Magnitude Estimation: An Application to Farmers' Risk-Income Preferences

George F. Patrick, Brian F. Blake and Suzanne H. Whittaker

Magnitude estimation, a technique developed by psychology for obtaining ratio scaled values, was used to derive risk-income preferences of ninety-one central Indiana farmers. Both variability-income and bankruptcy-income measures were developed and related to farmers' socio-economic attributes. Wealth and education had limited effects compared with off-farm employment, percent debt and expected levels of income, percent debt and net worth growth. Magnitude estimation provided reliable estimates of preferences. Farmers gave greater importance to the bankruptcy-income measure of risk-income preferences, but only a small portion of the variation of either measure could be explained.

Agricultural economists have been interested in farmers' risk-income preferences and effects of these preferences on decision-making for many years. However, as indicated by Roumasett, there is no consensus regarding how to define risk or measure risk preferences. Risk has sometimes been viewed as the variance or another measure of dispersion of possible outcomes.[1] Alternatively, risk has been viewed in a "safety first" context as the chance of loss or possibility of disaster. Furthermore, as reviewed by Young, there has been a considerable discussion of difficulties associated with alternative methods of measuring risk preferences. Only a limited number of studies have estimated farmers' risk preferences and even fewer studies have focused on relationships between farmers' attributes and their risk preferences.[2] Close association of farmers' attributes and risk-income preferences could facilitate utilization of risk-income preference information in farm management extension, microeconomic policy, and other applications.

This study utilizes an easily applied alternative measurement technique, magnitude estimation [Stevens], to develp risk-income indices which are then related to various farmer attributes. Both the variability of possible outcomes and possibility of disaster concepts of risk are considered in a multiple goals context. Alternative methods of estimating risk attitudes are briefly reviewed in the first section of this paper, but emphasis is given to the farmers' attributes used to explain these risk preferences. Second, the

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[1]For a brief criticism of the mean-variance approach and additional references see Bessler.

[2]Lin, Dean and Moore found that Bernoullian utility functions provided greater accuracy in predicting crop patterns than the lexicographic and profit maximization formulations but did not relate farmers' attributes to their risk preferences.

theory behind magnitude estimation and the procedures used in this study are described. Based on the studies reviewed in the first section, a model relating farmers' attributes and risk-income preferences is developed and the results obtained are presented in the third section. Implications of the study are discussed in the final session.

Measuring Risk-Income Preferences

Various techniques based on the expected utililty framework have been used to elicit utility functions [Dillon], but there has been considerable discussion of the merits of these technique [Young]. The utility functions elicited do not permit interpersonal comparisons concerning risk attitudes. However, Pratt developed a measure of risk aversion which is defined for a specified money amount and allows interpersonal comparisons of risk attitudes because it is independent of the scale and origin of the utility function.

Halter and Mason used a modified-Ramsey technique to elicit utility functions and compute Pratt coefficients for 44 Oregon farmers in 1974. Eleven farm and operator characteristics were analyzed in regression analyses with the Pratt coefficients as the dependent variable. Percent of land owned, education, and age were statistically significant in linear form. Education squared and the education-percent ownership and education-age interaction factors also were related to the Pratt coefficients. Whittaker and Winter reported on a follow-up study in which similar elicitation procedures were used for the same farmers in 1976. In their analysis, they found that the signs for all the estimated regression coefficients were reversed from those obtained in 1974. They suggest a variety of possible causes of the differences in the results obtained, including unreliability of point risk measures and hypotheses to be tested.

Dillon and Scandizzo utilized age, income, household size, and ethical attitude toward betting to predict risk attitudes of a sample of land owners and tenants in Northeastern Brazil. Both tenure groups were more risk adverse when subsistence was at risk than when it was not. Ethical beliefs against gambling and age were associated with greater risk aversion for both groups. Increases in income predicted a decrease in risk aversion while household size had mixed effects. They concluded that most, but not all, peasants are risk averse and that the distribution of risk attitudes is not well represented by the mean.

Binswanger developed an "experimental" method which involved interviews over an extended period and the use of actual financial compensation at realistic levels. The gamble chosen by the respondent indicated the level of risk aversion. Risk aversion tended to increase as the stakes of the game increased, and all but one of 118 individuals were risk averse. Binswanger attempted to predict differences in attitudes toward risk in terms of age, schooling, assets, land rented, salaried employment, working age adults per family, progressiveness, net transfers, luck in previous games, and attitude toward gambling. Although only a small portion, 5 to 21 percent, of the variation in the risk aversion coefficients was explained, in most instances schooling and good luck in prior games were associated with risk aversion. Wealth and the other variables had only limited impacts on risk aversion.

Grisley and Kellogg used the Binswanger procedure for 40 Thai farmers. They found that farmers initially exhibited decreasing risk aversion, then increasing, and finally decreasing risk aversion as the stakes increased. This did not support their hypothesis that the decision makers were risk adverse and would have increasing risk aversion over the games considered. They also found that land owners, larger farmers, and older farmers were not less risk adverse than renters, smaller farmers, and younger farmers as is commonly hypothesized.

Moscardi and de Janvry developed an indirect measure of risk preference based on observed economic behavior which was the dependent variable in a regression analysis

with a number of socio-economic and structural characteristics for 45 Mexican families. Seven variables explained 37 percent of the variation. Off-farm income, extent of land under control, and membership in a solidarity group were all negatively associated with risk aversion. Family size, schooling, and age were not statistically significant.

These studies have used different concepts of risk aversion and techniques for estimating farmers' risk attitudes, but all have encountered difficulties.[3] Direct elicitation procedures have produced inconsistent results with respect to risk attitudes. Binswanger also found the Dillon-Scandizzo interview technique to be unreliable and misleading. Very substantial costs are involved in applying the experimental method. Knowles has criticized the experimental approach, such as used by Binswanger and by Grisley and Kellogg, on the basis that it does not avoid the utility of gambling problems.

Additional criticisms of the experimental approach are that farmers received money to play with and may have viewed this as "funny" money and although actual choices are observed, the circumstances are artificial and the subject needs a considerable learning period. The observed economic behavior approach used by Moscardi and de Janvry requires rather restrictive assumptions to specify the component attributable to risk aversion.

Difficulties have also been encountered in determining factors associated with risk preferences. Although similar variables have been used in the various studies, the results have not been entirely consistent. Some variables have had the expected sign and have been statistically significant in some studies, but not in others. In most cases, substantially less than one-half of the variability in risk aversion has been associated with the factors considered.

Several factors may contribute to the difficulties of measuring risk-income preferences and the socio-economic characteristics associated with them. Young and Musser, as well as psychological reviews such as [Slovic, *et al.*,] have suggested that measures of risk preference differ over time and situations. Some, but not all, of this variation represents unreliability.[4] It is not clear to what extent the low coefficients of determination found in predicting risk-income preferences from socio-economic characteristics result from unreliability of the measure rather than independence of the variables. Previous empirical studies have generally not been concerned with reliability of the measures used. Second, many of the studies have considered only a limited number of farmers. Variability of results from study to study may reflect the small samples used.

Finally, the studies may represent the application of an inappropriate explanatory system. Typically, analyses regressing risk preferences and farmers' socio-economic characteristics are couched in causal terms. These analyses attempt to identify those socio-economic characteristics which "increase," "decrease," "lead to," or "determine" risk preferences. Low coefficients of determination are seen as failures to identify factors which "cause" differences among individuals. However, should the R^2s be high? Many variables, such as the information processing style of the decisionmaker or knowledge of alternatives, may intervene between the socio-economic characteristics of a farmer and his risk preferences. It is these intervening factors which current theories of decision-making postulate as "causes." Socio-economic characteristics may serve as proxies

[3]Although not concerned with risk-attitudes directly, Harman *et al.* found that age, education, asset level, acres of cropland, and proportion of cropland owned was associated with the importance of the goal "avoid being forced out of business." Acres of land, owned land, proportion of land owned, net worth, debt-asset rates, asset level, number of dependents, age, and tenure could predict "avoid years of low profits or losses." The R^2s of the regression equations were .189 and .413, respectively.

[4]Unreliability is the percentage of total variance that is estimated to be random variation. Cook and Campbell provide an overview of the unreliability effects.

for some of these intervening variables, but other intervening variables may, at best, be only indirectly related to these characteristics. It may be more theoretically justifiable to view the relationships between socio-economic characteristics as descriptive analyses indicating the concentration of risk preferences within a socio-economic category rather than as a strictly causal analysis.[5] In this case, assuming adequate sample size and reliable measures, the low coefficients of determination imply that risk-income preferences are distributed across groups rather than concentrated within particular types.

Study Procedures

The risk-income preferences of individual farmers are measured in this study by magnitude estimation (ME) procedures. ME is one of a class of "ratio scaling" techniques [Hamblin, Stevens] in which an individual judges the magnitude or intensity of a given item as a ratio of another item as the base. In this study, a base goal is assigned a value of 100. The respondent is asked to assign points to each of the other goals so that the scores reflect the importance of each goal relative to the base goal. For example, if a farmer thinks goal B is twice as important as the base goal, then he would give 200 points to goal B. However, if goal B is only half as important as the base goal, the farmer would assign only 50 points to goal B. Any number of points can be given to a goal as long as the score reflects the importance of that goal relative to the base goal.

An estimate of reliability can be obtained by varying the base goal used for comparison [Nunnally]. For example, suppose a farmer thinks that goal X is worth 200 in importance when compared with Y, the base goal assigned 100 points. This farmer should then judge Y to be worth 50 if goal X is made the base goal and assigned 100 points. The degree that identical ratios of goals are not repeated with alternative base goals represents alternative form or equivalence reliability. Conversely, the proportion of variance unique to a given base goal is typically considered to be the proportion of random error contained in that measure.

The ME procedure has several potential advantages for measuring farmers' goals. First, it is a well documented procedure which has been found to yield reliable results in a variety of contexts. For example, it has been used to determine the subjective value of money [Stevens], wages [Hamblin], seiousness of crime [Sellin and Wolfgang], national power [Shinn], degree of affinity for various animals [Carpenter and Blackman], as well as the more usual psychophysical phenomena. The psychophysical theory underlying the technique is outlined by Hamblin and by Torgenson and critically examined by Ross. Second, ME is realtively simple to apply. Individuals are required to assign numbers to goal statements which reflect the goal's importance, relative to a base goal, for the individual.

Finally, ME scores for farmers who generate reliable ratio scaled judgements should be comparable across individuals and permit scalar transformations. Rating scales and Thurstone scaling procedures traditionally used to measure farmers' preferences yield an "interval" scale with an arbitrary origin and fixed intervals separating the scale points on the underlying continuum. According to Stevens, the scale numbers, X, of an interval scale can be transformed to a set of numbers, X', following the rule:

$$X' = aX + b \qquad (a > 0)$$

Differences among individuals in the origin and scale separations can hinder aggregation of scores across individuals and interpersonal comparisons of preferences. "Ratio" scales, in contrast, are invariant only with respect to transformation of the form:

$$X' = cX \qquad (c > 0)$$

As demonstrated by Torgenson and Ross,

[5]For a discussion of the difficulties involved in postulating a causal relationship with unspecified intervening processes see Cook and Campbell.

ratios among scores are independent of the origin and size of the (equal) intervals among scale points. Therefore, by establishing the same baseline for all individuals and scoring all items in terms of multiples of that baseline, comparisons of scores among individuals can be made.[6] For example, two farmers may be comparable in that goal X may be twice as important as goal Y for both of them. This 2:1 ratio should be comparable — even though a given goal is more important to one farmer than the other when the goals are considered separately. This is also true if one farmer's subjective scale of importance has more divisions or intervals than the other representing the fact that one farmer discriminates more finely among goals than does the other.

A sample of 91 farmers drawn randomly from a list of agricultural producers in three Central Indiana counties were interviewed in this study. Information was obtained about the current family and farm situation. Farmers were also asked about their desired future income for consumption, expected percent net worth growth, and anticipated percent debt in three years. For a further discussion of the sample and data collection procedures, see Patrick, Whitaker and Blake.

The farmers assigned points to each of eight goals; this procedure was repeated three times using a different statement from the goal set as the base goal in each trial. In the first trial, the base goal statement was "a farm business that produces a stable year-to-year income" (stable income). In subsequent trials the base goals were "to avoid being unable to meet loan payments and/or avoid foreclosure on my mortgage" (bankruptcy) and "to be recognized as a top farmer in my community" (recognition). The income goal included in the goal set was stated "to attain a desirable level of family living."

Spearman-rho correlations were calculated to check (1) the respondents' scoring consistency among trials and (2) the effect of the base statements on the rank ordering of the goals. The median correlation for the sample between the trials using base 1 (stable income) and 2 (bankruptcy) was .637; between 1 and 3 (recognition), .651; and between 2 and 3, .720. These results indicate that farmers could rank goals more consistently with bases 2 and 3. Therefore, the ME base 1 results were not used in further analyses.[7] Nine farmers with Spearman-rho coefficients of .4 or less with bases 2 and 3 were eliminated on the basis of inconsistency.[8]

Two measures of risk-income preferences were developed using the ME procedure. The first, a stability-income measure, is the average of the base 2 and 3 points assigned to the goal "a farm business which produces a stable income" when "attain a desirable level of family living" is indexed to equal 100 points.[9] The second, a bankruptcy-income measure, is the average of points assigned to the goal "avoid being unable to meet loan payments and/or avoid foreclosure on my mortgage" when desirable income is the index. The stability-income measure can be interpreted as approximating the variability of possible outcomes concept of risk, and the bankruptcy-income measure is in the safety-first context. Higher values on each measure indicate greater risk aversion. The mean

[6]These ratios can be used in goal programming models (Patrick and Blake) to quantify trade-offs among multiple goals.

[7]The differences in medians between trials involving base 1 were significantly lower than the base 2 and 3 trial at the 5 percent level. The bankruptcy and recognization goals represent the highest and lowest ranked goals respectively for most farmers. These farmers may have found it easier to assign values to other goals with the base being at either extreme. Carpenter and Blackwood have found that the order of items has a small but significant effect in some cases. In this experiment, part of the difficulty with the results obtained on the first trial may be due to the interviewee's lack of familiarity with the technique.

[8]A total of 21 farmers had Spearman-rho coefficients of .4 or less in comparison with base 1.

[9]Because of the ratio properties of the data, transformations can be performed to index any of the goals as equal to 100.

value of the stability-income measure was 110.4, significantly less than the 142.9 mean of the bankruptcy-income measure. The simple linear correlation between the two measure was .355.

Empirical Results

The risk-income preferences of farmers were hypothesized to vary with characteristics of the operator, family, and farm as well as target levels of various goals.[10] Based on previous studies, older farmers, those with dependent children and larger percentages of debt to total assets are expected to be more risk averse. Education and factors representing wealth are expected to be related to lower levels of risk aversion. The implications on risk aversion of holding an off-farm job and the three-year target levels for future income for family living, percent debt, and percent net worth growth are less clear.[11] Farmers with off-farm income may be less risk averse because of the security provided by this income while individuals who are highly risk averse may seek off-farm jobs for security. Individuals with high target levels for income and net worth may be less risk averse than individuals with lower target levels. Higher planned percent debt may indicate less risk aversion or the individual's knowledge that borrowing is necessary to achieve other goals.

The estimated coefficients and t values for the stability-income and bankruptcy-income equations in linear form with 77 observations are presented in Table 1. Positive coefficients indicate greater risk aversion as the variable increases. Similar to studies previously reviewed, the attributes considered in this analysis explain less than one-half of the total variation in risk-income preferences, and the overall stability-income equation is just significant at the 10 percent level. A number of variables have coefficients which are statistically significant at the ten percent level or higher and have the same sign in both equations. Tillable acres, net worth, presence of livestock, and average gross farm income had t values of less than .3 in a preliminary version of the equations and were excluded from further analysis.

Moscardi and de Janvry, as well as Dillon and Scandizzo, found that older farmers were more risk averse. In the stability-income equation, the age variable had the expected positive sign, but the t value was extremely low. However in the bankruptcy-income equation, age was negative and significant. Many of the older farmers had very few or no debts, and the possibility of repayment difficulties or bankruptcy may have been viewed as very remote and assigned a low value. In contrast, many younger farmers had substantial debts or were considering borrowing additional money in the future and possibilities of financial difficulties were of concern.

Education was included through two dummy variables, one was for technical education after high school or some college, and the second for completion of college. Both variables were positive in the stability-income equation indicating greater risk aversion by more educated farmers. This was contrary to the relationship expected based on other studies, but neither coefficient was significant. In the bankruptcy-income equation, college education had the expected negative sign, but was less than one-half the size of the standard error.[12]

[10]There is likely to be some interaction between risk-income preferences and target levels of various goals, but these interactions are not considered in this study. The correlations between the independent variables did not exceed .48. The correlation for planned future income available for family living and planned percent debt was −.41, for net worth and planned percent net worth growth was −.08, and for percent debt and planned percent debt was .36.

[11]Although not specified in the questionnaire, comments by the farmers indicated they were specifying target levels in nominal terms.

[12]An alternative formulation with education coded a 1 for high school, 2 for some college or vocational school, and 3 for college graduation resulted in positive coefficients in both equations which were smaller than their standard errors.

TABLE 1. Estimated Coefficients of Risk-Income Equations, Central Indiana Farmers, 1979.[a] (n = 77)

Variable	Stability-Income	Bankruptcy-Income
Age (years)	0.1180	−1.6638
	(0.2379)	(1.9553)
Technical education[b]	7.8791	0.7300
	(0.7401)	(0.0400)
College education[c]	21.8448	−11.7801
	(1.5180)	(0.4773)
Children under 18[d]	−23.2410	−40.6141
	(1.7246)	(1.7561)
Percent debt	0.0655	1.775
	(0.3554)	(3.7237)
Off-farm job[e]	−15.8244	−30.8419
	(1.6638)	(1.8895)
Planned future income ($1,000)	−0.3212	−0.9558
	(0.9503)	(1.6476)
Planned percent debt	0.3243	0.2128
	(1.7401)	(0.6652)
Planned net worth growth (percent over 3 years)	0.2426	0.6469
	(1.6728)	(2.5990)
Constant	101.7751	217.0740
	(10.3260)	(3.9935)
R^2	0.2047	0.4097
F	1.9155	5.1657

[a]"t" values are indicated in parentheses.

[b]Technical education is coded as 1 for technical training beyond high school or some college and 0 for no additional training.

[c]College education is coded as 1 if college was completed and 0 otherwise.

[d]Children under 18 is coded as 1 if there are children under 18 years of age in the household and 0 otherwise.

[e]Off-farm job is coded as 1 if the farm operator or spouse has an off-farm job and 0 otherwise.

The presence of children under 18 years of age in the household was associated with lower levels of risk aversion in both equations. It was hypothesized that households with dependent children would be more risk averse than households without children, but this was not supported by the results. The intercorrelation between age and children under 18 was −.47, but the coefficients changed only slightly with alternative model specifications.

Although the percent debt had only a limited relationship to risk aversion in the stability-income equation, it was highly significant in the bankruptcy income equation. A lower level of risk aversion was associated with farmers with a higher percentage of debt.

If either the farmer or spouse had an off-farm job, then the stability-income and bankruptcy-income measures were both significantly reduced. This suggests that operators with off-farm income were less risk averse. However, the results can also be interpreted as indicating that these operators give greater emphasis to a desirable level of family living.

The higher the planned future income, the lower the apparent risk aversion in both equations. These results could be interpreted as indicating greater emphasis on income for a desirable level of living, but if one expects a higher income in the future, they are likely to be less concerned with risk.

Planned percent debt and percent net worth growth have positive coefficients in

both risk-income equations. The greater risk aversion of the individuals who are planning faster growth appears inconsistent with the common view that rapid growth can involve greater risk. However, these individuals could be placing a lower importance on attaining a desirable level of family living in order to achieve higher rates of net worth growth.

Implications

Risk-income preferences of farmers, at least theoretically comparable across individuals, can be obtained through ME procedures. The Spearman-rho correlations indicate that farmers assign values to goals which are consistent across different base goals. The ME procedure is easier to use than a modified-Ramsey approach, does not require the detailed experimental data used by Moscardi and de Janvry, or the extended interviews of the Binswanger's experimental method. Like other interview methods, ME is based on the farmer's ability and willingness to describe his preferences and goals, but the flexibility of use and ease of application are advantages. As discussed by Patrick and Blake, the ratios derived through ME procedures can be used in goal programming models to specify tradeoffs among alternative goals.

The bankruptcy-income index had a significantly higher value than the stability-income index suggesting farmers may give greater weight to the safety first context of risk. The R^2 of the bankruptcy-income descriptive model was also higher than the stability-income model. Although the statistical significance of the overall equations differ, the signs of the coefficients are generally the same whether the variability or safety first concept of risk is used. The results indicate that risk aversion does not vary closely with age and education. Both risk aversion measures increased with actual and planned percent debt and with planned net worth growth. Expected levels of income, net worth growth, and percent debt had major roles in explaining risk-income preferences of farmers and should be included in future studies.

This study, like the others reviewed, can explain less than one-half of the variation in farmers' risk attitudes. Within a descriptive model, these coefficients of determination imply that specific levels of risk-income preferences are not highly concentrated within subgroups of farmers on the basis of factors of *a priori* interest. Although a number of factors considered to be of interest were included in this analysis, risk-income preferences were found to be more general in their distribution.

Several reasons suggest that a descriptive rather than causal model may be more appropriate for investigating the relationship of farmers' risk-income and socio-economic characteristics. First, as discussed previously, there can be conceptual ambiguities in a causal model because of a multiplicity of possible intervening processes. Second, a descriptive framework can avoid the logical tautologies inherent in many analyses conducted within a causal framework. For example, does a specific socio-economic characteristic (e.g., current debt load) produce a risk-income preference or does a risk-income preference result in a farm organization which produces that socio-economic characteristic? Finally, a causal model may often be unnecessary to the objective for which many analyses are conducted. Although some applications do require causal assumptions [Patrick and Blake; Baquet, *et al.*], many applications in farm management extension, development program planning, and aggregate public policy require only a descriptive framework.

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