}$ used. Possible bias due to nonlinearity should be investigated but the fact that rejections tend to be emphatic or not at all lets one hope that these tests are not misleading.

Clearly, the tests strongly support the notion that $SCAR_2$ represents these data better than the other forms. The inadequacy of CAR might have been anticipated from the charts of Section III, because CAR does not allow for decreasing risk aversion. However, the fact that $SCAR_1$ frequently improves so little on CAR is more surprising.

The charts of Section III contain suggestions that some panelists responded differently to the different types of questions. Functional forms could be sensitive to this. For instance, the three farmers for whom CAR and $SCAR_1$ give very poor fits--$B_2$, $C_{6f}$, $C_7$--are all cases in which the charts show much higher risk aversion for L questions than for V questions.

Table 5. Estimates Based on Specified Question Types*

| Respondent and Question Type (number observations) | $B_2$-V(5) | | | $B_2$-L(4) | | | $B_5$-V(12) | | | $B_5$-R(8) | | | $B_5$-L(4) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Form Equation | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ |
| $\lambda_1$ | .0049 | .0062 | .10 | .15 | .19 | .46 | .035 | .060 | 1.56 | .072 | .090 | .44 | .035 | .045 | .102 |
| $\lambda_2$ | | .0015 | .0029 | | .0078 | .00030 | | .014 | .025 | | .020 | .0045 | | .019 | .0227 |
| $\beta$ | | | 30.1 | | | 260 | | | 5.7 | | | 1248 | | | 15.8 |
| SSM | 2970 | | | 4.8 | | | 779 | | | 358 | | | 75 | | |
| SSR | 54 | 51 | 7.3 | 4.7 | 2.3 | .79 | 73 | 61 | 18 | 3.6 | 3.3 | 1.2 | 39.9 | 39.2 | 38.6 |
| $R^2$ | .98 | .98 | .998 | .02 | .52 | .84 | .91 | .92 | .98 | .990 | .991 | .997 | .47 | .48 | .49 |
| Significance Level | .25 | .1 | | .5 | .5 | | .005 | .005 | | .1 | .05 | | N | N | |

| Respondent and Question Type (number observations) | $B_7$-V(12) | | | $B_7$-L(5) | | | $C_1$-V(5) | | | $C_1$-R(10) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Form Equation | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ |
| $\lambda_1$ | .0059 | .0076 | .036 | .026 | .033 | .082 | .032 | .043 | .046 | .34 | .49 | 1.09 |
| $\lambda_2$ | | .0018 | .0010 | | .0055 | .000004 | | .007 | .002 | | .095 | .0013 |
| $\beta$ | | | 23 | | | 16521 | | | 3.8 | | | 240 |
| SSM | 5218 | | | 455 | | | 175 | | | 56 | | |
| SSR | 70 | 63 | 2.4 | 52 | 36 | 9.7 | 1.4 | .72 | .59 | 2.6 | 2.4 | 1.5 |
| $R^2$ | .987 | .988 | .9995 | .89 | .92 | .98 | .992 | .996 | .997 | .95 | .96 | .97 |
| Significance Level | .0001 | .0001 | | .25 | .25 | | .5 | .75 | | .25 | .1 | |

N: Clearly nonsignificant

* Estimates based on data in thousands of dollars

Table 5. Estimates Based on Specific Question Types* (cont.)

| Respondent and Question Type (number observations) | $C_2$-V(4) | | | $C_2$-R(10) | | | $C_7$-V(5) | | | $C_7$-L(5) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Form Equation | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ |
| $\lambda_1$ | .003 | .0032 | .096 | .110 | .137 | 1.72 | .0053 | .0054 | .15 | .11 | .14 | .44 |
| $\lambda_2$ | | .0008 | .00049 | | .033 | .00004 | | .0053 | .0049 | | .0080 | .000076 |
| $\beta$ | | | 120 | | | 191000 | | | 106 | | | 2424 |
| SSM | 4076 | | | 79 | | | 3585 | | | 31 | | |
| SSR | 98.1 | 88.8 | 6.1 | .96 | .92 | .26 | 1.31 | 1.31 | .015 | 6.2 | 2.5 | .036 |
| $R^2$ | .976 | .978 | .999 | .988 | .988 | .977 | .9996 | .9996 | .9999 | .70 | .88 | .998 |
| Significance Level | .25 | .17 | | .025 | .005 | | .025 | .01 | | .01 | .01 | |

| Respondent and Question Type (number observations) | $C_{6s}$-V(7) | | | $C_{6s}$-L(4) | | | $C_{6f}$-V(4) | | | $C_{6f}$-L(4) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Form Equation | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ | CAR | $SC_1$ | $SC_2$ |
| $\lambda_1$ | .0030 | .0030 | .0031 | .0063 | .0075 | .019 | .005 | .061 | .4 | .042 | .054 | .129 |
| $\lambda_2$ | | .0030 | .0030 | | .0016 | .00085 | | .016 | .004 | | .0066 | .00056 |
| $\beta$ | | | 11.2 | | | 377 | | | 70 | | | 130 |
| SSM | 6524 | | | 1719 | | | 1837 | | | 53 | | |
| SSR | 6.7 | 6.7 | 6.7 | 135 | 132 | 117 | 18.3 | 15.7 | 3.7 | 29.4 | 15.1 | 2.0 |
| $R^2$ | .9990 | .9990 | .9990 | .92 | .92 | .93 | .99 | .991 | .998 | .453 | .717 | .962 |
| Significance Level | N | N | | N | N | | .45 | .32 | | .26 | .24 | |

N: Clearly nonsignificant

* Estimates based on data in thousands of dollars

Table 5 shows the results of fitting each form to responses to particular types of questions. Each instance in which a panelist showed risk aversion in answering four or more questions of each of two types is included. On the matter of comparing functional forms, $SCAR_2$ still appears significantly better. One expects lower significance levels as numbers of observations decline. Of the ten tests in Table 5 involving 8 to 12 observations (5 to 9 d.f.), the significance level is higher than .005 in half the cases and .25 at the lowest.

Estimated coefficients do seem to change materially with question type. Tests of the statistical significance of changes in $SCAR_2$ coefficients are reported below. The test used is the conventional F-test for equality of linear regression coefficients. As an example of the calculation, consider $B_2$. If coefficients are allowed to vary, the total SSR is 8.39 (7.3 + .79 from Table 5). If coefficients are restricted, SSR is 18 from Table 4. In linear regression the ratio $\frac{18-8.09}{8.09} \cdot \frac{3}{3} = 1.2$ would be distributed as F with 3 and 3 d.f. and would be significant at the .4 level. This and other cases for which there are a suitable number of observations are summarized in Table 6.

Again, the results of the tests are consistent with suggestions from the charts--there were significant differences in responses to types of questions, but not by all panelists.

Differences in coefficients between respondents for the same question types are of the same order of magnitude as differences in question types, so we judge that these are also statistically significant.

While the good fit of $SCAR_2$ functions is encouraging, it should be kept in mind that our data included only modest possible losses. It seems likely that, for really large losses, the tendency of any SCAR function to become ever steeper as losses increase will not correspond to reality. This needs to be carefully investigated in future studies.

Table 6. Approximate Significance of Effects of Question Types

| Respondent | df | F-value | Level of Significance |
|---|---|---|---|
| $B_2$ | 3,3 | 1.2 | .4 |
| $B_5$ | 6,15 | 2.4 | .08 |
| $B_7$ | 3,11 | 2.1 | .15 |
| $C_1$* | 3,10 | 2.1 | .16 |
| $C_2$* | 3,9 | 18.6 | .005 |
| $C_{6s}$ | 3,5 | .1 | .95 |
| $C_{6f}$ | 3,2 | .04 | .95 |
| $C_7$ | 3,4 | 26.1 | .005 |

* To avoid extensive recomputing, the one L observation for $C_1$ and $C_2$ was treated as a V and SSR for V increased proportionally from .59 to .71 for $C_1$ and 6.1 to 7.6 for $C_2$.

## V. Review of Results

Although the impressions and results reported in Sections III and IV do not justify firm conclusions about properties of farmers' utility functions, it is the writers' view that serious evidence is offered which should be combined with other evidence in making practical judgements about agricultural producers' behavior and should be taken into account in planning future studies.

Two kinds of future empirical studies are immediately suggested by the present experience. The maintained hypotheses of this study that risk aversion characterizes most important business decisions of individual entrepreneurs and that absolute risk aversion decreases with wealth should be checked. One way would be to study actual business decisions with enough background information on the decision-maker's total prospect to be sure that the investigator can correctly interpret observed decisions. For farm entrepreneurs this suggests a number of intensive studies. For financial reasons and availability of qualified researchers' time, this would probably involve just a few farmers at the outset. These would be case studies directed toward the indicated primary objective.

The other type of studies clearly needed are sampling studies with enough entrepreneurs in a given sample to assure reasonable representativeness of a chosen class of entrepreneurs. Samples should be chosen to assure reasonably strong statistical inferences about characteristics of the chosen population.

Obtaining reliable indications of properties of utility functions for large groups of entrepreneurs clearly poses severe interviewing difficulties. One must obtain highly personal information and be sure that it is validly interpreted. Respondents must be induced to make careful calculations at some psychological cost without the prospect of high personal gains. On the whole it seems that large-scale sampling for utility measurement might well be postponed until further case studies and smaller sampling studies produce further experience and some validation of interviewing procedures.

The present study falls in-between these types. More farmers were interviewed than could be studied intensively with available resources. A sample of 13 farmers is not large enough to reliably establish characteristics of an interesting class of entrepreneurs. In retrospect, however, there were offsetting advantages in the size of the panel. A number of interviews could be held with each respondent. The two researchers were able to conduct all of the interviewing. Some farm and personal characteristics of individuals could be recalled from one visit to another. It was not necessary to structure the interviews as rigidly as would have been the case with a large panel.

Though not to be regarded as conclusive, the results look worthwhile. The good fit of $SCAR_2$ functions is striking and certainly justifies further trials with this form. The good fit also lets one hope that use of non-optimal statistical techniques has not produced huge errors and biases. The estimated utility functions may be pretty good approximations for these particular farmers.

The study provides substantial additional evidence for diminishing absolute risk aversion by individuals. As utility concepts for corporations and other institutions are sharpened, comparisons will be interesting.

The principal discouraging result in the authors' view is the large number of risk preferred and risk neutral responses. This has been primarily explained as failure of the interviewers to elicit a careful calculation. As noted in Section III, some such answers should be expected when stakes are low and in situations in which financial considerations do not sufficiently dominate the respondent's motivation. If, however, risk aversion is characteristic of most entrepreneurs' business decisions, stakes of $5,000 to $50,000 should not be required to bring it out. This has to be restudied using case studies of actual decisions and different interviewing designs and techniques. Large stakes and possible losses can be introduced earlier. Perhaps enough can be learned about other prospects to use business-related questions. Respondents can be asked to rationalize their indicated decisions after which questions designed to check the rationalizations can be employed. This should be an interesting and productive area of future research.

Another slightly disconcerting result was that question type seemed to matter as much as it did (Table 5, 6). However, in this study, question type was confounded with size of stake, possibility of loss, and time of questioning, so a variety of interpretations are possible. Some future interviews should be designed to separate effects of these possible influences.

Another aspect of this type of research that needs further development is the statistical. Additional forms for the utility function should be studied. Knowles [24, p. 147] did fit logarithmic ($\psi(x)=\log(x+\gamma)$) and power ($\psi(x)=(x+\gamma)^{\delta}$) functions to the data from R questions. For both cases the function has no practical interpretation for $x < -\gamma$. Of his eight estimates of $\gamma$(for $B_5$, $C_1$, $C_2$, $C_{5p}$) the range was $1,000 to $44,600. All but one were below $10,000. These limits are just too small to serve as good representations for the chosen panel. Modifications should be developed for future studies.

Methods of statistical inference for this kind of work also need to be reconsidered.

Recall that the estimates and tests of Section IV were carried out using methods from linear least-squares analysis. If response errors, x-w, are normally distributed, the estimates are maximum likelihood and the tests, though not exact, may not be too bad. However, if our presumptions of upward sloping, concave utility functions are correct, a bounded error in the responses may be a more reasonable presumption. In the case of a V question, recall that

(5.1) $.5\,\psi(y_1) + .5\,\psi(y_2) = \psi(w)$ and let $y_1 < y_2$.

Then

(5.2) $\psi' > 0 \Rightarrow w > y_1 \qquad \psi'' < 0 \Rightarrow w < \frac{y_1+y_2}{2}$

If these constraints are recognized by the respondent, his response x will also satisfy

(5.3) $y_1 < x < \frac{y_1+y_2}{2}$

and the error, x-w, will be bounded. It seems reasonable that w might be the mode of the distribution of x and that the density f(x) would satisfy

(5.4) $f'(x) \overset{s}{=} (w-x) \qquad y_1 < x < \frac{y_1+y_2}{2}$

where "$\overset{s}{=}$" means "equal in sign."

Two possible probability densities for x that satisfy (5.3) and (5.4) are a triangular

(5.5)
$$\begin{aligned} f(x) &= \frac{4\,(x-y_1)}{(y_2-y_1)(x-y_1)} & y_1 \le x \le w \\ &= \frac{4\,(y_1+y_2-2x)}{(y_2-y_1)(y_1+y_2-2w)} & w < x < \frac{y_1+y_2}{2} \\ &= 0 & \text{elsewhere} \end{aligned}$$

and a beta density (see Johnson and Klotz [19]),

(5.6)
$$f(x) = \frac{1}{B\,(r+1,\ rk+1)} \quad \frac{(x-y_1)^r\,(\bar{y}-x)^{rk}}{(\bar{y}-y_1)^{r+rk+1}} \qquad y_1 < x < \bar{y}$$

where B is the beta function and

$$r > 0$$

$$\bar{y} = \frac{y_1+y_2}{2}$$

$$k = \frac{\bar{y}-w}{w-y_1}.$$

A researcher could obtain maximum likelihood estimates of parameters of a utility function using either density. With a given sample ($y_{1t}$, $y_{2t}$, $x_t$ t=1..T) and trial values of the parameters (also r in (5.6) when using the beta density) the $w_t$ could be obtained from (5.1). This would permit calculating the likelihood (or log likelihood) for the trial parameters and one could then iterate for ML estimates. Testing and/or Bayesian statistical analysis would be further challenges. Note that the problem of heteroscedastic disturbances (Section IV, p. 36) would be resolved because a variance appropriate to the observed $x_t$ and the estimated parameters of $\psi$ would be ascribed to each response error.

For an L question, (5.1) would be replaced by

$$.5\ \psi(z-w) + .5\ \psi(-w) = \psi(0)$$

and (5.3) by

$$Q<x<\frac{z}{2}$$

For R, we have

$$(*)\ .5\ \psi(y_1) + .5\ \psi(y_2) = .5\ \psi(z) + .5\ \psi(w)$$

If $z>y_2$, this leads to

$$y_1 + y_2 - z<x<y_1.$$

If $y_1<z<y_2$, than

$$y_1<x<y_1 + y_2 - z$$

If $z<y_1$, then

$y_1 + y_2 = z<x$ and there is no general upper limit for x. If $\psi$ is bounded from above, (*) may then have no solution.

Appendix I

Empirical Studies of Utility: A Review

The earliest attempts to elicit utility functions were conducted in an experimental situation involving small but real wagers. One of the first major experiments was done by Mosteller and Nogee [27], in which the concept for the experiment grew out of an article and discussions with Friedman and Savage [9]. The procedure used by Mosteller and Nogee was to present the subject with a poker dice hand which they would have to beat in order to win. The subject was given an amount that could be won from the gamble with the choice of refusing to bet, and receiving nothing or paying 5¢ to accept the bet. The procedure is known as the Von Neumann-Morgenstern lottery. The payoff for the gamble was adjusted and the subject could only choose to accept or reject the gamble. No indifference point was elicited. Since an indifference amount was not directly elicited, an operational definition of indifference was used. Mosteller and Nogee describe their procedure for calculating the indifference point.

> For each hand a range of offers had been made. The proportion of times the subject elected to play each offer was calculated, and these points were plotted on ordinary arithmetic graph paper with the vertical axis as percent participation and horizontal axis as amount of offer in cents. A freehand curve or a broken-line curve was then fitted to these points. The abscissa value of the point where this curve crossed the 50 percent participation line gave in cents the subjects' indifferences offer for that hand. In other words, for that hand this calculation yielded an interpolated offer which the subject would be equally likely to accept or reject if given the opportunity (p. 383).

For each of a series of offers x, they inferred the inequality

$$(1-p)\psi(-5) + p\psi(x) > \psi(0)$$

if the bet was accepted and

$$(1-p)\psi(-5) + p\psi(x) < \psi(0)$$

if the bet was rejected.

The interval of offers for which a bet was sometimes taken and sometimes not, was called the zone of inconsistency. This would imply a utility function that was probabilistic in some sense.

Seven different poker dice hands were presented with different offers and over more than one session. For each indifference point calculated through their procedure a utility index can be assigned to each of the seven indifference offers by knowing p and setting $\psi(0) = 0$ and $\psi(-5¢) = -1$. The values can be arbitrarily set as long as $\psi(-5¢) < \psi(0)$. The nine points of the utility function were plotted and a freehand or broken line utility function was drawn.

With this utility curve for each subject, predictions were made for more complicated gambles. Their predictions, based on the measured utility functions, are of the form that if expected utility is positive, the gambles will be taken more than 50 percent of the time. The predictions were, in general, reasonable but not as good as they had hoped.

Among the criticisms and comments Mosteller and Nogee make about their own study is the lack of uniformity of experience that the subjects had. Since the dice were not rolled when a subject refused to play, the number of times a subject saw a particular hand played depended on the participation rate of himself and those in his group. What effect this would have on the results is not entirely clear. However, the implication would seem to be that the zones of inconsistency would be affected (decreasing with increased experience). When the more complicated risk-taking bets were used to check the adequacy of their estimated utility function, the zones of inconsistency increased. Lack of uniformity of experience may also have had some affect on the assumption of subjective probability and objective probability being equal. Even though the objective probabilities of beating a particular poker dice hand were given, the subject may have revised this according to the number of times he experienced that particular hand and the outcomes.

Other comments that Mosteller and Nogee made are interesting and yield some important insights. Though the use of actual money gambles may have made the experiment more realistic, the triviality of the sums involved raise some doubt as to whether there was enough incentive to provide responses that would reflect the type of decisions that would be made in a practical setting.

Another early study is reported in Davidson, Suppes, and Siegel [4]. This study was an effort to improve upon the Mosteller and Nogee experiment and, consequently, measured both utility and subjective probability following an outline developed by Ramsey [30]. The experiment was designed to avoid any possible bias due to utility of gambling by presenting the decision-maker with two lotteries rather than a choice between a lottery and a certain prospect. In addition, several devices were tested for finding one that generated a chance event whose subjective probability was 1/2. After rejecting both a coin and standard die, a die with nonsense syllables was finally used. Presumably the dice used in the Mosteller and Nogee experiment may have had a subjective probability for individual decision-makers that differed from the stated mathematical odds of fair dice.

Having found a chance event with subjective probability of one-half, the particular form of the experiment allows one to find points that are equally spaced in utility. The first game presented to the subjects involved a choice between a standard lottery and a lottery that was equivalent to a certain prospect because both outcomes of the lottery were the same. This was necessary in order to present the subjects with lotteries in subsequent games that allowed for the possibility of both financial losses and gains and yet allowed for the construction of a utility index. However, in the experiment the subject was required to choose one option or the other and there was no direct interpretation for indifference. Bounds on the indifference amount were elicited. One could consider using a statistical definition of indifference as Mosteller and Nogee did. However, as Davidson, et. al., report, this was not feasible:

> The fact is that our subjects responded with nearly 100 percent probability with respect to all offers presented then, i.e., once they chose a given option over another, they consistently held to this choice, and did not change their minds when the same two options were subsequently presented together. The primary reason for this kind of response is no doubt the relative simplicity of the offers. Mosteller and Nogee, using the much more complicated game of poker dice to generate chance events, did get a distribution of responses. A second reason for this constancy of responses we obtained is probably the relatively high ratio of one cent to the amounts of money used to make up the offers. Finally, we remark that we gathered the data relevant to determining a subject's utility curve over a period of about two hours, rather than a period of months as is the case of the Mosteller and Nogee experiments (1957, p. 41).

The Davidson, et. al., study used a system of inequalities to approximate perfect measurement, where the perfect measurement should be between the upper and lower bounds that are elicited. They note that the error in measurement from the perfect measurement accumulates as successive points are determined. This problem of accumulating errors will exist whenever there is not perfect measurement and a utility index is set up which depends on previously elicited points (see Knowles [24], Appendix 5.2).

In summarizing their results, they report that for the 19 subjects they interviewed all of them satisfied the hypothesis regarding the existence of a chance event with subjective probability of one-half. For 15 of the 19 subjects, their behavior was consistent enough to satisfy the hypothesis leading to a utility function that was unique up to a linear transformation. For some subjects they redid the interviewing after a few days to several weeks and found little change in the responses. However, they do point out that the checks for transitivity that they did omit should have been run and there were some checks that did fail, but were recomputed. While these subjects failed to be consistent in every response, in general, they were consistent. Of the four subjects who failed in their responses to have their utility measured, two were particularly averse to gambling. The other two were very tense during the experiment and were aware of their erratic responses. They state that it would "be very interesting to explore possible connections between 'rationality' in decision-making of the sort tested here and other personality traits" (1967, p. 194).

For most subjects the utility curves were not consistent with a linear utility function and, in fact, resembled the type of curve hypothesized by Friedman and Savage. Among the criticisms they had for their own study, one was that the method elicited points that were equally spaced in utility and that a set of alternatives could not be determined in advance. Closely related offers are made from one offer to the next and sometimes subjects realized that there was a predetermined system from one game to the next. They note that:

> A method which, while retaining the merits of the present approach, allowed the utility measurement of alternatives chosen in advance would have clear advantages: it would apply to alternatives other than amounts of money; the same offers could be made to all subjects; the offers could be given in a random sequence; the experimenter would be relieved of the necessity of performing calculations during the experiment; and (equally important) the experimenter would not know, at the time the decisions were made, what decisions a subject should make to verify the theory (1967, p. 204).

The method used in our study did have the advantages that Davidson, et. al., stated as desirable. In fact, the amounts chosen in the Von Neumann-Morgenstern questioning were predetermined. Moreover, the parameters of the utility function could be estimated without constructing a utility index.

The use of actual money wagers has been used in some other studies since the Davidson, et. al., study. One of these is by Becker, DeGroot, and Marschak [2]. They used a method similar to Mosteller and Nogee, the Von Neumann-Morgenstern method, but with some changes. They elicited certainty equivalent amounts and did not use a statistical definition of indifference. However, they did have a check on the subjects' consistency in which repeated estimates of the same points on the utility curve were elicited. This was accomplished by eliciting successive midpoints in utility by using probabilities of one-half. The method proceeded by selecting two endpoints and eliciting a midpoint. Then by using the midpoint and one of the endpoints, quartile points could be elicited. Finally, both the quartile points were used, which for the subject that was consistent in his choices, the original midpoint value would be elicited. They found that for four consistency checks most of the differences between the midpoints that should have been equal were non-zero.

Strictly interpreted this violates the expected utility hypothesis. They did make an important observation, though:

> It should also be noted, however, that the differences in prices decrease, on the average, from session to session, indicating that behavior does become, in some sense, more consistent with an expected utility model as the subject becomes more familiar with the task. Thus, despite the fact that the model does not precisely fit the behavior of the subjects, there is some indication that it approximates such behavior and that the model becomes more appropriate as the subject becomes more familiar with the experiment (p. 230).

Although the experimental methods with real rather than hypothetical rewards and losses for measuring risk preferences have for the most part been abandoned by researchers in economics, a recent study by Binswanger [3] merits some discussion. The study was conducted in the semi-arid, tropical areas of India. Initially, there was an attempt to use a hypothetical situation and elicit certainty equivalents in a method similar to that used by Dillon and Scandizzo [6], who used simulated farming problems.

Attempts were made to make the questions meaningful in terms of the farmers own experience, although the exact wording of the interviews is not given. However, Binswanger found large inconsistencies which he attributed to investigator bias, preferences for other activities, and learning difficulties of the farmers, many of whom were illiterate. It is difficult to say what caused many of the problems Binswanger encountered without knowing more details of the interviews. However, questions that are too elaborate in order to be more meaningful have many potential problems. The problem due to the correlation of the hypothetical situation and the initial prospect is present. The fact that other objectives and attributes of the farmers' utility functions entered into the response suggests that the question dealt with more than just financial considerations.

Given the interviewer bias and instability of results relative to experimental games, Binswanger opted for the experimental approach in which actual choices are observed rather than hypothetical decisions which may have never been seriously contemplated. One important aspect of the Binswanger study was to let subjects make several choices over a six-week period which allowed them to become familiar with the game and to reflect upon their choices. Nevertheless, there are a number of problems with this study, many of which have been cited in earlier studies. While the choices made are real, the circumstances are contrived. The situation resembles more casino-like gambling than it does a real world decision. Moreover, "the gambling was limited so that the worst possible outcome was a zero gain, and it thus involved gifts to the respondent" (p. 396). Despite reliability tests that suggested the behavior with gifts was not significantly different when the respondent was given the money of the certainty game a day ahead and then asked to choose, the realism of such games is questionable. However, the results of Binswanger and from our study are strikingly similar with much of the hypothetical questioning that involved hypothetical gifts.

Binswanger observed some phenomena that have been noted previously; in particular the effects of learning and experience. After a number of experimental games had been performed at trivial levels, hypothetical questions were introduced at higher payoff levels before proceeding to the main experiment. These hypothetical questions were used throughout the sequences of games at different payoff levels. While at the early stages the choices from the hypothetical questions differed from the choices of the actual gambles, as the sequence proceeded, this difference decreased. He also notes that there may have been some problems with the personal probabilities that the respondents had for the outcomes of a flip of a coin, especially given the personal experiences an individual respondent may have had.

One of the principle results of the Binswanger study was that as the level of payoffs in the game rose so did risk aversion, as defined by partial relative risk aversion.[1/] Zeckhauser and Keeler [37] note that decreasing risk averse utility functions that also exhibit non-decreasing relative risk aversion displays increasing partial relative risk aversion. They also note that in choices involving gains as presented in the V and L questioning with no losses, that partial relative risk aversion is increasing if $x/y_2$ is a decreasing function of $y_2$. For the risk averse responses we do observe this to some extent for all individuals except B-3, C-6s and C-2, although it is not as striking or persistent as the downward drift in $\lambda$ shown in the charts. The Binswanger study also showed a decrease in observations in the risk neutral-to-preferred classes as the game level rose. This is consistent with the large number of non-risk averse responses at very low levels in the V and L questioning.

Despite some renewed interest in the experiment method, there are some major problems with it that have led many researchers to reject it as a viable means of measuring risk preferences. First, the experiments have often been carried out with amounts that are trivially small. Moreover, the experiment is usually set up so that the subjects will average out as gainers and not losers. Subjects who realize this may treat their winnings as non-permanent "funny money" rather than their own. Funding to support games at realistic levels does not appear to be available at the present time. If it were, there would exist the problem of interpreting the wealth prospects of the subjects which will change from game to game.

Second, though we observe actual choices, we observe them under artificial and contrived circumstances. The subjects seem to need to go through a learning process that is quite unfamiliar to some. It is difficult to make strong inferences or generalizations about real world risk attitudes from information gathered under laboratory experiments. Nevertheless, the Mosteller and Nogee study along with Davidson, et. al., study are two of the most important studies to be done in this area. Yet they have been largely ignored by agricultural economists even with a renewed interest in experimental methods. Studies that have been done since the 50's have been refinements on their methods using hypothetical situations rather than actual lotteries in which payoffs have been exchanged.

Studies using hypothetical choices have been reviewed quite extensively elsewhere (see Keeney and Raiffa [21]; Hull, Moore, and Thomas [18]; and in agricultural economics, Young [36] and Knowles [24]). However, there are a few important comments that should be made. The framing of the hypothetical questions is very critical so as to avoid potential sources of bias in the responses. If the questioning is too abstract, the subject may have difficulty understanding or relating to the problem. On the other hand, attempts to make the questioning more elaborate and realistic to make it easier for the subject to respond may do more harm than good. Extraneous considerations may be introduced into the problem so that responses do not reflect just risk preferences, but other preferences as well. Moreover, the questioning may be framed in such a way that the hypothetical venture is correlated with the subject's initial or current prospect so that responses reflect not only risk preferences, but also the joint distribution between the hypothetical venture and the current prospect (see Hildreth [14] and Hildreth and Tesfatsion [17]). The questioning in the present study was posed so as to be statistically independent of other contingencies.

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1/ Definitions for absolute, relative, and partial relative risk aversion are respectively:

$$A(w) = -\psi''(w)/\psi'(w)$$
$$R(w) = -w\,\psi''(w)/\psi'(w)$$
$$P(w,y) = -y\,\psi''(w+y)/\psi'(w+y)$$

Where w is wealth and y is gain.

This appears to have been a problem in a number of studies. Grayson [11] interviewed small independent oil wildcatters and presented each with a hypothetical drilling venture in a method similar in many respects to the Mosteller and Nogee method. In his method, the probability of a successful drilling venture was varied until indifference between accepting or rejecting the venture was achieved. While Grayson reported that many individuals had difficulty dealing with the probabilities in the hypothetical decision, especially when the probability of success was much higher than they faced in real life, the consideration of other contingencies may also have affected the responses. The responses then would reflect not only risk preferences, but the correlation of the hypothetical drilling venture and these prior contingencies as well. Grayson remarked that:

> (One) difficulty was the attempt by operators to keep introducing other facets of the venture. Despite the instructions, an operator might ask, "Who gets the intangibles? Is it an isolated area? Am I the operator? Is it gas or oil?", etc.
>
> I explained that these considerations could, for the most part, be incorporated into the payoff or investment figures. But, where this was not possible, they were instructed to assume that such factors were satisfactory. Most were able to proceed after this reinforcement [p. 317].

It would appear that the subject's responses to the questioning that Grayson presented depended on their current business and operations. Their request for more information would be a desire to find out how these ventures would affect or be correlated with their initial prospect.

This was a potential problem in a study by Swalm [34] as well, who interviewed corporate executives using the Von Neumann-Morgenstern approach by eliciting certainty equivalents. In drawing the utility curves freehand, Swalm found some disturbing results, among them was a consistent pattern of sharp slopes in the negative quadrant (where $\psi(0) = 0$). Points in the positive quadrant tended to fall on a smooth, continuous curve while those in the negative quadrant did not. Swalm believed that "this might be due to control procedures that bias managers against making any decision that might lead to a loss" (p. 134). The questioning may also give us further clues. A sample question given by Swalm for losses is:

> Suppose your company is being sued for patent infringment. Your lawyer's best judgment is that your chances of winning the suit are 50/50; if you win, you will lose nothing, but if you lose, it will cost the company $1,000,000. Your opponent has offered to settle out of court for $200,000. Would you fight or settle? (p. 131)

Swalm reported that if the respondent had trouble envisioning this problem or had a special reaction to it, the question was put in a different context, but with the same money figures. This questioning has a number of inherent problems. A multiple objective utility function may be the appropriate means of analyzing this situation. A lawsuit may affect other objectives or goals of the firm, win or lose. Bad publicity from a lawsuit may not only affect other objectives but also have an affect on the initial prospect. A lost suit may have an adverse affect on existing or current corporate sales, especially if a large portion of sales go to the public vis-a-vis other businesses. Besides current sales there may be a secondary affect, resulting in future gains or losses. There may be a steady loss of business due to the lawsuit. Other actions or payments may be conditional upon the outcome of the lawsuit. While questioning of the type Swalm used offers a realistic and motivating hypothetical situation for subjects to respond it, it may actually be a Pandora's box in disguise.

A study of Officer and Halter [28] in an agricultural setting using the Von Neumann-Morgenstern method and the Ramsey method may have had biased responses due to other contingencies involved in the decisions. Officer and Halter report that the questions were framed in terms of single-person games against Nature, but in such a way so as to imply a fodder reserve context, admitting in a footnote that this was done purposely "because keeping fodder reserves may include other virtues not accounted for in the mean and standard deviation of the different fodder reserve levels" (p. 264). While the derived utility functions may be good for predicting decision-making under uncertainty regarding fodder reserves, the initial prospect problem will result in estimated utility functions with a bias and, therefore, not very good in analyzing other types of decisions under uncertainty.

The study by Lin, Dean, and Moore [25] set out to test if utility maximization explained actual behavior better than profit maximization. The conclusion was that it did, although it did not predict actual behavior all that well. In this study the Ramsey method was used, modified somewhat from the Officer and Halter study, to estimate utility functions. Six large-scale California farms were used in the study; four partnerships and two corporations. In the use of the Ramsey method, the decision-makers were asked to play a series of nine "games against nature." The payoffs in the Ramsey method were presented as net farm income (i.e., net of taxes) and the two equally likely states of nature were explained as "favorable" and "unfavorable" economic conditions. This phrasing may have been innocuous; however, there may have been the initial prospect problem (see Knowles [24], Appendix 2.1). While the response may have been given quicker with this sense of realism, the responses may or may not have been biased.

In the present study we have dismissed risk neutral and risk lover responses as not accurately reflecting a decision-makers' true preferences. Yet, many other studies have observed these preferences (see Young [36]). What explanation is there for risk lover preferences in these other studies? There are a number of possible reasons. First, there is the initial prospect problem discussed above in connection with elicitation using hypothetical ventures. The example in Knowles ([24], Appendix 2.1), shows how a decision-maker with an underlying risk averse utility function, responds as a risk lover due to the correlation of the hypothetical venture and initial prospect (see also the example in Section II, pages 8-10). However, a recent study of Halter and Mason [12], did not appear to have this problem of other contingencies yet reported that their panel was equally distributed among risk averse, neutral and preferring classifications. However, the hypothetical ventures in Halter and Mason involved sure windfall gains. The disappearance of risk preferring responses occurs under one of two conditions. First, for ventures in which all outcomes are non-negative as the level of possible gains increase, risk preferring responses decrease. This was observed in the present study (see Table 3, p. 10) and by Binswanger. Second, when ventures contain both losses and gains, risk preferring responses may disappear entirely. In the present study, the Ramsey questions involved losses. No risk preferring responses were observed. A study by Spetzler [33] in which he interviewed executives of one company, investments with success and failure were presented and no risk preferring responses were observed here either. Most of the studies that report risk neutral or risk preferring decision-makers have not met one of these two conditions in presenting choices to the decision-makers.

There is also a problem with the methods of estimating the utility functions in a number of the studies discussed above. The principle methodology has been to construct a utility index from the responses and to regress this index on a polynominal functional form. The indexing procedure has a number of inherent problems due to the compounding of errors. This was noted by both Davidson, Suppes, and Siegel and by Spetzler. It is noted in Knowles ([24], Appendix 5.2) that even when the errors are independent and identically distributed, the error term using the utility index as the dependent variable will be autocorrelated and heteroscedastic. Furthermore, in estimating the utility function of farmer C-5 with just the Ramsey data, where no risk preferring responses were observed, and using the utility index method, a risk preferring utility function was estimated (see Knowles, Appendix 5.4). Spetzler, who recognized the compounding problem of the utility index procedure, used a different indexing procedure in which the errors were not compounded. However, his parameter estimates depend on the indexing scale, as is shown in Knowles (Appendix 5.5). Indexing the utility function is troublesome and may lead to false conclusions. Therefore, studies using the indexing procedure to estimate utility should be viewed with some skepticism.

The fitting of polynomials to elicited data is also troublesome and is discussed by Hildreth [15]. Fitting cubics has sometimes resulted in risk-preferring ranges as reported by Young. For these reasons the use of polynominal utility functions was rejected in the present study.

A study by King and Robison [23], offers some interesting alternatives to measure risk preferences. They implement stochastic dominance with respect to a function to elicit upper and lower bounds on the absolute risk aversion functions. Their method offers the decision-maker a choice between two distributions with six equally likely outcomes.2/ Assuming that a CAR function approximates the risk preferences over the range of outcomes, preferring one distribution over the other will put an upper or lower bound on the risk aversion function, depending on which distribution is chosen. The method is performed over a number of income ranges. While the method has some definite advantages and should be considered in future research, there are some problems which should be noted. The number of outcomes in the distribution should be limited so as not to confuse the decision-maker and allow a careful calculation. Some decision-makers may respond better to distributions with less than six outcomes. The distance between the upper and lower bounds on the risk aversion functions seems to be important. If the bounds are far apart they will not be useful because a large class of functions for preferences will be consistent with the bounds. However, if they are too close together one may be better off using more traditional methods because more precision may involve more choices and increase the likelihood of miscalculation on the part of the decision-maker. Some careful restructuring of their experiment may avoid some of these problems and yield fruitful insights.

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2/ If one of the outcomes were varied to achieve indifference between the two distributions, a modified Ramsey method would result and utility functions could be estimated directly.

Finally, a recent and important contribution by Schoemaker [31] offers some contrasting viewpoints for economists to consider. His book notes a number of violations to expected utility theory, both from his own research and the research of others. In particular the concept of the rational-economic man is questioned, especially from the research by psychologists. He states that "this book hopes to shift research and thought on economic questions of value, preference, and risk in the direction of psychology, in particular toward information-processing views. The research will show that current economic theory is inadequate in accounting for observed laboratory behaviors" (p. 3). The objective of the study is to identify conditions under which expected utility provides an approximate description of decision-making. The concept of bounded rationality is emphasized in Schoemaker's study in which "at best, we can expect people to behave rationally within the framework of their knowledge and subgoals" (p. 38). Empirical evidence by psychologists, which showed systematic violations of the axioms of expected utility theory, has led to a consideration of biases, heuristics, and other alternative descriptive theories (see also Kahneman and Tversky [20]). One of the primary assumptions here is that if expected utility is to hold in the real world, it must also hold in a laboratory or controlled setting (p. 8). However, it is because of bounded rationality that this may not be true since the laboratory setting offers decisions that are contrived, unfamiliar, and perhaps very complex that would lead to what Schoemaker refers to as a high degree of cognitive strain that results in the use of heuristics and other decision rules that violates expected utility theory. Furthermore, a laboratory setting may not offer comparable incentives with real world decisions. However, an important assumption made by Schoemaker is that "different motivational (and other) conditions between the laboratory and the real world do not impact in essential ways on the cognitive processes underlying people's decision making"(p. 8). This is a crucial assumption for most experimental work in the social sciences that is rarely made explicit and even more rarely actually tested. Choices made in the laboratory are either hypothetical or real but contrived and whether the cognitive process is the same here as in the real world is certainly a moot point.

Schoemaker discusses four research studies. The first is a positivistic test of expected utility theory. Since according to the positivistic view a descriptive theory should not (or cannot) be tested by testing the truth of the assumptions, it should be tested according to its predictive power. Refuting the expected utility theorem by refuting an axiom would be an example of the fallacy of denying the antecedent. Different axiom systems lead to the maximization of expected utility (see Fishburn [7]), so that a violation of one particular axiom will not refute the theory. However, it does raise some questions for Fishburn's [8] system where the axioms are necessary and sufficient. Schoemaker's positivistic test elicits risk attitudes over four different intervals and then examines choices made involving preferences made for information in an urn problem that should depend on risk attitudes. He noted that expected utility did not predict better than chance. However, the choices were hypothetical and complex. Lack of motivation and experience may have been a problem.

The next study examined insurance decisions with students and insurance clients. This study highlighted decision-makers limited ability to process information and noted that in the real world insurance is often "not bought but sold." The hypothetical choices presented involved pure loss alternatives. The assumption of risk aversion and the role of context and problem presentation were examined. The assumption of risk aversion was questioned because most individuals preferred insurance coverage on high-probability, low-loss (i.e., low variance) hazards to low-probability, high loss (i.e., high variance) hazards with the same expected value. Those who were better off financially appeared to be more risk averse as well. It is interesting to note though that the insurance clients tended to be older professionals and white collar workers and presumably more experienced with insurance decisions than students (also presumably financially better off). They tended to be more consistent in their responses and the nature of their decision rules tended to be less intuitive and more calculative than the students. They also had more experience with the losses involved in the hypothetical choices.

An important issue with this study dealt with context influences. Mathematically equivalent choices were presented to the subjects, in a gambling context and in an insurance context. The differences in responses were significant. While Schoemaker states that expected utility theory has no explanation for this, the initial or current prospect problem discussed earlier may be present. Choices will reflect not only risk attitudes but also the joint distribution of the hypothetical insurance choice and the current prospect, thus confounding the response. Given the significant effect that the context had on responses, further research should more fully investigate the impact of the dependence of the choices with the initial prospect.

The third study investigated the nature that statistical knowledge had on decisions. Two groups of students were used, one which had some statistical training and another which did not. Evidence from cognitive psychology suggests that "one's ability to process information (perceiving, coding, storing, recognizing, retrieving, etc.) is a function of past experiences and can be improved through learning." Therefore, "it is hypothesized that statistical training constitutes a form of mental training and programming that (1) reduces the cognitive strain associated with probabilistic information processing; (2) increases the quality of risk assessment; and (3) affects the nature of the decision rule in the direction of multiplicative models," (p. 94) which consider probability and value simultaneously rather than additively or separately. A hypothetical duplex gamble was used in this study and in general the findings were consistent with the hypothesis. "Statistically trained subjects appear to find the task considerably easier and to develop decision rules that come closer to normative rules (e.g., maximizing expected utility) than do untrained subjects. The findings support the hypothesis that subjects strike a balance between the quality of the decision rule and the cognitive strain associated with its execution" (p. 108).

The final study Schoemaker considers is an examination of further risk taking in the loss domain and the influence that a gambler's context has on revealed attitudes. The two choice situations involve a lottery with a certainty equivalent and mathematically identical gambles in an insurance context. It was found that the context made a difference and that the insurance formulation led to more risk averse responses. While Schoemaker states that neither expected utility nor the other descriptive theories he discussed can account for this phenomenon, a correlation with the initial prospect appears to be a plausible explanation.

Schoemaker suggests in his epilogue that the findings of his research suggest that some revisions in our beliefs about the expected utility hypothesis are needed. Whether this calls for a new general theory to replace expected utility, as Schoemaker argues, is a conclusion that will meet some resistance. The direction for a general descriptive theory of decision under risk should contain three components according to Schoemaker. The first component should be to model how decisions are framed and represented psychologically. This includes a consideration of aspiration levels and not just final wealth levels.[3/] A better understanding of how aspiration levels vary across individuals, tasks and contents and how the decision is framed is needed.

The second component concerns the psychologically relevant outcome space. This includes context effects, the role of regret, and a redefinition of risk aversion. This essentially involves a consideration of the dimensionality of the outcome space. Finally, the third component concerns the notion and measurement of "basic tastes and preferences." This includes a much more dynamic perspective on tastes and preferences, i.e., how they are acquired, shaped, and modified.

While it is undeniable that the decision theory that economists are interested in can be enhanced and enriched by the influences of psychologists, it would be a mistake to claim that expected utility theory is totally inadequate for our purposes. We need to know to what extent we can extend our knowledge from the laboratory to the real world. Experience would appear to bring about less cognitive strain and increased consistency with expected utility theory. Decision-makers who are engaged in economic decisions for which they have been trained or have developed some experience may be more consistent with expected utility than many experiments may be suggesting. However, inconsistencies must surely occur in the real world, and what impact this has for economic analysis is unclear.

Finally, economists, and in particular proponents of expected utility, have not been unaware of the problems and suggestions that Schoemaker points out. Multiple objective decision theory and the theory concerning the dependence of a venture and current prospect are important in addressing the first two components that Schoemaker discusses. With regard to the third involving the dynamic aspects of tastes and preferences, important insights would be crucial here not in replacing expected utility but in complementing it.

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3/ I believe Menger ([26], p. 224) was one of the first to have noted this.

Appendix II

Notes on Questions Regarding Expectations

While questioning about expectations was not extensive and the responses were not used in the formal analysis of Section IV, it seems desirable to report this experience briefly. Investigators need to pool their results and impressions in this area to design successively more fruitful approaches.

Expectations regarding commodities in which the farmer regularly dealt--feeders, cattle, hogs, corn, wheat, soybeans--for relevant dates in the near future (3 to 15 months) were considered.

Panelists seemed to have good intuitive notions of probability (in a few cases supplemented by formal study) and found it natural to talk of future events in terms of probabilities. Most, however, had some hesitation in expressing their own probabilities. Typically one to three commodity prices on specified future dates were all that could be covered in an interview.

Usually the farmer was first asked what he regarded as the most likely price for a particular commodity in a particular month; for example in March several were asked about the likely price of 250-pound barrows and gilts in January. The reply was either an approximation, e.g., "about $40" or a range, e.g., "around $38-42." The interviewer tried to get answers in a form that would describe properties of a probability distribution. The answer to the "most likely" question was interpreted as giving an approximation to the mode.

An indication of the median was next sought, "Do you think the price is more likely to be above $40 or below $40?" If above, query repeated was for $41. Usually a price was soon found such that the respondent believed higher and lower prices were equally likely. Questioning then took one of two forms. Respondents were asked to assign probabilities ranges of prices, e.g., (37, 41) and (41, 45), or to indicate terciles--the first tercile being a price that was twice as likely to be below the realized price as to be above. Probabilities associated with terciles were sometimes compared to the chance of drawing a white ball from a hat containing 2W, 1B. Exact framing of the question was varied according to the apparent preferences of the panelist, but a tercile question often ended with a positive answer to a question like, "So you think the chance of a price above $38 is about like the chance of a white ball?"

Once respondents started expressing beliefs as probabilities, most appeared interested and seemed to consider carefully, often making several small adjustments in an initial answer. For some commodity and date combinations, agreements among respondents was pretty close. For example, in March, 1977, the five who gave medians for choice steers in July, 1978, gave 48, 50, 50, 52, 52. Their reasons were pretty much the same: herds had been substantially liquidated over the previous two dry years, range conditions had become better so liquidations should stop. The current price was 36.

On the other hand, the seven medians for corn in November, 1977, were 1.80, 2.10, 2.22, 2.25, 2.30, 2.45, 2.50; the current price being 2.40.

The authors were interested in indications of symmetry or asymmetry in the distribution being investigated. Three possible indications of right skewness were: (1) median greater than mode; (2) interval of given length immediately to right of median has lower probability than similar interval to left; and (3) right tail some distance from median has higher probability than corresponding left tail. Distributions were classified as skewed to right if two of the three indications of right skewness were obtained and to left if two opposite indications were obtained. They were classified as symmetric if there were no indications of asymmetry and at least one indication of symmetry, e.g., mode-median. Of 34 classifiable distributions 7 were symmetric, 15 skewed right, and 12 skewed left. This suggests that a model-builder should allow flexibility on this property.

All producers indicated a variety of sources of information--radio, television, newspapers, government, and extension bulletins. Most subscribed to a market news and outlook service.

We had two main reasons for exploring expectations. One was to get some experience and some notions as to whether enough information about distributions might be potentially available to make Bayesian analysis promising. The other was to judge whether or not our interviewing resources would yield enough information to make analysis of real-life decisions a practical possibility in this study.

On the first question, we found farmer's willingness to talk and calculate seriously in probability terms quite encouraging. On the second matter, it quickly became clear that we could not obtain sufficient background on beliefs in this study to analyze real-life decisions well. This and our similar conclusion about information on the panelists' initial prospects led us to turn to asking about the hypothetical decision problems reported in earlier sections.

Appendix III

Table 7

Tabulations of Responses

(entries, except λ, in thousands of dollars: - in λ column indicates risk preference responses)

| Respondent | Question Type | $y_1$ | $y_2$ | z | x | a | λ |
|---|---|---|---|---|---|---|---|
| $B_1$ | V | 0 | .2 | | .1 | .1 | 0 |
| | | 0 | 1 | | .25 | .375 | 2.44 |
| | | 0 | 3 | | 1.3 | 1.4 | .18 |
| | | 0 | 8 | | 3.5 | 3.75 | .063 |
| | | 0 | 15 | | 4 | 5.75 | .15 |
| | | 0 | 20 | | 6 | 8 | .090 |
| | | - .2 | 7.8 | | 2.5 | 3.15 | .18 |
| | | 0 | 1 | | 1 | .75 | - |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 40 | | 20 | 20 | 0 |
| $B_1$ | L | | | 8 | .5 | 1.75 | 1.39 |
| $B_2$ | V | 0 | .2 | | .1 | .1 | 0 |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 3 | | 1.5 | 1.5 | 0 |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 10 | | 5 | 5 | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 20 | | 9 | 9.5 | .020 |
| | | - .2 | 7.8 | | 3.8 | 3.8 | 0 |
| | | 0 | 50 | | 20 | 22.5 | .016 |
| | | 0 | 80 | | 30 | 35 | .013 |
| | | 0 | 120 | | 50 | 55 | .0057 |
| | | 0 | 200 | | 78 | 89 | .0045 |
| $B_2$ | L | | | 50 | 3 | 11 | .23 |
| | | | | 80 | 5 | 17.5 | .14 |
| | | | | 120 | 5 | 27.5 | .14 |
| | | | | 200 | 6 | 47 | .12 |

Table 7 (continued):

| Respondent | Question Type | $y_1$ | $y_2$ | z | x | a | λ |
|---|---|---|---|---|---|---|---|
| $B_3$ | V | 0 | .2 | | .1 | .1 | 0 |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 3 | | 1.5 | 1.5 | 0 |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | | | | | | 0 |
| | | 0 | 20 | | 10 | 10 | 0 |
| | | 0 | 40 | | 15 | 17.5 | .026 |
| | | - .2 | 7.8 | | 3.5 | 3.65 | .038 |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | | | | | | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 40 | | 15 | 17.5 | .026 |
| | | 0 | 50 | | 25 | 25 | 0 |
| | | 0 | 80 | | 40 | 40 | 0 |
| | | 0 | 120 | | 55 | 57.5 | .0028 |
| | | 0 | 200 | | 85 | 92.5 | .003 |
| $B_3$ | L | | | 8 | 2 | 1 | .31 |
| | | | | 50 | 25 | 0 | |
| | | | | 80 | 30 | 5 | .013 |
| $B_3$ | R | 0 | 0 | -1 | 1 | 0 | 0 |
| | | 0 | 1 | -1 | 2 | .5 | 0 |
| | | - 1 | 1 | 2 | - 2 | 0 | 0 |
| | | - 1 | 2 | -2 | 3 | .5 | 0 |
| | | - 2 | 2 | 3 | - 3 | 0 | 0 |
| | | - 2 | 3 | -3 | 4 | .5 | 0 |
| | | - 3 | 3 | 4 | - 4 | 0 | 0 |
| | | - 1 | 4 | -3 | 6 | 1.5 | 0 |
| | | - 2 | 6 | -4 | 8 | 2 | 0 |
| | | - 1 | 8 | -4 | 11 | 3.5 | 0 |
| | | -20 | 20 | -30 | 30 | 0 | 0 |
| $B_4$ | V | 0 | .2 | | .1 | .1 | 0 |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 3 | | 1.5 | 1.5 | 0 |
| | | 0 | 5 | | 2.75 | 2.62 | - |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 20 | | 10 | 10 | 0 |
| | | - .2 | 7.8 | | 3.5 | 3.65 | .038 |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 40 | | 20 | 20 | 0 |

Table 7 (continued):

| Respondent | Question Type | $y_1$ | $y_2$ | z | x | a | λ |
|---|---|---|---|---|---|---|---|
| $B_4$ | L | | | 8 | 3 | | .131 |
| $B_5$ | V | 0 | .2 | | .075 | .088 | 5.22 |
| | | 0 | 1 | | .45 | .025 | .403 |
| | | 0 | 3 | | .6 | .45 | 1.09 |
| | | 0 | 5 | | .8 | .85 | .849 |
| | | 0 | 8 | | 1 | 2.5 | .689 |
| | | 0 | 15 | | 3.5 | 5.5 | .179 |
| | | 0 | 20 | | 4.5 | 7.25 | .141 |
| | | - .02 | 7.8 | | .75 | 2.28 | .727 |
| | | 0 | 50 | | 10 | 17.5 | .066 |
| | | 0 | 80 | | 20 | 30 | .030 |
| | | 0 | 120 | | 20 | 40 | .034 |
| | | 0 | 200 | | 20 | 60 | .035 |
| $B_5$ | L | | | 50 | 10 | 7.5 | .066 |
| | | | | 60 | 20 | 10 | .030 |
| | | | | 120 | 20 | 20 | .034 |
| | | | | 200 | 20 | 40 | .035 |
| $B_5$ | R | 0 | 0 | -1 | 1.5 | .125 | .33 |
| | | 0 | 1.5 | -1 | 4 | 1.125 | .29 |
| | | - 1 | 1.5 | 4 | -2 | .625 | .22 |
| | | - 1 | 4 | -2 | 5 | 1.5 | 0 |
| | | - 2 | 4 | 5 | -2.5 | 1.125 | .10 |
| | | - 2 | 5 | -2.5 | 6.5 | 1.75 | .14 |
| | | - 2.5 | 5 | 6.5 | -3 | 1.438 | .13 |
| | | - 1 | 6.5 | -2.5 | 8 | 2.75 | 0 |
| | | - 2 | 8 | -3 | 11 | 3.5 | .09 |
| | | - 1 | 11 | -3 | 17 | 6 | .07 |
| $B_6$ | V | 0 | .2 | | .1 | .1 | 0 |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 3 | | 1.5 | 1.5 | 0 |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 10 | | 5 | 5 | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 20 | | 10 | 10 | 0 |
| | | - .2 | 7.8 | | 3.6 | 3.7 | .025 |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 40 | | 20 | 20 | 0 |
| | | - 4 | 4 | | 0 | 0 | 0 |
| | | 0 | 50 | | 25 | 25 | 0 |
| | | 0 | 80 | | 40 | 40 | 0 |

Table 7 (continued):

| Respondent | Question Type | $y_1$ | $y_2$ | z | x | a | λ |
|---|---|---|---|---|---|---|---|
| $B_6$ | V | 0 | 120 | | 60 | 60 | 0 |
| | | 0 | 200 | | 100 | 100 | 0 |
| | | 0 | 500 | | 200 | 225 | .0016 |
| $B_6$ | L | | | 50 | 10 | 7.5 | .066 |
| | | | | 80 | 15 | 12.5 | .044 |
| | | | | 120 | 20 | 20 | .034 |
| | | | | 200 | 25 | 37.5 | .028 |
| $B_7$ | V | 0 | .2 | | .15 | .125 | - |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 3 | | 1.5 | 1.5 | 0 |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 10 | | 4.6 | 4.8 | .032 |
| | | 0 | 15 | | 7 | 7.25 | .012 |
| | | 0 | 20 | | 9 | 9.5 | .020 |
| | | - .2 | 7.8 | | 3.5 | 3.65 | .037 |
| | | 0 | 8 | | 3.6 | 3.8 | .050 |
| | | 0 | 10 | | 4.5 | 4.75 | .040 |
| | | 0 | 15 | | 7 | 7.25 | .018 |
| | | 0 | 40 | | 18 | 19 | .010 |
| | | 0 | 50 | | 20 | 22.5 | .016 |
| | | 0 | 80 | | 30 | 35 | .013 |
| | | 0 | 120 | | 45 | 52.5 | .0087 |
| | | 0 | 200 | | 75 | 87.5 | .0052 |
| $B_7$ | L | | | 8 | 3 | .5 | .13 |
| | | | | 50 | 12 | 6.5 | .052 |
| | | | | 80 | 19 | 10.5 | .033 |
| | | | | 120 | 25 | 17.5 | .026 |
| | | | | 170 | 30 | 35 | .023 |
| $C_1$ | V | 0 | .2 | | .12 | .11 | - |
| | | 0 | 1 | | .7 | .6 | - |
| | | 0 | 3 | | 1.7 | 1.6 | - |
| | | 0 | 8 | | 5.4 | 4.7 | - |
| | | 0 | 15 | | 7 | 7.25 | .018 |
| | | 0 | 20 | | 8.5 | 9.25 | .030 |
| | | - .2 | 7.8 | | 3.5 | 3.65 | .038 |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 40 | | 20 | 20 | 0 |
| | | 0 | 50 | | 15 | 20 | .036 |
| | | 0 | 80 | | 20 | 30 | .030 |

Table 7 (continued):

| Respondent | Question Type | $y_1$ | $y_2$ | z | x | a | λ |
|---|---|---|---|---|---|---|---|
| $C_1$ | L | | | 8 | .5 | 1.75 | 1.39 |
| | | | | 50 | 0 | 12.5 | ∞ |
| | | | | 80 | 0 | 20 | ∞ |
| $C_1$ | R | 0 | 0 | - .2 | .5 | .075 | 2.81 |
| | | 0 | .5 | - .2 | .8 | .275 | .541 |
| | | - .2 | .5 | .8 | - .375 | .181 | .576 |
| | | - .2 | .8 | - .375 | 1.1 | .331 | .436 |
| | | - .375 | .8 | 1.1 | - .4 | .281 | 1.87 |
| | | 0 | 1.1 | - .375 | 2 | .731 | .51 |
| | | - .375 | 1.1 | 2 | - .575 | .538 | .75 |
| | | - .2 | 2 | - .4 | 4 | 1.35 | .72 |
| | | - .375 | 4 | - .575 | 5 | 2.01 | .33 |
| | | - .375 | 5 | - .575 | 6.5 | 2.64 | .33 |
| $C_2$ | V | 0 | .2 | | .175 | .138 | - |
| | | 0 | 1 | | .7 | .6 | - |
| | | 0 | 3 | | 2 | 1.75 | - |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 15 | | 6.5 | 7 | .036 |
| | | 0 | 20 | | 10 | 10 | 0 |
| | | - .2 | 7.8 | | 5 | 4.4 | - |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 8 | | 5 | 4.5 | - |
| | | 0 | 15 | | 10 | 8.75 | - |
| | | 0 | 40 | | 25 | 22.5 | - |
| | | 0 | 50 | | 20 | 22.5 | .016 |
| | | 0 | 80 | | 30 | 35 | .013 |
| | | 0 | 120 | | 60 | 60 | 0 |
| | | 0 | 200 | | 90 | 95 | .002 |
| $C_2$ | L | | | 8 | 4 | 0 | 0 |
| | | | | 50 | 25 | 0 | 0 |
| | | | | 80 | 50 | - 5 | - |
| | | | | 120 | 60 | 0 | 0 |
| | | | | 200 | 70 | 15 | .006 |
| $C_2$ | R | 0 | 0 | - .5 | .9 | .1 | .86 |
| | | 0 | .9 | - .5 | 1.5 | .48 | .12 |
| | | - .5 | .9 | 1.5 | - .8 | .28 | .38 |
| | | - .5 | 1.5 | - .8 | 2 | .55 | .21 |
| | | - .8 | 1.5 | 2 | - 1.1 | .4 | .19 |
| | | - .8 | 2 | - 1.1 | 2.75 | .71 | .28 |
| | | - 1.1 | 2 | 2.75 | 1.4 | .56 | .18 |
| | | - .5 | 2.75 | - 1.1 | 4 | 1.29 | .25 |
| | | - .8 | 4 | - 1.4 | 5.75 | 1.89 | .18 |
| | | - .5 | 5.75 | - 1.4 | 7.5 | 2.84 | .088 |

Table 7 (continued):

| Respondent | Question Type | $y_1$ | $y_2$ | z | x | a | λ |
|---|---|---|---|---|---|---|---|
| $C_{5f}$ | V | 0 | .2 | | .175 | .14 | - |
| | | 0 | 1 | | .5 | .5 | 0 |
| | | 0 | 3 | | 1 | 1.25 | .48 |
| | | 0 | 5 | | 2.5 | 2.5 | 0 |
| | | 0 | 8 | | 3 | 3.5 | .13 |
| | | 0 | 15 | | 6 | 6.75 | .055 |
| | | 0 | 20 | | 7.5 | 8.75 | .052 |
| | | - .2 | 7.8 | | 2 | 2.9 | .26 |
| | | 0 | 1 | | 1 | .75 | - |
| | | 0 | 8 | | 4 | 4 | 0 |
| | | 0 | 15 | | 4 | 5.75 | .15 |
| | | 0 | 40 | | 10 | 15 | .061 |
| | | 0 | 50 | | 15 | 20 | .036 |
| $C_{5f}$ | L | | | 8 | .5 | 1.75 | 1.4 |
| | | | | 50 | 5 | 10 | .14 |
| $C_{5s}$ | V | 0 | .2 | | .15 | .13 | - |
| | | 0 | 1 | | .75 | .63 | - |
| | | 0 | 5 | | 2 | 2.25 | .16 |
| | | 0 | 8 | | 4 | 4 | 0 |
| . | | 0 | 15 | | 5 | 6.13 | .036 |
| | | 0 | 20 | | 10 | 10 | 0 |
| | | - .2 | 7.8 | | 3.9 | 3.85 | - |
| | | 0 | 50 | | 15 | 20 | .036 |
| $C_{5s}$ | L | | | 8 | 1 | 1.5 | .69 |
| | | | | 50 | 5 | 10 | .14 |
| $C_{5fs}$ | R | 0 | 0 | - 1 | 1.5 | .13 | .33 |
| | | 0 | 1.5 | - 1 | 2.5 | .75 | 0 |
| | | - 1 | 1.5 | 2.5 | - 1.75 | .313 | .085 |
| | | - 1 | 2.5 | - 1.75 | 3.5 | .813 | .066 |
| | | - 1.75 | 2.5 | 3.5 | - 2.5 | .438 | .056 |
| | | - 1.75 | 3.5 | - 2.5 | 4.5 | .94 | .047 |
| | | - 2.5 | 3.5 | 4.5 | - 3.5 | .5 | 0 |
| | | - 1 | 4.5 | - 2.5 | 6 | 1.75 | 0 |
| | | - 1.75 | 6 | - 3.5 | 8 | 2.19 | .014 |
| | | - 1 | 8 | - 3.5 | 10.5 | 3.5 | 0 |
| | | -20 | 20 | -30 | 30 | 0 | 0 |
| | | -10 | 20 | -20 | 30 | 5 | 0 |

Table 7 (continued):

| Respondent | Question Type | $y_1$ | $y_2$ | z | x | a | λ |
|---|---|---|---|---|---|---|---|
| $C_{6f}$ | V | 0 | .2 | | .14 | .12 | - |
| | | 0 | 1 | | .55 | .53 | - |
| | | 0 | 3 | | 1.6 | 1.55 | - |
| | | 0 | 8 | | 4.5 | 4.25 | - |
| | | 0 | 10 | | 5.7 | 5.35 | - |
| | | 0 | 15 | | 7.7 | 7.6 | - |
| | | 0 | 20 | | 11.2 | 10.6 | - |
| | | - .2 | 7.8 | | 4.2 | 4 | - |
| | | 0 | 50 | | 20 | 22.5 | .016 |
| | | 0 | 80 | | 35 | 37.5 | .006 |
| | | 0 | 120 | | 50 | 55 | .006 |
| | | 0 | 200 | | 78 | 89 | .005 |
| $C_{6f}$ | L | | | 50 | 9.8 | 7.6 | .067 |
| | | | | 80 | 14.5 | 12.8 | .046 |
| | | | | 120 | 16 | 22 | .043 |
| | | | | 200 | 20 | 40 | .035 |
| $C_{6s}$ | V | 0 | .2 | | .12 | .11 | - |
| | | 0 | 1 | | .6 | .55 | - |
| | | 0 | 3 | | 1.75 | 1.63 | - |
| | | 0 | 8 | | 3 | 3.5 | .13 |
| | | 0 | 10 | | 3 | 4 | .18 |
| | | 0 | 15 | | 6.5 | 7 | .036 |
| | | 0 | 20 | | 9.5 | 9.8 | .010 |
| | | - .2 | 7.8 | | 2.9 | 3.4 | .117 |
| | | 0 | 50 | | 29.5 | 27.3 | - |
| | | 0 | 80 | | 50 | 45 | - |
| | | 0 | 120 | | 55 | | .003 |
| | | 0 | 200 | | 85 | | .003 |
| $C_{6s}$ | L | | | 50 | 20 | 2.5 | .016 |
| | | | | 80 | 30 | 5 | .013 |
| | | | | 120 | 40 | 10 | .012 |
| | | | | 200 | 75 | 12.5 | .005 |
| $C_7$ | V | 0 | .2 | | .198 | .15 | - |
| | | 0 | 1 | | .9 | .7 | - |
| | | 0 | 3 | | 1.6 | 1.55 | - |
| | | 0 | 8 | | 3.7 | 3.85 | .038 |
| | | 0 | 10 | | 5 | 5 | 0 |
| | | 0 | 15 | | 7 | 7.25 | .018 |
| | | 0 | 20 | | 10 | 10 | 0 |
| | | - .2 | 7.8 | | 3.9 | 3.85 | - |
| | | 0 | 1 | | .998 | .75 | - |
| | | 0 | 8 | | 4 | 4 | 0 |

Table 7 (continued):

| Respondent | Question Type | $y_1$ | $y_2$ | z | x | a | λ |
|---|---|---|---|---|---|---|---|
| $C_7$ | V | 0 | 15 | | 7.5 | 7.5 | 0 |
| | | 0 | 40 | | 20 | 20 | 0 |
| | | 0 | 50 | | 25 | 25 | 0 |
| | | 0 | 80 | | 35 | 37.5 | .0063 |
| | | 0 | 120 | | 50 | 55 | .0057 |
| | | 0 | 200 | | 75 | 87.5 | .0052 |
| $C_7$ | L | | | 8 | 2 | 1 | .30 |
| | | | | 50 | 5 | 10 | .14 |
| | | | | 80 | 6 | 17 | .12 |
| | | | | 120 | 7 | 26.5 | .10 |
| | | | | 200 | 8 | 46 | .09 |

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