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RISK PREFERENCES OF AGRICULTUAL PRODUCERS:

THEIR MEASUREMENT AND USE

Douglas Young, William Lin, Rulon Pope, Lindon Robison, and Roger Selley

Objective 2 of regional research project W-149 intends: "To estimate risk premiums required by primary producers and associate these estimates with personal, business and economic attributes of primary producers (e.g., age, education, tenure, enterprises, business size and organization, location)." This objective was based on the view that knowledge of risk preferences of individual agricultural producers is necessary for many useful private managerial and public policy analyses of decision making under risk. It further indicates an implicit faith in researchers' ability to obtain reliable estimates of individual risk perferences by conventional measurement techniques. Support of these beliefs among W-149 participants was indicated by the reported willingness of researchers from nearly all states in the project to participate in a unified effort to estimate utility functions for a sample of producers for a major commodity within their respective states.[1]

However, USDA failed to authorize funding for this proposed unified regional effort, and recommended instead a limited pilot study that would demonstrate the feasibility of obtaining risk preferences and of using such information to evaluate and formulate supply stabilization or other national agricultural policies. The ensuing discussion at last year's W-149 committee meeting led to the conclusion that there should be a thorough reevaluation of the usefulness and feasibility of various approaches to measuring risk preferences before proceeding further. A subcommittee of five members was appointed to conduct that reevaluation. This paper represents the subcommittee's report to the W-149 membership.

As groundwork for the subcommittee's task, four members presented papers on various aspects of the topic at an invited papers section organized by Roger Selley at the WAEA Meetings in Bozeman, Montana, during July 1978. The papers presented at the Bozeman meetings are as follows: 1. Lin, William. "Producers' Formulation of Expectations and Risk Response;" 2. Pope, Rulon. "Econometric Analysis of Risk Models -- Some Explorations and Problems;" 3. Robison, Lindon and Robert King. "Specification of Micro Risk Models for Farm Management and Policy Research," and 4. Young, Douglas and Jill Findeis. "Characteristics of Producers: Their Willingness and Ability to Bear Risk."

This report relies heavily on these four papers and subsequent discussions and correspondence among subcommittee members. While the subcommittee did not reach agreement on all issues, there was a loose consensus on most of the conclusions presented in this report.

Douglas Young, Rulon Pope, Lindon Robison, and Roger Selley are Assistant Professors in the Departments of Agricultural Economics at Washington State University, University of California-Davis, Michigan State University, and University of Arizona, respectively. William Lin is an economist with ESCS/USDA, Washington, D. C. The authors gratefully acknowledge Peter Barry's valuable advice and suggestions during the preparation of this report and throughout the subcommittee's deliberations.

The specific objectives of this report are to review and critically evaluate the current state of knowledge on risk preference measurement methods and empirical results, to suggest promising methodologies for incorporating risk considerations into various research and extension applications, and to present the subcommittee's conclusion on the desirability of a coordinated project effort to elicit producer utility functions.

The report is organized into six major sections. The first provides necessary background by reviewing the definitions of risk and risk preferences that have been typically used in empirical studies. Section two is devoted to a critical evaluation of alternative methodologies which have been employed to measure risk preferences. The third section assesses what has been learned about the willingness of agricultural producers to bear risk from previous empirical studies. To build a foundation for specific constructive methodological suggestions, the fourth section reviews the need for and feasibility of incorporating risk preferences, by alternative methods, into various extension and research applications. Section five describes in detail some promising recently developed empirical methodologies. The final section of the report presents the subcommittee's general recommendation on the desirability of a coordinated project utility function elicitation effort and also summarizes the various methodological suggestions for specific extension and research applications.

Concepts of Risk and Risk Preferences

Definitions of Risk

Among applied researchers the two most popular definitions of risk have been: (1) measures of dispersion such as variance or standard deviation; and (2) "chance of loss" or the probability (α) that random net income (Π) will fall below some critical or "disaster" level (d); formally, Pr $(\Pi \leq d) = \alpha$.

Among farmers, however, high levels of variability alone do not necessarily imply high levels of "risk." For example, if wheat producers had been asked during 1973-74 as wheat prices were fluctuating between three and six dollars per bushel whether wheat farming was a risky business, a likely response by many might have been, "It used to be, but with prices like these any fool could make money."

The preceding discussion indicates that the concept of risk in popular usage considers more statistical moments than variance alone. Analytical usefulness, however, not popular usage, should be the final arbiter of the concept of risk to be used in research applications. From this perspective, it becomes clear that the behavioral decision making model employed will determine the appropriate concept of risk. If different decision models are appropriate for different situations, then risk definitions should be adjusted accordingly. As James Roumasset points out, researchers favoring "safety first" models such as those developed by Telser and Kataoka prefer definition (2) above, whereas those favoring Bernoullian (expected utility maximization) models prefer difinition (1).

Practically speaking, the "measure of risk" of interest to the researcher can often be considered as the argument(s) of the objective function being used, excluding the measure of central tendency. Although the objective function of the general expected utility decision model is a function of (potentially) all statistical moments of the risky actions a_i, i = 1, ..., n, available to the decision maker, it has been popular among empiricists to assume that the utility function is quadratic or that profits are normally distributed yielding the simpler function of mean and variance only:

$$\underset{i}{\text{Max}}\ (EU)_{a_i} = f(\mu_{a_i}, \sigma_{a_i}^2)$$

Whether higher moments should be included in the objective function can be viewed as an empirical question. Does the inclusion of higher moments significantly improve the ability of the model to predict behavior? Or in normative applications does expected utility depend enough upon higher moments to merit their inclusion? It should be noted that objective functions derived from safety first models, such as Kataoka's maximize d subject to Pr $(\Pi \leq d) \leq \alpha$, can also be expressed as functions of the mean and standard deviation of the available action set (Pyle and Turnovsky).

Risk Preference Definitions

A frequently used and intuitively appealing characterization of an individual's risk preference is that a risk averter (preferrer) will pay (must be paid) to avoid a fair bet, whereas a risk neutral individual will be indifferent between taking and not taking such a bet. A fair bet is defined as one for which the expected monetary value (EMV) is zero. An example is a lottery with 0.01 probability of winning $99 and 0.99 probability of losing $1, i.e., 0.01(99) + 0.99(-1) = 0. An intuitively appealing quantitative measure of the degree of risk aversion is the magnitude of the payment to avoid participation in a fair bet, or the risk premium (RP). If the premium is positive, the decision maker is said to have an aversion to risk. If an individual prefers risk, as indicated by requiring a bribe to consent to forego the opportunity to engage in a fair bet, the risk premium is negative.

An action with a zero expected monetary value (a fair bet) is a special case. More generally, the risk premium for a risky action is the difference between its expected monetary value (EMV) and its certainty equivalent (CE). The CE of a risky action is the certain outcome that yields an identical level of satisfaction.

Risk aversion is a local measure; that is, its sign and degree can vary depending upon the stakes involved. Many people, for example, who whould willingly participate in the modest lottery described above, might be willing to pay a substantial premium to avoid the gamble if the stakes were inflated to $99,000 and -$1,000.

Most formal definitions of risk aversion rely on the Bernoullian conclusion, implied by the reasonable "axioms of preference" of ordering, continuity, and transitivity (von Neumann and Morgenstern), that risk preferences can be encoded in a utility function for money (income or wealth). Positive marginal utility of income, i.e., $U'(M) > 0$, is commonly assumed for the utility function. Within the framework of Bernoullian decision theory, which identifies the optimal risky action as that which maximizes expected utility, there are several measures which yield equivalent risk preference classifications. Table 1 summarizes the classification rules for five commonly used measures. The measures in Table 1 assume the existence of a utility function, U(M), and associated expected utility function, $EU(\mu,\sigma^2)$, which incorporates the mean and variance of the monetary outcomes of risky actions:

A Bernoullian utility function is unique only up to a positive linear transformation; that is, the same action will maximize expected utility for $Z = a + bU$, $b > 0$, as for U. In recognition of this property, Pratt developed $-[U''(M)/U'(M)]$ as a unique measure of absolute risk aversion which yields the same value for both Z and U. Pratt also defined $-[U''(M)/U'(M)]M$ as a measure of relative risk aversion. Definition (iii) in Table 1 directly measures the impact of a change in risk (σ^2) on expected utility. Definition (iv), attributable to Magnusson, represents the marginal rate of substitution between variance of income and expected income. This measure can be interpreted graphically as the reciprocal of the slope of an iso-expected-utility curve (see Figure 1). The risk premium for a_2 can also be illustrated graphically in Figure 1 as $(\mu_2 - \mu_1)$ = [(EMV of a_2) - (CE of a_2)]. Point a_1 is the CE of a_2 because it is the certain or zero-risk action which yields equivalent expected utility.

Table 1. Risk Preference Classification Criteria Within Expected Utility Framework

	Range of measure for		
Measure	Risk averse	Risk neutral	Risk preferring
(i) $U''(M)$	<0	=0	>0
(ii) $-U''(M)/U'(M)$	>0	=0	<0
(iii) $\partial EU/\partial\sigma^2$	<0	=0	>0
(iv) $(d\mu/d\sigma^2)_{EU=constant}$	>0	=0	<0
(v) risk premium	>0	=0	<0

In the safety first decision model, maximize $E(\Pi)$ subject to $\Pr(\Pi \leq D) \leq \alpha$, or maximize D subject to $\Pr(\Pi \leq D) \leq \alpha$, the magnitudes of α and/or D provide measures of risk aversion. For a given α, the higher is D or the desired "required minimum" income, the stronger the risk aversion.

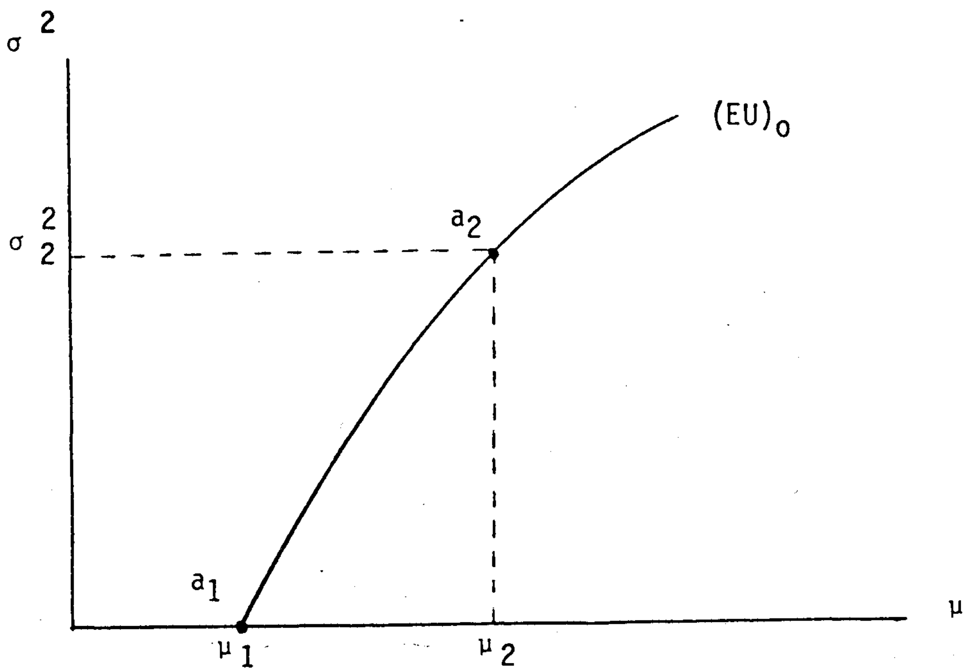

Figure 1. Iso-expected-utility curve

Similarly for a given D, a smaller α or "acceptable disaster exposure probability" indicates stronger risk aversion. If a corresponding certainty equivalent in terms of μ and σ^2 can be derived for a safety first decision rule, then risk aversion measure (iv) can be computed for a safety oriented decision maker as well (see Moscardi and de Janvry for an application).

Methods of Measuring Risk Preferences

Individual Risk Preference Measurement

Much of the lack of progress in our knowledge of producer risk preferences stems from lack of confidence in techniques for their empirical measurement. To increase understanding of the difficulties facing the empirical researcher in this area, four widely varying approaches to measuring risk attitudes are described and evaluated in this section. They are: 1) direct elicitation of utility functions (D.E.U.); 2) experimental methods (E.M.); 3) observed economic behavior with respect to factor demand and output supply (O.E.B.); and 4) other methods.

1. Direct elicitation of utility functions

Officer and Halter, and Lin, Dean, and Moore, and several others have directly elicited utility functions by interview procedures designed to determine points of indifference between certain outcomes and bets or risky options involving hypothetical gains and losses. The three best known variations of these interview procedures are referred to as the von Neumann-Morgenstern, modified von Neumann-Morgenstern, and Ramsey methods (Dillon; Officer and Halter). A new interview format recently proposed by Halter and Mason has potential for simplifying the process and making it more systematic. After a series of points in U-M space have been identified in the interview, an explicit utility curve can be fitted to the points by regression analysis.

The D.E.U. technique has been criticized as subject to bias arising from different interviewers, preferences for specific probabilities (for example, a 50:50 bet), confounding from extraneous variables, and negative preferences toward gambling (Roumasset; Binswanger, 1978a). Choice of an inappropriate functional form for the utility function can also lead to undesirable implications (Lin and Chang). Also, utility associated with the outcome of a particular risky action is probably dependent upon more variables than monetary gains and losses alone. Our inability to hold these other variables constant, or to properly include them in model specifications, while eliciting utility functions is likely to lead to substantial imprecision.

In our view, even if the above "technical" sources of bias could be removed by refined interviewing and econometric techniques, the representativeness of choices involving hypothetical gains and losses in a parlor game setting could be questioned. Does a utility function elicited in a short interview around a farmer's living room coffee table reflect his attitudes toward risk in real world decisions? In the latter case, unlike the former, he has much more time to consider a decision, can and often does solicit advice from family members and friends, and is fully aware that he must live with the consequences of his decision.

Although the preceding remarks indicate sources of considerable a priori concern, ultimate judgments on the validity of the D.E.U. approach should consider the ability of the approach to produce results that are in accord with observed economic behavior. The unique comparative study by Lin, Dean, and Moore evaluated Bernoullian utility, lexicograhic utility, and expected profit maximization models. The authors concluded that although the expected profit model was the poorest predictor, "None of the models predicted actual behavior well, with a strong tendency for all models to predict more risky behavior than was in fact observed" (p. 507). These results confirm the need for further progress in developing techniques for measuring risk preferences and incorporating them into predictive models. Also, more empirical tests of the performance of alternative methodologies, incorporating criteria of operational practicality, expense, and theoretical structure, as well as predictive capability, are needed. An important recent empirical comparison of the D.E.U. approach to a proposed experimental method is described below.

2. Experimental methods

Binswanger (1978a) has recently reported on an "experimental" method, drawing on psychological research, for measuring risk preferences of more than 350 peasants in rural India. This approach involved use of actual financial compensation at significant levels, was conducted in a series of several visits over five or more weeks with the respondent, permitted ample time to reflect on each decision and discuss it with others if desired, and required only a simple choice among eight gambles whose outcomes were determined by a flip of a coin. Impressive efforts were made to teach respondents the nature of the game, to elicit responses reflecting true feelings, to avoid interview bias, and to eliminate other sources of error. Binswanger developed the experimental approach after rejecting as a total failure an effort to measure risk preferences by the D.E.U. interview method. His field checks on the interview method revealed it to be subject to extreme bias, and to "radically mismeasure the real extent of risk aversion." Binswanger concludes "...that evidence on risk aversion from pure interviews is unreliable, nonreplicable and misleading, even if one is interested only in a distribution of risk aversion rather than reliable indvidual measurement" (1978a, p. 45). [Underlining is Binswanger's]

We believe that the realistic experimental approach utilized by Binswanger goes far in remedying some of the more serious measurement flaws of the D.E.U. method. We are less convinced that such games could be funded for realistic levels of gains associated with major farm decisions in the United States. Binswanger spent approximately $2,500 for prize money in his Indian experiment. He estimated a comparable experiment in the U.S. would require $150,000 for prizes alone--an amount he implies is not unreasonable given the cost of many modern research projects (1978b, p. 54).

3. Observed factor demand and output supply behavior

The doubts surrounding the validity of directly elicited utility functions have encouraged researchers to seek indirect measures of risk preferences. This approach compares observed economic behavior with respect to factor demand and output supply to behavior predicted by theoretical models incorporating risk and risk preferences. For example, the theoretical model developed by Moscardi and de Janvry from a safety first framework led to the first order conditions:

$$\text{(1a)} \qquad MVP_i^e = P_i/(1 - \theta K), \; i = 1, \ldots, n$$

where: MVP_i^e and P_i equal the expected marginal value product and the competitive price of input i, θ = the coefficient of variationof stochastic yield (output price was assumed constant); and K = the measure of risk aversion, analogous to (iv) in Table 1.

By observing the level of input usage of a particular farmer, inserting that level into an estimated production function, and evaluating the associated MVP_i^e, Moscardi and de Janvry were able to solve for the farmer's K, from

(1a) as:

$$(1b) \qquad K = \frac{1}{\theta}\,(1 - P_i/MVP_i^e)$$

More generally, expected utility maximization under risk leads to first order conditions of the form (Magnusson, p. 65; Anderson et al., p. 163):

$$(2) \qquad E(MVP_i) = MFC_i + R_a I_r, \quad 1 = 1, \ldots, n$$

where: $E(MVP_i)$ = expected marginal value product of input i; MFC_i = nonstochastic marginal factor cost of input i; and $R_a I_r$ = a "risk adjustment" that is a product of the entrepreneur's local risk aversion coefficient (R_a), as defined by difinition (iv) in Table 1, and the marginal contribution to risk of additional input use (I_r).

Assuming I_r is positive, risk aversion ($R_a > 0$) implies a positive "risk adjustment:" that is, a risk averse expected utility maximizing entrepreneur will "stop short" of equating E(MVP) to MFC.

Equation (2) suggests a theoretical approach for solving for R_a in terms of empirically observable magnitudes:

$$(3) \qquad R_a = [E(MVP_i) - MFC_i]/I_r$$

In practice, however, obtaining appropriate estimates of I_r can be difficult without invoking excessively restrictive assumptions on the sources and functional specification of stochastic influences.

Section five of this paper describes in greater detail an econometric approach proposed by Pope (1978a) that provides estimates of an assumed constant risk aversion coefficient under certain assumptions.

On the supply side, Brink and McCarl derived indirect estimates of risk aversion coefficients of 38 large Cornbelt farmers by comparing their elicited cropping plans to those predicted by a variation of Hazell's MOTAD linear programming model. The objective function of this model incorporated a risk aversion coefficient which was parametrically varied from zero (risk neutral) to high levels. The value of the risk aversion coefficient that minimized the difference between the model's predicted plan and the farmer's actual plan was selected to present the farmer's risk preferences.

The O.E.B. approach discussed above shares with the D.E.U. approach the advantage of furnishing measures of risk aversion that can be incorporated directly into models of economic decision making under risk. Furthermore, the O.E.B. approach escapes the compelling criticism that the revealed risk preferences may not be germane to real world decisions. Unfortunately, the O.E.B. method is vulnerable to serious errors of inference. Because it measures risk preferences on the basis of the difference between actual factor use or output supply levels and the levels associated with the (risk neutral) expected profit maximizing solution, it attributes the entire difference to risk aversion. In actual fact, a multitude of other explanations such as inaccurate or incomplete technical and market information, different resource endowments, capital constraints, different objective functions, and different subjective probability assessments could underlie some or all of the residual attributed to risk aversion. Moscardi and de Janvry (p. 711) recommend careful screening of the data to eliminate observations for which constraints other than risk aversion are likely to influence the results, but this is likely to be extremely difficult in practice.

4. Other Methods

Certain non-theoretical methods could also conceivably be used to acquire evidence on an individual producer's risk preferences. For example, a producer that chooses to acquire additional land on a crop share basis as opposed to cash renting, who forwards contracts or hedges his expected production, who purchases crop insurance, and who maintains maximum flexibility would merit a relatively high risk aversion index. Although this approach has some practical appeal, any index that could be constructed to measure the degree of use or nonuse of different risk management strategies would likely be arbitrary. This method, like the O.E.B. approach, would be subject to attributing behavioral differences to risk aversion that were due to other factors. For example, risk averse farmers may fail to hedge on the futures market simply because they are unaware of the opportunity or because no market exists for the commodities they produce.

Another approach to determining individual risk preferences is to utilize psychological or sociological classification criteria. For example, behavioral indices of willingness to bear risk could be constructed on the basis of an individual's rankings, assigned by himself or by third parties, on personality characteristics that are found to be correlated with risk attitudes (Jellison and Riskind). Rural sociologists and some agricultural economists (Feaster; Finley; Kivlin and Fliegel) have generally analyzed farmer risk bearing attitudes in the context of studies measuring innovativeness or technology adoption rates. Indices of willingness to innovate or adopt new techniques are generally assumed to be inversely related to risk aversion, and might provide an indirect index of risk preferences.

Although both the risk management strategy observation and the psychological index methods have some pragmatic appeal, they do not furnish coefficients of risk preferences that are derivable from explicit theories of decision making and, therefore, are difficult to incorporate into predictive models.

Aggregate risk preference measurement

Most public policy applications of risk theory require knowledge of the aggregate or "average" level of risk aversion of an entire industry or sector of producers, rather than of specific individuals.

Empirical efforts to estimate aggregate risk aversion or risk response have relied on variants of what we termed the O.E.B. method. Assuming variance of net returns increases as output increases, a risk averse entrepreneur will stop short of the point where marginal cost equals competitive expected price (Sandmo; Magnusson) resulting in a leftward shift of the firm's supply curve. If risk aversion prevails in the aggregate, industry supply will also be negatively related to perceived variability of net returns due to price instability. The desire to estimate the output effects and program costs of government price and income stabilization programs for farm commodities has motivated several researchers to incorporate risk variables in econometric models of supply response (Behrman; Just; Traill; Lin; Ryan). Consistent with the hypothesis of aggregate risk aversion, the coefficients on risk variables have generally been negative.

If interpersonal utility comparisons were judged permissible, it might be conceptually feasible to construct the utility function of an entire industry or group by appropriately aggregating the individual utility functions of a large representative sample of members of the group. Practical considerations would likely prohibit such an exercise however.

Lin and Moore (pp. 21-25) have noted some difficulties associated with econometric risk supply response models and have suggested a programming approach for eliciting an aggregate coefficient of risk aversion for use in a regional programming model incorporating risk preferences. Their suggestion makes use of a search procedure to identify the risk aversion coefficient at the aggregate level which yields production response closest to the actual one, in the context of mean and variance analysis.

Empirical Evidence on Risk Preferences of Agricultural Producers

Recognizing the limitations of the alternative techniques for measuring risk preferences, can we safely agree with John Dillon's (1977, p. 110) assessment that, "As a point of empirical fact, most decision makers are risk averse"? Table 2, which summarizes the findings of several studies which have used the D.E.U., E.M., and O.E.B. approaches for measuring risk preferences of agricultural producers, should help answer this question. Although the tabulation in Table 2 is not exhaustive, it is probably as complete as any compilation available in the literature to date.

One of the most striking revelations in Table 2 is the very small total number of agricultural producers whose risk preferences have been elicited. Furthermore, there was no attempt in most studies to achieve industry representativeness in sample selection. Prominent U.S. studies such as those by Brink and McCarl and Lin, Dean, and Moore were decidedly biased towards very large, high income farms. These sample limitations, combined with previously cited measurement problems, make any generalizations from the evidence in Table 2 to the general populations extremely tenuous.

One tentative conclusion is that farmers in less developed countries appear to be more uniformly risk averse than their wealthier counterparts in developed countries. Among the studies of Australian and American farmers, individuals manifesting risk preferring attitudes over at least some ranges were always observed when the measurement technique did not preclude this possibility. The classification technique utilized by Brink and McCarl permitted only risk neutrality and risk aversion which resulted in most of the sample being classified as risk neutral or slightly risk averse. Among the American and Australian studies, excluding Brink and McCarl, the percentage of the sample exhibiting risk neutral or risk preferring attitudes over at least some ranges varied from 0 percent (Webster and Kennedy, D.E.U. method) to 100 percent (Francisco and Anderson) and averaged about 50 percent. In conclusion, it is our judgment that the possibility of risk neutral or risk preferring attitudes over some ranges among a significant fraction of agricultural producers in developed countries cannot be excluded on the basis of the available evidence.

What systematic relationships, if any, between risk preferences and producer attributes can be deduced from the studies listed in Table 2? The greater incidence of risk aversion in developing countries is consistent with the widely accepted hypothesis of decreasing absolute risk aversion with respect to wealth. In fact, most scholars would likely be willing to assume risk aversion among farmers living close to the margin of subsistence on a priori grounds.

Only the studies by Moscardi and de Janvry, Dillon and Scandizzo, Binswanger, and Halter and Mason, among those reviewed, focused explicitly on

Table 2. Description of Empirically Measured Risk Preferences of Individual Farmers from the Literature

Source	Description of Sample	Method[a]	Sample Size	Percent Distribution of Sample by Risk Classification			
				Averse	Neutral	Prefer-ring	Mixed[b]
1. Binswanger	Indian farmers and landless laborers	E.M.					
		0.50 real[c]	119	71	0	19[d]	--[e]
		5.00 real[c]	117	84	0	9[d]	--[e]
		50.00 real[c]	118	89	0	2[d]	--[e]
		500.00 hyp.[c]	118	97	0	1[d]	--[e]
2. Conklin, Baquet, and Halter	Oregon orchardists (U.S.A.)	D.E.U.	8	37	0	13	50
3. Dillon and Scandizzo	Brazilian small farmers and sharecroppers	D.E.U.[f]					
		Owners, S.A.[g]	56	70	9	21	--[e]
		Sharecroppers, S.A.[g]	47	58	8	34	--[e]
		Owners, S.R.[g]	56	87	0	13	--[e]
		Sharecroppers, S.R.[g]	47	79	0	21	--[e]
4. Francisco and Anderson	Australian pastoralists	D.E.U.	21	0	0	5	95
5. Halter and Mason	Oregon grass seed growers (U.S.A.)	D.E.U.	44	33[h]	33[h]	33[h]	--[e]
6. Lin, Dean, and Moore	Large scale California farmers (U.S.A.)	D.E.U.	6	50	33	0	17
7. McCarthy and Anderson	Australian beef ranchers	D.E.U.	17	48	29	23	0
8. Officer and Halter	Australian wool producers	D.E.U.					
		I, MVM[i]	5	60	20	20	0
		II, MVM[i]	5	40	40	0	20
		I, RAM[i]	5	20	0	60	20
		II, RAM[i]	5	80	0	20	0
9. Webster and Kennedy	Australian sheep and grain farmers	D.E.U.					
		E.F.[j]	5	80	0	0	20
		MVM[j]	5	100	0	0	0
0. Brink and McCarl	Cornbelt farmers (U.S.A.)	O.E.B.	38	66	34	0	--[k]
1. Moscardi and de Janvry	Mexican peasant farmers	O.E.B.	45	100	0	0	--[k]

See next page for footnotes to this table.

Table 2. Description of Empirically Measured Risk Preferences of Individual Farmers from the Literature (continued)

[a] E.M., D.E.U., and O.E.B. refer to experimental, directly elicited utility, and observed economic behavior methods, respectively.

[b] The risk classification "mixed" includes that portion of the sample having utility functions with both risk averse and risk preferring regions within the relevant range.

[c] Binswanger derived local risk aversion coefficients from gambles with payoff levels of 0.50, 5.00, 50.00, and 500.00 rupees. (The reported daily wage for agricultural workers in the study area was three to six rupees.) Real financial payoffs were made for all but the 500 rupee game which involved hypothetical compensation. Binswanger argued that hypothetical gambles gave reliable results _if_ the respondents had previously participated in the real payoff games. Results presented here are from Table 4 in Binswanger (1978a, p. 17).

[d] Percentages do not sum to 100 because from 2.5 to 10.1 percent of the respondents were classified as "inefficient."

[e] Risk preference classifications were evaluated at a particular point so "mixed" classifications are impossible.

[f] Dillon and Scandizzo used the basic interview approach of the D.E.U. method, but did not actually fit utility functions.

[g] Risk preferences were elicited for owners and sharecroppers separately for two cases: with subsistence assured (S.A.) and with subsistence at risk (S.R.).

[h] Halter and Mason did not present an exact tabulation of risk preference classifications, but reported "that the number falling into each category was about equal."

[i] Officer and Halter derived utility functions for the same sample in two different time periods referred to as Stages I and II which were separated by a year. In Stage I, three models were used: von Neumann-Morgenstern, Modified von Neumann-Morgenstern (I, MVM), and Ramsey (I, RAM); in Stage II only two methods were used: Modified von Neumann-Morgenstern (II, MVM) and Ramsey (II,RAM). The results of the von Neumann-Morgenstern model used in Stage I are not present in Table 2 as this model gave the worst results, and was subsequently dropped from use in Stage II.

[j] Two methods were used: The (E,F)-Approach and Modified von Neumann-Morgenstern (MVM). The (E,F)-Approach elicited the farmer's tradeoff between expected income (E) and focus-loss income (F), where F is the "required minimum income" in the safety first formulation, maximize E subject to $Pr(\pi \leq F) \leq \alpha$.

[k] "Mixed" classifications were impossible because a constant risk aversion coefficient was assumed by the methodology.

the relationship between producer attributes and risk preferences. The results of regressing the individual risk aversion coefficients obtained for the Mexican farmers surveyed by Moscardi and de Janvry on various socioeconomic characteristics are summarized in Table 3.

The signs of the estimated relationships in Table 3 generally agreed with the authors' hypotheses. The significant negative relationships between risk aversion and land under control and off-farm income are consistent with the hypothesis of decreasing absolute risk aversion with respect to wealth.

Dillon and Scandizzo's results from Northeastern Brazil revealed sharecroppers to be less risk averse on the whole than owners. They also found a higher degree of risk aversion for choice situations where subsistence was at risk.

Table 3. Regression Estimates: Risk Aversion Versus Socioeconomic and Structural Characteristics

Variables in Logs	Regression Coefficient	t-value
Intercept	2.079950	1.9248
Z_1 = age	0.632502	1.0728
Z_2 = schooling	-0.121252	-0.4496
Z_3 = family size	-0.011686	-0.0424
Z_5 = off-farm income	-0.091616	-2.0901
Z_6 = land under control	-0.477450	-3.0141
Z_7 = solidarity group membership	-0.365100	-2.3103
	R^2 = 0.37	F = 6.78

Source: Moscardi and de Janvry, p. 716.

The most thorough examination of relationships between farmer characteristics and risk preference is found in Binswanger's (1978a) study involving peasant farmers in rural India. Binswanger computed a very large number of cross-sectional regressions utilizing different definitions of risk aversion as the dependent variable, different sets of independent variables, various functional forms, different subsets of the farmer sample, and alternative ways of handling respondents who made inefficient choices. Binswanger computed separate equations for games involving different levels of gains because an individual's degree of risk aversion often changed as the "stakes" were raised.

In summary, Binswanger found:

> Wealth appears to have surprisingly little effect on the extent of risk aversion. Schooling tends to reduce risk aversion, while prior luck in the sequence of games consistently reduces risk aversion. Other personal characteristics [sex, progressiveness dependency ratio, amount of land rented, and age, among others] have less clear impact and, in any event, given the similarity of risk attitudes, the quantitative impact of most variables on the extent of risk aversion is modest (Binswanger, 1978a, p. 1).

Although studies such as those by Binswanger, Moscardi and de Janvry, and Dillon and Scandizzo suggest fruitful hypotheses and methodologies, the vast differences between the peasant settings of these studies and modern commercial agriculture probably preclude generalizing the results to farmers in developed countries. Consequently, Halter and Mason's results for 44 Oregon grass seed growers interviewed in 1974 are of considerable interest. The results of regressing Pratt's absolute risk aversion coefficient, evaluated at each respondent's reported 1973 gross income, on selected socioeconomic characteristics are reported in Table 4.

The significant negative linear relationship between education and risk aversion is consistent with Moscardi and de Janvry's and Binswanger's results. The positive and negative relationships of percent ownership and age, respectively, with risk aversion depart from the results of the developing country studies and probably contradict the a priori hypotheses of many observers. However Halter and Mason caution 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 (Halter and Mason, p. 107).

For example, when interactions are considered, Halter and Mason point out that advancing age was associated with increased risk aversion for college graduates, but reduced risk aversion for high school and grade school graduates. Also, percent ownership was associated positively with risk aversion for grade school graduates but negatively for college graduates.

Table 4. Regression Estimates: Local Risk Aversion Versus Social and Economic Characteristics

Variable	Regression Coefficient	Student's "t" value
Constant	11.547	1.64
Percent owner	0.192	4.70
Education	-6.793	-2.38
Age	-2.088	-2.24
Education squared	1.088	3.02
Percent owned x education	-0.060	-4.08
Education x age	0.587	2.07

Source: Halter and Mason, Table 2.

Halter and Mason's results suggest interesting hypotheses. However, due to the specificity of their sample and to the unresolved doubts surrounding the measurement reliability of the D.E.U. approach, further empirical and theoretical investigation is necessary before these results could be generalized to broader populations.

Potential Uses of Producer Risk Preferences: Review and Research Recommendations

Before it is possible to recommend directions for future research on risk preferences, we believe it is necessary to address the fundamental questions: Why is it necessary to know producer risk preferences in the first place? Or more specifically, what potential uses does this knowledge have? Answers to these questions are important for two reasons. First, it is impossible to frame hypotheses or identify appropriate methodologies outside the context of the particular predictive or prescriptive problem at hand. Second, recognizing the added cost of measuring risk preferences and the unproven reliability of the measures, it is necessary to evaluate within the context of the specific problem whether attempted measurement is worthwhile. For many problems, some alternative approach may be more appropriate.

In light of the preceding argument, implications for future research are discussed under the following four potential areas of application: 1. tailoring farm management extension recommendations to the manager's risk attitudes; 2. designing rural development and technology transfer programs; 3. aggregate policy evaluation models; and 4. microeconomic policy or predictive applications.

Farm Management Extension Applications

Fertilizer application rates (de Janvry), enterprise diversification strategies (Lin, Dean, and Moore), cattle stocking rates (Dean et al.), and weather protection strategies (Baquet et al.) are a sampling of the farm management decisions that have been examined in the literature where the manager's risk preferences could influence the "optimal" decision. Given the pervasive influence of uncertainty in agriculture, most other agricultural production, marketing, and financial decisions could be added to this list.

The desire to tailor extension farm management programs to the current risk preferences of particular farmers provides one potential justification for measuring individual risk preferences. Although this application is recommended by some advocates (Makeham, Halter, and Dillon), we believe the time, cost, and practical problems associated with direct elicitation of utility functions are likely to limit their use in extension programs. Budget and manpower limitations generally prevent extension programs from providing much one-to-one advice of any kind. Even if researchers were to hand an extension worker an elaborate set of equations relating risk aversion at all relevant loss and gain levels to personal and business attributes for farmers in his district, the personal and evolutionary nature of attitudes toward risk would probably prevent their confident application to specific individuals. There likely exists considerable heterogeneity in risk preference among individuals with superficially common business and ecnomic characteristics (recall evidence in Table 2). Furthermore, an individual's willingness to bear unidimensional monetary risk is likely to change from situation to situation given the multidimensional nature of most decisions.[2] Changing objectives, information, and constraints may make an individual's single-attribute risk aversion coefficient an elusive moving target.[3] Neither farmers nor field extension personnel are likely to consent to obtaining personal updatings of utility functions or safety first margins every time a new recommendation is given.

In light of the above discussion, what should extension specialists and researchers interested in developing materials and models with extension applications do? It seems clear that risk should not be simply ignored as it often has been in the past, but it is also clear that an ambitious campaign to elicit and catalogue momentary risk preferences is unlikely to be a wise use of resources given the current state of the art.

Addressing the extension issue first, we recommend that emphasis be placed on providing information on alternative strategies and their outcome probabilities and on teaching principles of decision making under uncertainty, rather than providing tailored substantive recommendations. These principles should include the importance of considering all realistic options, assessing the probabilities of outcomes, and assessing one's willingness and ability to bear the risk associated with the particular decision. The approach recommended here has been followed by a recent national SEA-Extension special needs project entitled "Dealing with Risk in Making Farm Decisions." The leaders of the project, A. Gene Nelson and Ted Nelson of Oregon State and Oklahoma State Universities, and their associates have assembled and developed a wide variety of valuable educational materials to assist extension workers in teaching farmers principles of decision making and information utilization.

The primary implication for researchers constructing models for extension applications is that any individual risk aversion parameters required by those models should be sufficiently simple and intuitive that they could be supplied by the farmer himself. Perhaps this means that the parameters should sometimes be of the safety first type rather than expected utility theory based risk aversion coefficients. An example of such an intuitive risk aversion parameter is the minimum number of years out of 10 that a farmer wants to cover at least the cost of fertilizer as a result of fertilization (de Janvry). If extension applications of a decision model require eliciting formal utility functions, the chances for its utilization are probably fairly remote.

Another reasonable approach for researchers constructing decision models for extension applications is to use financial ability to bear risk as a proxy for willingness to bear risk. The justification for this approach is the presumed close relationship between ability and willingness to bear risk. This reasonable relationship apparently underlies the widely accepted hypothesis of decreasing absolute risk aversion with respect to wealth. Examples of risk aversion rules based on financial ability to bear risk are requirements that the probability of being forced into bankruptcy, forced to restructure debt, or falling above a certain debt/asset ratio be less than a certain specified value, α. The main advantage of this approach is that it relies primarily on relatively well understood and accessible financial and wealth position characteristics of the firm. A reasonable outlet for individual farmers to inject differential feelings about risk bearing is through adjustment of the α coefficient.

Researchers can also provide useful information to extension workers by ranking management choices by their risk efficiency using rules of stochastic dominance. One of these rules, Meyer's criterion, is discussed at length in section five of this paper.

Technology Transfer and Rural Development Applications

Moscardi and de Janvry justify their elaborate effort to estimate individual risk aversion coefficients for peasants in Puebla, Mexico, on the following basis:

> Attitudes toward risk are major determinants of the rate of diffusion of new technologies among peasants and of the outcome of rural development programs. If they are going to be

> effective, new technologies and rural development programs need to be tailored to the attitudes toward risk of particular categories of peasants (Moscardi and de Janvry, p. 710).

While this argument is probably true, estimating single-attribute risk aversion coefficients and relating them to socioeconomic variables is an incomplete and awkward approach to the problem at hand. There are a number of factors that determine willingness to adopt new technology or to participate in rural development programs other than single-attribute risk aversion. If technology adoption or development program participation is of primary concern, it seems appropriate to use these phenomena as dependent variables directly, and to include all relevant factors as independent variables, as has been done in several agricultural economics and rural sociology studies within the development literature (for example, see Rochin and Witt; Feaster; Finley). A review by Havens of variables commonly used in technology adoption studies listed: (1) size of operation, (2) education (3) social status, (4) contact with information, and (5) social participation. Other variables such as age, local group identification, opinion leadership, management practices, and attitude toward credit have also been used but less frequently.

Although we have argued that estimating individual risk aversion coefficients may not be the most effective approach to planning rural development and technology transfer programs, there are other policy and predictive applications for such coefficients in development research (e.g., Sutinen). Recognizing the proximity of many developing country farmers to the margin of subsistence, and the absence of institutional provisions to protect individuals from unfortunate economic outcomes in such countries, we think it is generally reasonable to assume risk aversion a priori in such settings as done in studies by Sutinen and Wolgin. Wiens' results for Chinese peasants confirm the existence of substantial risk aversion which tended to decline with increasing farm size.

Aggregate Policy Evaluation Models

It is our consensus that estimating risk response coefficients econometrically in industry supply models provides the best approach to accounting for the effects of aggregate behavioral responses to induced changes in market risk. The primary advantages of this approach are: (1) It directly provides quantitative measures of changes in the quantities of policy interest, specifically projected price and output, and producer and consumer surpluses. (2) It offers flexibility in the inclusion of alternative formulations of producer expectations of prices and risks. (3) It permits direct incorporation of government policy variables. (4) The level of geographic aggregation (state, regional, or national) and crop type (spring or winter wheat, irrigated or nonirrigated acreage, etc.) can be chosen by the researcher. (5) These equations can be estimated from generally accessible aggregate time series data.

Given the consensus on the appropriateness of econometric risk supply response models for industry-wide policy evaluations, we recommend that researchers concentrate on methodological refinements along the lines suggested by the previously listed 1978 WAEA paper by Lin.

Microeconomic Policy and Predictive Applications

We have argued that farm management extension, development program planning, and aggregate public policy model applications generally do not justify measurement of individual risk preferences, or at least not formal measures based on directly elicited utility functions. There is a fourth area, however, which we loosely refer to as microeconomic policy and predictive applications, where such measures could be justified. The studies by Baquet, Halter, and Conklin; Harris and Nehring; and Lin, Carman, Moore, and Dean (LCM & D) provide examples of such microeconomic policy and predictive applications. Banquet et al. incorporated producer risk preferences in an attempt to compute the value of publicly supplied weather forecast information to southern Oregon orchardists. Harris and Nehring incorporated the degree of risk aversion into a theoretical model for determining the maximum bid price for an acre of land by farmers in different farm size classes; they assumed absolute risk aversion to be the same for all farmers in a given size class. LCM & D examined how individual risk preferences could influence the impact of income tax provisions on output and risk taking behavior.

For studies in this category, knowledge of the "typical" risk preferences characterizing a particular class of farmers, rather than those of individual farmers, are often needed to generalize the policy implications of the results. This is an important distinction since it is not at all certain that risk preferences within such classes are the same.

We shall address the following three important questions concerning the incorporation of risk preferences in microeconomic policy and predictive studies: 1. Does the sensitivity of the results to risk preferences and practical research feasibility considerations justify incorporation of risk preferences? 2. Which hypotheses concerning relationships between risk preferences and producer attributes should be tested? and 3. What promising methodologies are available for measuring risk preferences and establishing relationships between risk preferences and producer attributes?

1. Sensitivity to risk preferences

The sensitivity issue requires assessing whether deviations from risk neutrality (expected profit maximaization) are likely to have much impact on the results. In the studies by LCM & D and Harris and Nehring it is fairly obvious that they will. LCM & D show theoretically how the configuration of risk preferences could determine whether income taxes will cause a shift to a less risky, more risky, or equally risky crop diversification plan. Risk preferences manifested in their sample generally predicted increased output and risk-taking due to the income tax provisions existing during the early 1970's. Harris and Nehring used a "composite" utility function derived from Lin, Dean, and Moore's study that was characterized by decreasing absolute risk aversion with respect to wealth and thereby farm size given the assumptions of their study. Based on this utility function and on other characteristics of the farm size classes used in this study the maximum bid price for land was revealed to be quite sensitive to risk aversion, especially for the smallest (Class IV) farms examined. Risk aversion lowered the predicted maximum bid prices by 2.3, 6.0, 6.9, 5.4, and 25.0 percent, respectively, for their Class 0, I, II, III, and IV farms which ranged in average size from 1,307 acres (Class 0) to 170 acres (Class IV). Based on the eight producers examined by Baquet et al., risk aversion increased the average value of frost forecasts per acre per day by \$0.66 or \$39.60/acre per season. This represented an increase of 14 percent over the risk neutral value.

There is no easy answer to the question of whether the added precision or policy relevance, if any, of incorporating risk preferences in such studies is worth the cost. The danger is that the difficulty or cost of eliciting utility functions for more than a small, possibly unrepresentative, sample of farmers will reduce the studies to methodological excursions rather than practical policy evaluation tools. This danger seems to have been realized, at least in part, in both the Baquet et al, and Harris and Nehring studies as reflected in the following qualifications of their results:

> The value of the forecast derived here is specific to the eight orchardists and their environmental conditions, and extrapolation to all orchardists in Jackson County cannot be made without assumptions regarding the risk philosophies and other input data of the unsampled orchardists...general recommendations as to appropriate frost protection strategies for all orchardists cannot be made and the value of the forecast for the entire county cannot be determined (Baquet et al., p. 519).

> [Use of the composite utility function from the Lin, Dean, and Moore study] requires two somewhat heroic leaps of faith -- that the LDM sample was representative of California farmers and that Iowa farmers, in general, have a utility function similar to that of their California counterparts. Because this numerical example was designed to be illustrative rather than definitive, however, it was thought to be worthwhile to pursue the risk consideration on the basis of the LDM utility function (Harris and Nehring, p. 166).

The question researchers must seriously ask themselves, especially for applications where results are not highly sensitive to risk preferences, is whether ignoring risk preferences will increase their chances of developing quantitative results for a larger and more representative sample of the population so that their conclusions will be of practical value to policy makers.

On the other hand, for applications where results are highly sensitive to risk preferences, efforts may be warranted in obtaining reliable risk preference measurements for appropriate representative samples of farmers. Analysis of the distributive impacts of risk modifying policies will often fall into this category.

2. Selection of hypotheses

Turning to the second question, it is clear from the discussion of the studies above that the specific problem will determine which hypotheses concerning relationships between risk preferences and producer attributes should be examined. That aside, we feel there are two groups of hypotheses that are likely to be of primary importance to most studies. The first group includes the relationship between risk preferences and structural features, especially farm size and legal form of ownership. For example, are larger or corporate farmers generally less risk averse than small or family farmers who are sole proprietors? The second, not unrelated, group of hypotheses involves examining the frequently assumed positive relationship between accounting measures of financial ability to bear risk and willingness to bear risk. Empirical research on these two groups of hypotheses are crucial to examining the important, but much neglected, dynamic structural implications of uncertainty in agriculture and of public policies to mitigate income instability. Equally important is the need to examine the differential historical capacity of farms of different sizes and types to survive and to maintain profitability under price and yield instability. Studies by Lin and Ingerson, Anderson, and Moore provide tentative evidence that small farms may benefit relatively from increased income stability, but much more empirical work is needed in this area.

3. Methodological options

Turning to the third question, which methodologies appear most fruitful for measuring risk preferences for use in microeconomic policy and predictive applications? Again, the answer will depend upon the specific problem. If the problem strictly requires risk preferences of individual producers rather than "typical" preferences of designated classes of producers, we believe the experimental method as utilized by Binswanger is most likely to provide reliable replicable measures of risk aversion, assuming the method is adequately funded and conscientiously executed. If particular care is taken to frame the questions in a realistic decision context and to avoid other sources of bias, the D.E.U. method offers a possible lower cost alternative. However, the damaging results emerging from Binswanger's comparison of the D.E.U. and the E.M. approaches indicate extreme caution should be exercised in relying on the results of the D.E.U. method.

If average risk preferences of designated classes of farmers are required, two methodological options are available. The first approach is typically carried out in two stages: (1) to estimate risk aversion coefficients for a large sample of individuals whose members vary according to the class attributes of interest; and (2) to describe the relationship between risk aversion level and personal or business attributes. Regression analysis and multivariate statistical techniques are statistical tools which can be used to describe these relationships (Binswanger, 1978a; Dillon and Scandizzo; Moscardi and de Janvry; and Halter and Mason).

The second approach would be to estimate aggregate risk aversion coefficients or risk responses of designated classes of farmers directly with econometric or risk programming models. Utilizing a risk programming approach, Weins estimated the risk aversion coefficient of small-scale peasant farmers in China to be approximately ten-fold that of larger-scale farmers. Alternatively, the econometric approach associated with risk supply response models could be applied to selected subsamples of the population; that is, separate equations could be calculated for small farms, large farms, or other classes of interest to obtain a measure of differential risk response. The problem under study could determine the dependent variable of interest such as acreage planted, bid prices for land, or frequency of utilization of selected strategies.

Carlson, for example, included a risk variable in an equation to explain the market price of semen from different dairy sires. His results revealed a negative coefficient on the risk variable indicating the dairymen in his sample imputed a "risk discount," on the average, to semen from young and unproven, and thereby more risky bulls.

We recommend that risk response models which bypass the direct estimation of formal risk aversion coefficients to focus directly on the measured impact of risk on the variable of interest be seriously considered whenever their estimation is feasible from available data. In our judgment, data availability is likely to pose the greatest constraint to the use of this method. Aggregate time series data are unlikely to be available, for example, to estimate separate risk-response acreage supply functions for small and large farmers.

Some Promising Methodological Developments

It seems clear that there are certain carefully selected problems for which formal measures of risk aversion of individual producers are required. In these situations we recommend serious consideration be given to Binswanger's experimental method or to refined versions of the D.E.U. approach such as that suggested by Halter and Mason. However, many policy and managerial applications require information on the approximate preferences of risk behavioral response of a certain group or class of farmers rather than for individuals. Two recent methodological developments which appear particularly fruitful for handling such problems are discussed in this section. They are:

1. Meyer's stochastic dominance criterion for identifying risk efficient action choices for a class of decision makers whose risk aversion functions fall between certain upper and lower bounds.
2. Econometric estimation of risk aversion coefficients.

Meyer's Stochastic Dominance Criterion

Efficiency criteria offer an alternative to directly elicited utility functions for finding preferred action choices. Efficiency criteria identify an efficient subset of all possible action choices from which well-defined classes of decision makers can find their expected utility maximizing action choice. How narrowly the class of decision makers is defined determines how many action choices are included in the efficient set.

Most efficient sets apply to classes of decision makers that can be defined using Pratt's coefficient of absolute risk aversion (measure ii in Table 1). Consider the classes of decision makers defined by first degree (FSD) and second degree (SSD) stochastic dominance. FSD finds the efficient set for all decision makers who prefer more to less, i.e., those for whom marginal utility of income is positive ($U'(M)>0$). Hence, the value of Pratt's coefficient of absolute risk aversion is unrestricted and the criterion finds an efficient set from which risk averse, risk neutral, or risk preferring in-individuals can find their expected utility maximizing choice.

SSD applies to a more narrowly defined class of decision makers than FSD. It requires that, in addition to positive marginal utility of wealth, marginal utility of wealth be decreasing ($U''(M)<0$). In terms of Pratt's measure, defined in Table 1, it restricts the coefficient of absolute risk aversion to be positive and applies only to the risk averse class of decision makers. Now only risk averse investors can be sure they will find their preferred action choice in the SSD efficient set.

The most restrictive efficiency criterion would be the class of decision makers identified by a single-valued utility function. In terms of Pratt's cooefficient of absolute risk aversion, this class of decision makers is identified by a single line equal to:

$$(1) \quad R(M) = \frac{-U''(M)}{U'(M)}$$

Jack Meyer suggested a new efficiency criterion which he called stochastic dominance with respect to a function. His suggested criterion offers a powerful alternative to existing criteria because it allows the definition of the efficient set to be more flexible than a single line defined by a utility function or the positive half space or whole space of risk aversion coefficients defined by SSD and FSD. Meyer deduced a method that identifies an efficient set for decision makers whose risk aversion measures are bounded by some lower ($R(M)_L$) and some upper ($R(M)_U$) risk aversion functions:

$$(2) \quad R(M)_L < R(X) < R(M)_U$$

Graphically, this might include the class of decision makers in Figure 2.

The potential application of Meyer's criterion seems promising. Robison and King demonstrated how this criterion can be used with Monte Carlo programming as the evaluative criterion -- i.e., a subroutine in the program which replaces the utility funciton as a means for determining preference between action choices. Thus, it identifies an efficient set for investors whose risk aversion function is bounded by some specified lower and upper limits.

Of course, much work remains to operationalize Meyer's criterion. Meyer's interval valued criterion appears to be an improvement over existing criteria. FSD and SSD, in most cases, fail to restrict the efficiency set to manageable numbers, particularly, when used in connection with Monte Carlo methods (see Anderson, 1975). Single-valued utility functions on the other hand, reduce the efficient set too much. In some cases the differences between the expected utilities of two action choices may not be statistically significant. Yet, as long as there is a difference, a single-valued utility function will indicate preference. Thus, the probability for rejecting an acceptable action choice from the efficient set may be large when the criterion is a single-valued utility function.

The next step to operationalize Meyer's criterion is to develop methods for measuring bounds on risk aversion functions for well-defined classes of decision makers. This question is being actively researched at Michigan State and some promising early results have been produced.

Econometric Estimation of Risk Aversion Coefficients

Econometric analysis of production usually is applied at some more aggregate level than the firm. Further, the methodologies vary considerably for cross section versus time series applications. The discussion here is perhaps relevant only to time series (or time series-cross section).

It is helpful initially to categorize in a general way the approaches utilized under certainty.

Primal: 1. Estimate a production function and use estimated parameters to make economic inferences (Hoch); 2. Estimate marginal conditions (from profit maximization); 3. Combine 1 and 2 into a complete system; 4. Estimate restricted reduced forms (Nerlove); and 5. Estimate arbitrarily constructed reduced forms without making any explicit assumption on the profit function (the most common approach).

Dual: 6. Estimate cost function parameters (often assumes an explicit primal problem, Nerlove); 7. Using Shepard's lemma, estimate a cost function and constant output factor demands or cost share equations (e.g., Binswanger, 1974); and 8. Using McFadden's lemma, estimate a profit function, factor demands, and output supplies (Lau and Yotopolous).

Assuming uncertainty and response to more than expected profit, it appears that only two of the above mentioned approaches have been empirically implemented.

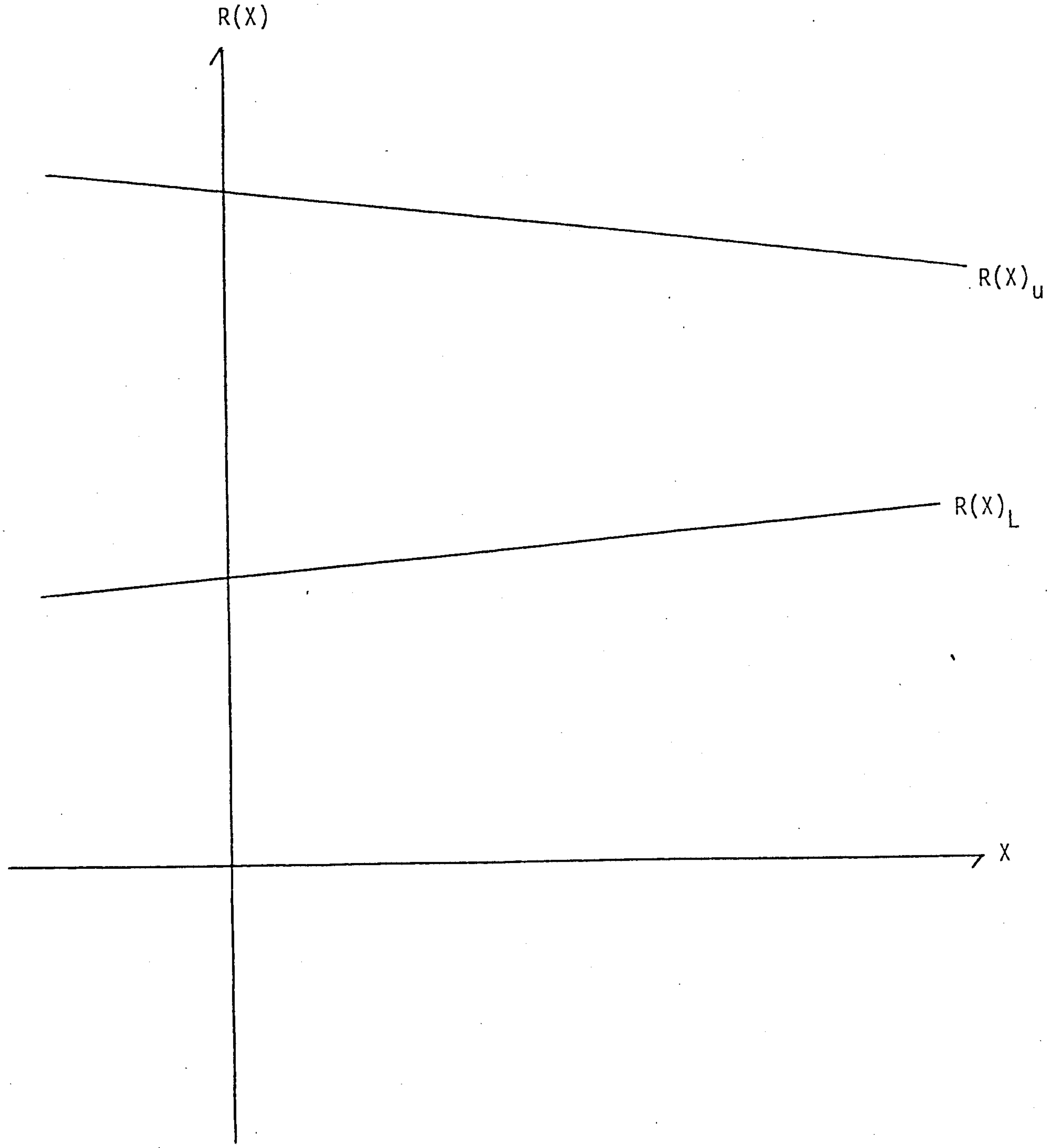

Figure 2. A Class of Agents Whose Risk Aversion Coefficients are Bounded by $R(x)_u$ and $R(x)_L$.

Wolgin estimated production functions and moments of revenue and analyzed calculated marginal conditions (see 1) to examine their conformity with risk aversion. In general, the analysis supported the hypothesis of risk aversion. Yet, no statistical test for risk aversion was conducted.

The second approach to risk response is that utilized by Behrman, Just and others. These studies are the risky counterparts to 5. No explicit behavioral model is specified, and hence, no rationality of behavior is imposed or tested. Finally, no hypothesis regarding risk aversion can explicitly be tested unless explicit behavioral assumptions are made. For these reasons (and for statistical efficiency), it seems fruitful to explore adaptation of other certainty methodologies to risk aversion.

Though Pope (1978b) has considered dual approaches under risk, the most straightforward adaptation appears to be associated with 3. It seems, however, that risk aversion inevitably leads to nonlinear equations when the objective function is based upon expected utility models. However, this problem is diminished when the utility function is represented as a simple mean-variance function with constant risk aversion. For the case of a Cobb-Douglas production function and price risk (and two outputs), the marginal conditions for a firm maximizing $EU = \mu - (\lambda/2)\sigma^2$ where μ = expected farm profit, σ^2 = variance of profit, and λ is a risk aversion coefficient are:

$$S_{ij} = \alpha_{ij} - \lambda\alpha_{ij}\left[q_j \frac{V(P_j)}{E(P_j)} + q_{j'} \frac{\text{Cov}\,(P_j, P_{j'})}{E(P_j)}\right] \qquad j', j=1,2 \quad i=1...N$$

where S_{ij} is the profit share of the ith input in the jth output evaluated at expected price, α_{ij} is the corresponding Cobb-Douglas elasticity, λ is a risk aversion parameter, q_j and $q_{j'}$ are the quantities of output j and j' respectively with P_j and $P_{j'}$ the respective output prices, V denotes variance, Cov denotes covariance and E is expectation. The subtleties of estimation of the above system and extensions to production uncertainty will not be discussed here (see Pope, 1978a). The point to be emphasized here is that within a socioeconomic class λ may be treated as fixed and hence, estimated (and tested for risk aversion, $\lambda = 0$). Using Chow type tests, one could test for differences in λ across groups. Alternatively, one could include an equation $\lambda = \lambda$ (T) where T is a group of socioeconomic variables (since λ is unobservable, Goldberger's procedures for unobserbable dependent variables are applicable). Pragmatically, however, such data on T are likely unavailable.

It would appear that the major virtue of this approach would center on efficient estimation of λ and associated tests for risk aversion. The essential point is that little attention has been paid to incorporating risk into the full range of methodologies customarily based upon profit maximization under certainty.

Summary of Principle Recommendations

This section presents the subcommittee's general conclusion on the desirability of a coordinated region-wide effort to elicit producer utility functions, and summarizes our various methodological recommendations for different research and extension problems. We recognize that general agreement by project participants on all the recommendations presented here is unlikely. We do hope, however, that these recommendations will provoke a thorough discussion of the issues involved and thereby provide a sounder basis for future individual and group research planning.

The recommendations are listed below beginning with the general conclusion and followed by the specific methodological suggestions.

1. A coordinated regional program to elicit individual utility functions for a large sample of producers, stratified by business and personal characteristics is not recommended at the present time. The file of utility functions that would be generated by such a program is considered likely to be surrounded by questions of measurement reliability, to have a relatively short shelf life, and to have limited applicability to specific extension and research problems.

We recommend instead that direct elicitation of individual utility functions be conducted only by individual project participants, or groups of participants, who are undertaking selected microeconomic policy and predictive analyses which require such information. In these cases, risk aversion coefficients should be measured for a specific, relevant sample as close as possible to the point in time when the decision is to be made. Such measurement is recommended when the results are demonstrably sensitive to individual risk preferences, and it is feasible to measure preferences of a sufficiently large and representative sample to permit generlizing policy conclusions to the relevant population. For these analyses we encourage serious consideration be given to Binswanger's experimental method which, on the basis of the limited evidence available, appears most promising in terms of reliability and accuracy. Where cost prohibits use of the experimental approach, we recommend refined versions of the D.E.U. method, such as that proposed by Halter and Mason.

While acknowledging the applied orientation of this regional project, we recognize there is scope and need for additional methodological refinement of individual risk preference measurement techniques by interested project participants. Also, there is a great need for empirical comparisons of the utility elicitation approach, experimental methods, and other techniques already developed to ascertain their relative feasibility and reliability. Final recommendations on individual risk preference measurement must await these empirical results.

In summary, given the primarily applied research mission of this regional project, we believe that problem definition must precede the decision to measure, and how to measure, risk preferences. This is important because so many managerial and policy analyses, as identified in the recommendations below, are better served by methods of incorporating risk considerations that do not rely on directly elicited individual utility functions. While future progress toward reliable, practical, and low-cost techniques for eliciting individual risk preference may reverse this conclusion, we believe the rudimentary state of development of current measurement techniques, plus the availability of alternative methods for many problems, counsels against a region-wide utility function elicitation campaign at this time.

2. Routinely eliciting individual utility functions to tailor farm management extension recommendations to a farmer's current risk preferences is not considered practical given the current state of the art. We recommend instead that:

a. Farm management extension specialists provide more and better information on alternative decision options and their objective outcome probabilities. They also should devote more effort to teaching principles of decision making and information utilization.

b. Researchers constructing normative decision models for use by farmers should use risk aversion parameters that are sufficiently simple and intuitive that they can be supplied by the farmer himself. Alternatively, these models might incorporate decision rules that depend upon objectively measurable financial ability to bear risk.

c. Researchers can rank decision options on the basis of rules of stochastic dominance. Meyer's criterion for identifying risk efficient decisions for decision makers whose risk aversion functions fall between certain bounds is a particularly promising method for certain prescriptive risk models.

3. Direct measurement of risk preferences of peasant farmers is not considered the most efficient method for predicting their willingness to adopt new technology or participate in rural development programs. We recommend analysis of historical experience using technology adoption or development program participation as dependent variables and including a broad range of independent variables relevant to the specific situation. In some applications, we believe it is reasonable to assume risk aversion a priori for developing country farmers given their precarious economic status.

4. For industry-wide policy analyses and other aggregate predictive applications, we recommend the conventional technique of estimating aggregate risk supply response (or other behavioral response) equations directly from aggregate data.

5. Where adequate data permit their estimation, we recommend consideration be given to direct econometric estimation of risk sensitive behavioral response functions for certain microeconomic predictive and policy analysis models incorporating risk.

6. Where average or typical risk aversion coefficients for specified groups are required, we recommend investigation of econometric procedures for deriving risk aversion coefficients. Data limitations, vulnerabiltiy to errors of inference, and rather restrictive underlying assumptions may constrain the use of this approach, however.

7. Farm size, legal form of ownership, and financial measures of ability to bear risk are producer attributes whose relationship to risk preferences particularly merit empirical research. The impact of changing risk levels on the historical survival and profit performance of varying types and sizes of farms also deserves further examination.

Footnotes

1. This support is based on a poll of the W-149 membership conducted by Charles Moore during early 1977 as reported in his memorandum of May 9, 1977, to Kenneth Farrell.

2. The equivalent terms unidimensional or single-attribute risk aversion are used to denote that the underlying utility function is a function of monetary income alone.

3. The issue of the stability of risk preferences is ultimately an empirical question whose resolution would require longitudinal studies. An alternative hypothesis is that risk preferences are relatively stable over time, but that changing behavior under risk is due to varying constraints and changing subjective assessments of expected values and variances. The area of expectation formation processes requires more research to satisfactorily resolve this question.

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