Utility Measurement for Those Who Need to Know

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A practical technique for estimating decision-makers' utility functions by survey or group methods is explained and illustrated. Results from a survey of 44 Oregon farmers are reported. Risk attitudes of respondents are related to farm and decision-maker characteristics. Regression analysis found age, education, and percentage of land ownership, either separately or jointly, to be statistically significant variables related to risk attitude. Risk attitudes measured from the estimated utility functions were found to be uniformly distributed across risk aversion, neutral and preference. Even though further empirical work is needed, it appears that the distribution of risk attitude among the human population cannot be predicted from a single variable.

There appears to be sufficient need for measuring decision-makers' utility functions in empirical and practical situations to justify showing how to do it in an efficient manner that anyone can apply. Most of the literature on eliciting utility functions has dealt with conceptual developments, perfection of procedures, and has remained at a fairly theoretical and abstract level [Anderson, et al.]. Empirical tests of behavioral hypotheses have been done with extremely small samples and lend little credence to the conclusions [Conklin, et al; Halter and Dean; Lin, et al.; Officer and Halter]. What is lacking are good applied prescriptions from experienced users on how to implement these procedures in an efficient, systematic fashion for a wide range of situations. Users of such procedures, besides empirical researchers who need larger samples, are extension teachers, classroom teachers, consultants, and those with business-customer relationships [Holt and Anderson; Robison and Barry].

The technique for obtaining the numbers required to estimate a utility function from a decision-maker has evolved considerably since our attempts in the Interstate Managerial Study [Halter]. Our latest study design was based on our ensuing research and teaching experience and that of others, [Anderson, et al.; Conklin, et al.; Lin, et al.; Officer and Halter] and provides a means for deriving utility functions for large numbers of individuals at low cost. This means we can now begin to formulate empirical hypotheses about the distribution of risk attitudes, their determinants and/or consequences in the human populations. Also, it means that practitioners can begin to apply these procedures in situations where knowing something about a client's risk attitude may make a difference in the outcome.

Finally, even those who suggest indirect methods for measuring risk attitude will some day need to know, if they are to make meaningful comparisons or to show their methods superior [Meyer, 1977a; 1977b; Moscardi and de Janvry; Porter et al.; Robison; Robison and Barry].

Utility Measurement Technique

The technique to obtain numbers for utility function estimation is to construct questions presenting a choice between two uncertain alternatives, and to ask the respondent to modify his answer to the questions until he

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indicates that he is indifferent between the alternatives. The questions are asked in conjunction with the following format which can be presented on a small card or blackboard.

Game 1

		Alternative Actions	
		A_1	A_2
Probability	½	d	c
of			
Occurrence	½	a	b

The four positions are filled in the following way: a is the respondent's income level (rounded);[1] b is ¾ of the respondent's income level or ¾ a (rounded); c is varied in asking the question until indifference is obtained and is set initially between b and d; and d is set equal to zero. The numerical relationship between the four positions will be in the alphabetical order indicated:
$a > b > c > d$.

The question asked is: Which alternative action do you prefer if you know that with probability ½ your monetary outcome would be either a or d if you take action A_1 and either b or c if you take action A_2? This question can be motivated with a brief discussion of the riskiness of farming and can be detailed to include the outcomes of the two alternatives. After a very few warm-up questions, most respondents understand the situation and proceed without further motivation.[2] Students in a classroom situation usually respond quickly after the group dynamics take over.

If the respondent picks A_1, this means c is too small and should be increased. If the respondent picks A_2, this means c is too large and should be decreased. Thus, c is varied until the respondent finds it difficult to decide between A_1 and A_2 and you conclude that he is indifferent, or he tells you.

The second "game" is constructed from the first game by replacing the zero or d position with the monetary value of the indifference point from Game 1.

Game 2

		Alternative Actions	
		A_1	A_2
Probability	½	Indifference 1	c′
of			
Occurrence	½	a	b

The question is phrased again and the number in position c′ varied until indifference is indicated. The prime on c indicates that the number will be different now. The a and b positions are as in Game 1 and the monetary size relationship among the four positions is still $a > b > c' >$ Indifference 1.

With two games you have sufficient information to calculate one point on the respondent's utility function after anchoring the function to an origin and one other point.

The formula for making the calculation is:

(1) Utility value of Indifference point 1 = ½ (utility of zero and utility value of Indifference point 2) or in shorthand:

$$u\ (\text{Ind. } 1) \text{ is } \tfrac{1}{2}\ [u\ (0) + u\ (\text{Ind. } 2)].$$

Now let one anchor point be [0, u(0)], the origin, and the other be [Ind. 2, u (Ind. 2)] = [Ind. 2, 200] and hence:

$$u\ (\text{Ind. } 1) = \tfrac{1}{2}\ (0 + 200) = 100.$$

The calculated point on the utility function is: (Ind. 1, u (Ind. 1) = 100).

We will give several illustrative examples from our survey and the reasons why the formula works after setting up more games to obtain additional points. The additional games (points) are necessary to extend the utility function so that it will include the gross income point and beyond if desired.

Game 3 has the same relationship among positions, but is tied to the first two games by using the monetary parts of the three points, i.e., 0, Ind. 1, and Ind. 2.

[1] We either ask the respondent directly for his approximate gross income or we present him with a card that shows monetary intervals and ask him to indicate which interval contains his previous year's gross income.

[2] Instructions to interviewers, layout of items on the interview schedule and card format used are available upon request from the Survey Research Center, Oregon State University.

Game 3

		Alternative Actions	
		A_1	A_2
Probability of	½	0	Indifference 1
Occurrence	½	a′	Indifference 2

In this game the number in the a′ position is varied until Indifference point 3 is reached. The prime on a indicates that the number will be different now. However, we expect the preference ordering a′ > Indifference 2 > Indifference 1 > 0 as before.

This basic structure can then be extended to cover the desired number of points. This is illustrated by Game 4 where we rotate, counterclockwise, the three indifference values, leaving the a″ position variable for finding Indifference point 4.

Game 4

		Alternative Actions	
		A_1	A_2
Probability of	½	Indifference 1	Indifference 2
Occurrence	½	a″	Indifference 3

Since we know the utility values for three of the monetary positions in Games 3 and 4, we calculate the utility of the new indifference points by addition and subtraction. Using the letters to stand for the four positions we have:

(2) u (a′) = u (b) + u (c) − u (d)

Using: u (b) = u (Ind. 2) = 200
u (c) = u (Ind. 1) = 100
u (0) = (0),
then: u (Ind. 3) = 200 + 100 − 0 = 300 from Game 3.

Using from Game 4:
u (b) = u (Ind. 3) = 300
u (c) = u (Ind. 2) = 200
u (d) = u (Ind. 1) = 100,
then: u (Ind. 4) = 300 + 200 − 100 = 400.

We now have 4 calculated points and two anchor points to use in estimating the utility function. We will illustrate the calculations using the answers from three respondents in our survey that are shown in Table 1.

We note that the three respondents were picked because they have the same gross income of $150,000 in position a of Game 1 and 2. From the utility functions estimated, and shown in Figure 1, you will note that the three cases illustrate three different types of functions; this is another reason for picking these three cases. Position b is ¾ of $150,000, which rounds to $115,000. In posi-

TABLE 1. Numerical Indifference Values Obtained from Three Respondents[a]

	Position			
Individual 1	a	b	c	d
Game 1	$150,000	$115,000	<u>$ 65,000</u>	$ 0
Game 2	150,000	115,000	<u>100,000</u>	65,000
Game 3	<u>180,000</u>	100,000	65,000	0
Game 4	<u>210,000</u>	180,000	100,000	65,000
Individual 2	a	b	c	d
Game 1	$150,000	$115,000	<u>$107,000</u>	$ 0
Game 2	150,000	115,000	<u>170,000</u>	107,000
Game 3	<u>225,000</u>	170,000	107,000	0
Game 4	<u>275,000</u>	225,000	170,000	107,000
Individual 3	a	b	c	d
Game 1	$150,000	$115,000	<u>$ 25,000</u>	$ 0
Game 2	150,000	115,000	<u>42,000</u>	25,000
Game 3	<u>77,000</u>	42,500	25,000	0
Game 4	<u>127,500</u>	77,500	42,500	25,000

[a]Numerical values corresponding to indifference points are underlined.

tions c and d of Game 1 and 2 for Individual 1 we have two indifference points, \$65,000 and \$100,000, and the anchor value zero. From formula (1) we calculate:

$u(\$65{,}000) = \frac{1}{2}[u(\$0) + u(\$100{,}000)]$. After assigning

$u(0) = 0$ and $u(100{,}000) = 200$, we obtain

$u(65{,}000) = 100$.

From formula (2) we obtain from Game 3:

$u(180{,}000) = u(100{,}000) + u(65{,}000) - u(0)$

$u(180{,}000) = 200 + 100 - 0 = 300$.

From Game 4:

$u(210{,}000) = u(180{,}000) + u(100{,}000) - u(65{,}000)$

$u(210{,}000) = 300 + 200 - 100 = 400$.

In positions c and d of Game 1 and 2 for Individual 2 we have the Indifference points \$107,000 and \$170,000. From Formula (1) we have

$u(107{,}000) = \frac{1}{2}[u(0) + u(170{,}000)]$. After assigning

$u(0) = 0$ and $u(170{,}000) = 200$, we obtain:

$u(107{,}000) = 100$.

From Formula (2) and Game 3:

$u(225{,}000) = u(170{,}000) + u(107{,}000) - u(0)$

$u(225{,}000) = 200 + 100 = 300$.

From Game 4:

$u(275{,}000) = u(225{,}000) + u(170{,}000) - u(107{,}000)$

$u(275{,}000) = 300 + 200 - 100 = 400$.

In position c and d of Game 1 and 2 for Individual 3 we have the indifference points \$25,000 and \$42,500. From Formula (1) we have:

$u(25{,}000) = \frac{1}{2}[u(0) + u(42{,}500)]$ and

$u(25{,}000) = 100$, after assigning:

$u(0) = 0$ and $u(42{,}500) = 200$.

From Formula (2) and Game 3:

$u(77{,}500) = u(42{,}500) + u(25{,}000) - u(0)$

$u(77{,}500) = 300$

From Game 4:

$u(127{,}500) = u(77{,}500) + u(42{,}500) - u(25{,}000)$

$u(127{,}500) = 300 + 200 - 100 = 400$

The five points for each individual are plotted in Figure 1. Polynomial equations (up to 3rd degree) were fitted to the points by ordinary least squares and illustrate three different types of utility functions, i.e., from left to right, quadratic, linear and cubic. We will have more to say about this when we discuss the results from our sample survey.

For the moment, notice that the measured utility numbers always occur at the same values, i.e., 0, 100, 200, 300, and 400. The differences between the curves occur because of the differences in dollar amounts which correspond to the indifference points obtained from the games. Also notice that the differences between the utility numbers are always the same, i.e., 100. Hence, the game structure establishes equal intervals of utility between indifference points. In fact, the length of this interval was established when the anchor points for the utility function were designated in Formula (1). Formula (1) comes from equating two equal intervals from Games 1 and 2.

Look again at Game 1. When the respondent indicates indifference between actions 1 and 2, he is telling us that his expected utility from each action is the same. We can write the expected utility for each action as follows:

$$\frac{1}{2}u(d) + \frac{1}{2}u(a) = \frac{1}{2}u(c) + \frac{1}{2}u(b).$$

Rearranging, we have:

$$u(a) - u(b) = u(c) - u(d)$$

From Game 2, at the point of indifference the expected utility of each action is:

$$\frac{1}{2}u(\text{Indifference } 1) + \frac{1}{2}u(a) = \frac{1}{2}u(c') + \frac{1}{2}u(b)$$

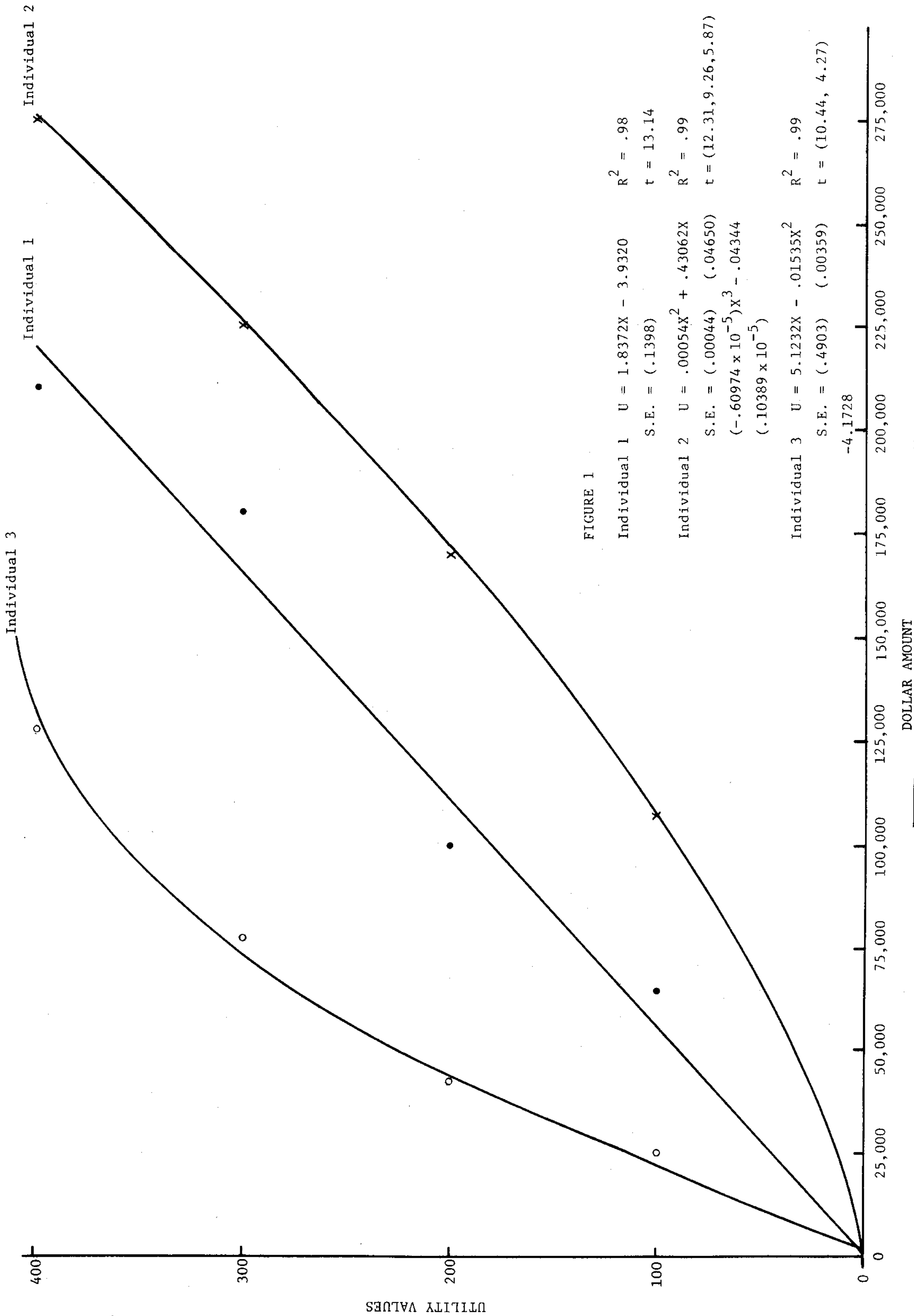

Figure 1. Utility equations.

Rearranging, we have:

u (a) − u (b) = u (c′) − u (Indifference 1).

The common interval between Game 1 and 2 is u (a) − u (b) and therefore:

u (c) − u (d) = u (c′) − u (Indifference 1).

Now since c is Indifference point 1:

2 u (Indifference 1) = u (d) + u (c′),

and since c′ is Indifference point 2 and d is equal to zero we have:

u (Indifference 1) = ½ [u (0) + u (Indifference 2)].

Making the assignment of u (0) = 0 and u (Indifference 2) = 200 establishes the length of the utility interval from zero to Indifference point 1 of 100 utils. The other games are then structured to maintain this interval between subsequent indifference points. That is what makes the procedure work and why the games are structured in the way that they are.

Utility Functions and Empirical Applications

With an efficient method of obtaining utility numbers and an ordinary least squares regression routine one can now estimate utility functions for larger samples of decision makers than was previously possible [Conklin, et al.; Halter and Dean; Lin, et al.]. With larger samples more interesting empirical hypotheses can be formulated and tested. From these tests and refutations new theoretical developments could be made. We report here on a sample of 44 decision makers who were farming in Oregon at the time of interviewing in 1974 and are known in the Willamette Valley as "grass seed farmers." Three of the utility functions estimated from this sample were shown in Figure 1. The entire sample showed linear, quadratic and cubic equations in almost equal proportions when R^2 and visual inspection were used as criteria of goodness-of-fit.[3].

In addition to the utility games our survey obtained data on 11 farm and decision maker characteristics.[4] These are the usual kinds of variables that one suspects might be related to risk attitudes [Halter; Halter and Dean; Officer and Halter]. Since there has not been much theoretical work completed on which to base the hypothesized relationships and samples of too small a size to make empirical estimates of parameters in the past, we had to rely on regression methods to sort out meaningful relationships. The results from this analysis, while subject to further investigation, indicate that the numbers obtained by the utility measurement technique described above are capable of distinguishing among individuals who have other characteristics which are more directly measureable.

We took as the dependent variable a measure of risk attitude that is defined as the negative ratio of the second to the first derivative of the utility function evaluated at the respondent's gross income level. This is called the Pratt coefficient after its founder and has the splendid property that it can be compared among individuals whereas the individual utility functions cannot be so compared [Henderson and Quandt; Pratt; Robison]. The risk attitude so derived is only defined at a point and is, thus, relative to the point chosen. The utility function itself cannot be characterized as to risk attitude in its

[3]Other functional forms could be fitted. Theoretical developments indicate that polynomial forms may not be the best choice for some purposes. There is little empirical evidence to indicate that such a choice makes any difference; however, the choice of function has been discussed recently in nonagricultural settings [Cohn, et al., Friend and Blume].

[4]These included: acres of grain, acres of grass seed, acres of other crops, dollar investment in livestock, percent of acres of grass seed of total farm acreage, percent of acres in annual grasses to total grass seed acreage, respondent's age, educational level, percent ownership of land operated, percent of total dollar investment which was money owed as a loan, mortgage or unpaid bills, and the number of years lived on present farm. Note that gross farm income is not included in this list. The observed correlation between the Pratt coefficient evaluated at the gross income level and gross income was −0.03.

entirety unless it is linear throughout, i.e., risk neutrality [Johnson]. When the 44 utility functions were evaluated for the Pratt coefficient at the decision maker's 1973 gross income level and classified by the sign of the coefficient into risk averse, risk neutral, and risk preference we found that the number falling into each classification was about equal.

The eleven farm and decision maker characteristics were entered into a stepwise regression routine with risk attitude (Pratt coefficient) as the dependent variable. Three variables were selected for further consideration. They were (in order of their statistical influence) percent of land owned, educational level and age. All 11 variables were also subjected to a backstep analysis which selected the least important variable first and dropped it from the model. This procedure dropped (in order of their least statistical influence) years on the farm and percent indebtedness. The variables of percent of land owned, educational level and age remained in the model. Visual inspection of the plotted data showed nonlinear trend lines and hence a second stepwise analysis was performed which included the linear and quadratic terms of the three variables as well as their linear interaction terms.

Results

Results of the regression analysis are shown in Table 2.

Linear terms for the three variables are significant as is the quadratic term for educational level and for ownership by education and education by age interaction terms. Signs for the coefficients for the linear terms of the variables remained unchanged during the stepwise-backstep analysis. Signs of the partial regression coefficients for the linear terms of these variables also remained unchanged throughout the regression analysis.

Evaluation of effects by inspection of results in Table 2 is difficult without plotting graphs for the variables in the model. These graphs are presented in Figures 2-6. Measures of risk attitude are plotted on the vertical axis with positive values signifying risk aversion and negative values signifying risk preferring.

Regression of risk attitude on percent ownership for five levels of education is shown in Figure 2. The strong interaction effect implies greater risk preference among higher educated farmers as percent ownership increases. Contrariwise, grade-school educated farmers demonstrated greater risk aversion with increasing levels of ownership.

TABLE 2. Results of Statistical Tests for Three Variables Remaining

Variable	Regression Coefficient	Stand. error of regress. coef.	Student's "t" value
Constant	11.547	7.152	1.64
Percent owner ...	0.192	0.041	4.70
Education	−6.793	2.854	−2.38
Age	−2.088	0.933	−2.24
Education squared	1.088	0.360	3.02
Percent owned x education	−0.060	0.015	−4.08
Education x age ..	0.587	0.284	2.07
(Variables excluded from model)			
Percent ownership squared			−1.188
Age squared			−0.071
Percent owned x age			−1.637

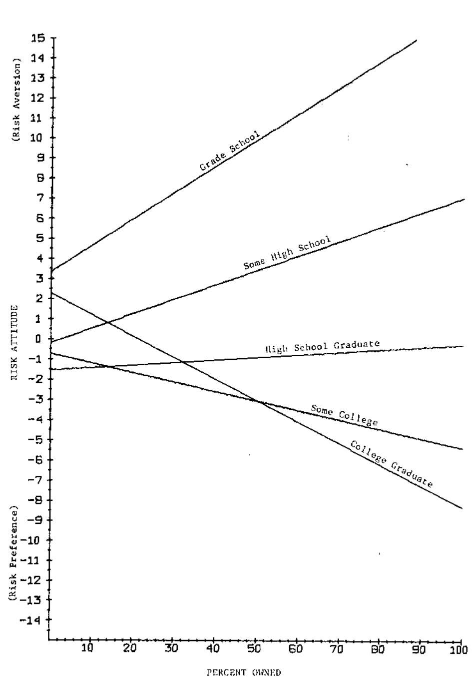

Figure 2. Regression of risk attitude on percent ownership for five levels of education.

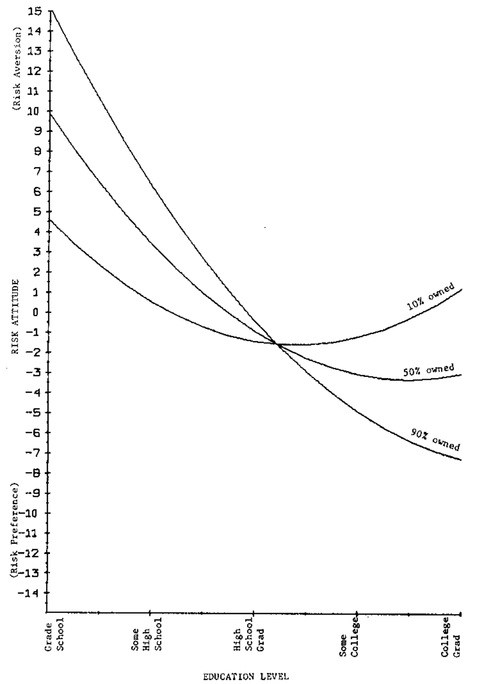

Figure 3. Regression of risk attitude on education for three levels of percent ownership.

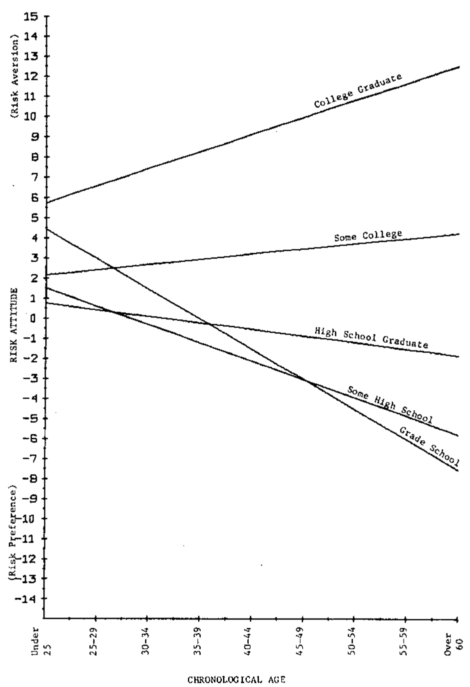

Figure 4. Regression of risk attitude on age for five levels of education.

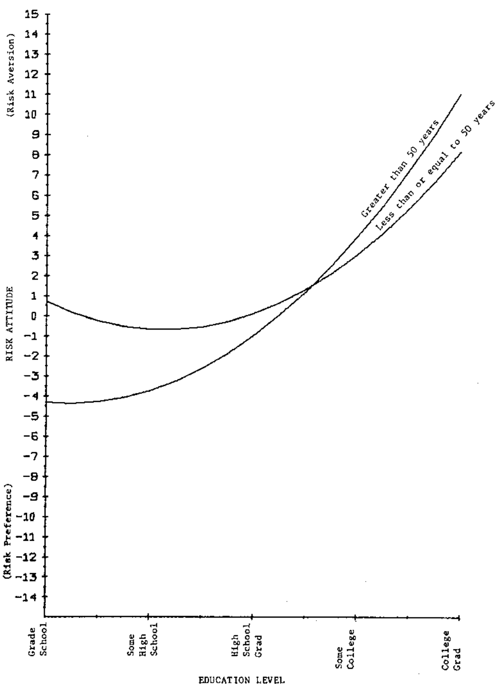

Figure 5. Regression of risk attitude on education for two levels of age.

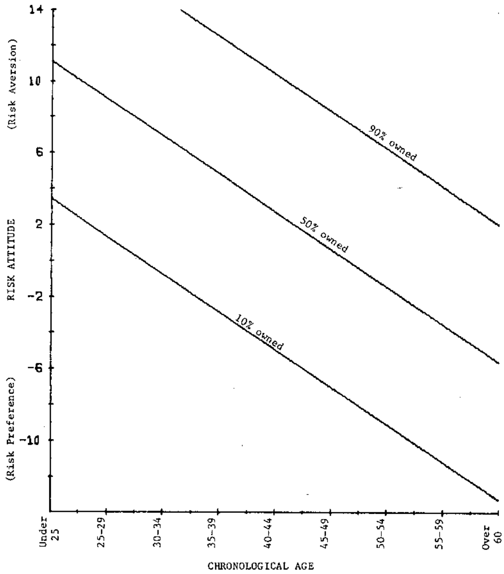

Figure 6. Regression of risk attitude on age for three levels of percent ownership.

Age effects were held constant at the mean value for this figure by inclusion of the age mean in the constant term. Figure 3 shows a second view of ownership and education interaction effects and the nonlinearity of the relationship. Farmers who owned high percentages of their land tend to show a risk preference attitude with increasing educational levels. Moreover, farmers who owned a relatively small percentage of land tend to become risk preferers, then risk averse with increasing educational levels. Data in these two figures suggest that a major shift occurs among the regression lines in which education level plays a role. The slope for the education levels in Figure 2 changes from positive to negative for post-high school farmers. And, all percent ownership lines intersect at the same post-high school point in Figure 3.

Education effects change dramatically when regressed in conjunction with age, as shown in Figures 4 and 5. (Again, effect of percent ownership was held constant at the mean value by inclusion of the percent ownership mean in the constant term). College graduates, according to Figure 4, become more risk averse with increasing age while grade school-educated farmers become more risk preferring. Viewing the age-education relationship from a different perspective, Figure 5 shows that grade school-educated farmers over 50 are more risk preferring than those under 50 but become more risk averse with increasing educational levels. Farmers who completed college and who are over 50 are more risk averse than are those who are under 50.

Finally, the relationship between risk attitude, age and percent ownership is examined in Figure 6. Risk preferences increase with age for all levels of percent ownership but older farmers with relatively low levels of ownership exhibited greater risk preference than did those with high levels of ownership. (Educational level was held constant by inclusion of the education mean in the constant term.)

In summarizing the data we suggest that one cannot account for the observed trends between any one variable and risk attitude without considering effects of the other variables jointly or conditionally. Education level, for example, interacts with both age and percent ownership and any evaluation of these two effects should consider level of education jointly.

Viewing the relationships from a temporal cause-effect perspective, one could interpret the results to mean that higher levels of educational attainment lead to a greater likelihood of attaining ownership over resources, which results in a person being less risk-averse. However, one could also view it from a psychological motivation perspective and say that the risk index is a measure of achievement motivation which results in higher educational attainment and greater skill in acquiring ownership of economic resources and of wealth itself. This would suggest that the risk attitude is acquired rather early in life and is relatively stable throughout one's lifetime.

The effect of chronological age is held constant in this interpretation. The experience of decision making, possibly a function of age, suggests a slightly different interpretation. This interpretation implies that a high level of achievement need is associated with a set of behaviors that is commensurate with an efficient entrepreneurial role. Among the role behaviors identified by McClelland and elaborated by Brewster is that of risk taking. Here, subjects with high need for achievement more often choose to select tasks with moderate risks than do subjects with low need achievement in games of skill as well as in games of chance. They tend to work in situations where their skill is most likely to pay off in terms of success, or, in gambling situations, prefer the safest bet they can get. They do not gamble on "long shots" where large amounts are rarely won, nor do they select tasks where only a small reward is assured. These latter strategies are associated with those of low achievement motivation. Thus, we find that older, less educated farmers are more risk preferring and that older, well educated farmers are risk averse. This interpretation assumes that the effect of percent ownership is held constant and implies that the achievement motive is subject to change through time as one ages.

Strictly speaking, one needs longitudinal data — data gathered in more than one time period — to draw conclusions about time effects and trends. Age effects are confounded with cohort characteristics, historical period and the biological effects of aging itself. Ideally, to disentangle such effects we would need to study several cohorts at the same age and measure the changes that occur through their lifetimes. Even this strategy would not permit us to remove all the confounding effects mentioned above, but it would permit us to make finer discriminations than are possible through cross-sectional analysis.

Summary and Conclusions

We have shown how to empirically estimate utility functions for monetary gains. The procedures are easy to understand, low cost to apply, and efficient in terms of time required to obtain answers when one recognizes the questions to ask.

We were not surprised that different shaped utility functions fitted the data points because we do not believe that all decision makers have diminishing marginal utility for monetary gains for all sizes of gains [Johnson; Roumasset]. Furthermore, we were not surprised when we evaluated the Pratt coefficient at the respondents' gross income point that the coefficients were not all positive. This was not surprising because we do not believe that all decision makers can be characterized by positive Pratt coefficients, i.e., risk aversion. However, we do believe that the equal proportions result should be subjected to further empirical tests. One need not expect equal proportions, but that does not mean that there are no risk preferences among farmers for any size of gain.

The relationships that we obtained between age, education, and resource ownership and risk attitude are most interesting but are in need of further theoretical elaboration and empirical testing. Implications for educational programs and policy formulation are clear: one cannot depend upon a single variable to predict the distribution of risk attitude among the human population.

Finally, further empirical work needs to be done with respect to monetary losses and how to obtain the utility function and its implications across both gains and losses.

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