Iran Agricultural Research 15:187-201 (1996)

MEASURING AND INCORPORATING ATTITUDES TOWARD RISK INTO MATHEMATICAL PROGRAMMING MODELS: THE CASE OF FARMERS IN KAVAR DISTRICT, IRAN

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(Received: September 21, 1996)

ABSTRACT

This paper contributes to the literature on risk analysis in developing country agriculture by quantifying the risk attitude for a sample of the farmers from Kavar district of Fars province, Iran. The Equally Likely Certainty Equivalent interview technique with imaginary payoffs was used to elicit the preference functions of farmers. It was found that all sample farmers were risk averse. However, there existed no higher risk takers in a particular village. The results of this study also suggested that risk aversion declines with farm size. The direct expected mathematical programming method was then adopted to compare the actual behavior of the representative farmers with their predicted behavior. The modeling results indicated that risk aversion, especially of small and medium farmers, has significant impacts on farmers' cropping decisions. Considering the high proportion of small and medium sized farms in Iran, knowledge of farmers' risk preferences is useful in rural development strategies and in the development and transfer of prospective technologies.

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تحقیقات کشاورزی ایران

(۱۳۷۵) ۲۰۱-۱۸۷ : ۱۵

اندازه‌گیری ودر نظر گرفتن گرایش کشاورزان به مخاطره در برنامه‌ریزی ریاضی : مطالعه موردی کشاورزان منطقه کوار ، ایران

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چکیده

روش‌های مختلف تعیین گرایش بهره برداران کشاورزی به مخاطره موزد بررسی و ارزیابی قرار گرفت و با توجه به برتری های روش "معادل مطمئن محتمل برابر" از آن برای برآورد توابع مطلوبیت و همچنین ضرایب خطرگریزی کشاورزان منطقه کوار در استان فارس استفاده شد. نتایج این مطالعه نشان داد که: اولا" همه کشاورزان مورد مطالعه، خطرگریز بودند و ثانیاً ضریب خطرگریزی با اندازه مزرعه، رابطه ای معکوس داشت. استفاده از "روش برنامه ریزی ریاضی انتظاری مستقیم" و مقایسه درآمدخالص مدل های بیشینه کننده مطلوبیت و همچنین بیشینه کننده فایده انتظاری با درآمدخالص فعلی کشاورزان نماینده گروههای مختلف نمایانگر اهمیت توجه به عامل خطرگریزی در تجزیه و تحلیل‌های اقتصادی و همچنین در استفاده از برنامه ریزی ریاضی برای تعیین برنامه بهینه بهره برداران کشاورزی است. باتوجه به نتایج این پژوهش و همچنین سهم قابل ملاحظه بهره برداری های کوچک و متوسط در کشاورزی ایران، توجه به این عامل در برنامه ریزی های اقتصادی و همچنین ایجاد و ترویج تکنولوژی جدید مورد تاکید است.

INTRODUCTION

Majority of less developed countries (LDCs) have achieved reasonable rates of growth in gross domestic product (GDP) over the past decades. However, a great deal of this growth has been in the secondary and tertiary sectors of the economy. The growth rate of agriculture has little more than kept pace with growth in the rural population (24).

With emphasis in recent years on the development of small-farm agriculture, many experts and agricultural scientists remain frustrated by the limited success of their projects. Small farmers frequently reject or only partially adopt improved technology. This occurs despite the technology's demonstration of higher levels of productivity in experimental plots, its calculated economic profitability for the farmer and its beneficial contribution to the larger society (23).

The more prevalent diagnosis of the causes of unsuccessful technology transfer is inadequate support systems for small-farm agriculture, such as extension, credit, or input supplies (23). Yet, these factors are only part of the problem. Many introduced technologies are simply inappropriate for the specific conditions of small-farm systems. This result largely from an inadequate understanding of components of small farm systems such as farmers' attitudes towards risk (13, 14, 23).

Many studies have demonstrated that farmers typically behave in risk-averse ways (4, 5, 6, 9, 17, 25, 26, 28, 29). Farmers often prefer farm plans that provide a satisfactory level of security even if this means sacrificing income on average. More secure plans may involve having less risky enterprises, diversifying into a greater number of enterprises to spread risks, using established technologies rather than venturing into new technologies and, in the case of small farmers, growing larger shares of family food requirements (14, 15).

There is an extensive literature on farmers' risk attitudes. Generally, these studies have demonstrated that the degree of risk aversion of small farmers is high compared to larger farmers (10, 12, 19). Because their tendency to be risk-averse, they naturally shy away from technologies with high risk, whether the risk is subjectively or objectively measured (2, 4, 13, 18, 25, 26).

This paper reviews the major approaches to studying risk attitudes of farmers. This is followed by eliciting the preference functions of the sample farmers in Kavar district, Fars province of Iran. To examine the importance of risk aversion on farmers' cropping decisions, models of utility maximization were then compared with risk neutral solutions. Based on these findings, conclusions are drawn in the final section of the paper

Measuring Risk Preference

Bernoulli's principle or "expected utility theorem" has been generally accepted as the major concept to describe the risk preference of a decision maker (22).Under the expected utility model, given a decision maker whose preference is consistent with the axioms of ordering and transitivity, continuity and independence, there exists a utility function which associates a single real number with any risky prospect faced by the decision maker (1). Let W be final wealth, consisting of initial wealth, w, plus the certainty equivalent (CE) of income in the current period, M, i.e.

$$W = w + M$$

Then for a utility function U(W) = U(w+M), Pratt (20) defined a measure of absolute aversion as

$$r_A = - U''(W) / U'(W)$$

where U'(W) and U"(W) are the first and second derivatives of a Bernoullian utility function. The absolute risk aversion measure (r_A) traces the attitude of an individual to a risky prospect as wealth rises but the prospect remains the same (3, 20). The index of absolute risk aversion is positive, zero, or negative for risk averse, risk neutral, and risk takers, respectively. Following Arrow (3) and Pratt (20), the hypothesis of decreasing absolute risk aversion for increases in W will be tested in this paper.

METHODOLOGY

Several techniques for designing interviews to elicit the preference functions of farmers are available. The most commonly used methods are the von Neumann-Morgenstern (N-M) model (27), the modified version of the N-M model or the Equally Likely Certainty Equivalent (ELCE) method, and the Ramsey or the Equally Likely but Risky Outcome (ELRO) method (1, 21).

In the N-M approach the decision maker is asked to choose between accepting a lottery with a probability of P for the most preferred consequence and 1-P for the subject's least preferred outcome and accepting a sure equivalent amount. The probability (P) is then varied until the decision maker is indifferent between the certain outcome and the risky one. By repetition of this procedure, many points on the utility function can be obtained. This model has been criticized for several reasons. First, the subject may have difficulty in working with probabilities which have more than a single decimal digit. Second, the subject may express preferences for some specific probability values which would distort the preference measurement. Moreover, the subject may have a strong disutility associated with gambling.

The ELCE model is designed to avoid bias due to probability preferences. Ethically neutral probabilities are used (i.e., P = (1-P) = 0.5). The subject is confronted with two-state risky prospects with equal probability of 0.5 for each state. This method overcomes the criticism of bias due to probability preference. However, it still has the difficulty that the subject is forced to select between a certainty and a lottery. Nevertheless, this problem may be minimized by presenting the questions as practical decision problems.

In the ELRO or Ramsey method, preference bias due to the utility or disutility for gambling is avoided. The subject is required to choose between two uncertain alternatives instead of between a lottery and a certainty as with ELCE. One value is then varied until the subject is indifferent between the lotteries. In this method, by using the same probabilities for the lotteries, probability preference bias is also avoided. However, it has a relatively more complicated questioning procedure compared to the ELCE method.

The experimental approach implemented by Binswanger (5) involved lotteries with real money payoffs. In a relatively large-scale study he developed this approach for measuring the risk attitudes of about 350 farmers in rural India. Respondents were offered a choice among a number of games with real money payoffs. Then each farmer was classified on a scale of risk aversion. Binswanger (5) claims that the experimental approach is superior to the approach using hypothetical payoffs.

The experimental method based on real money bets needs a large sum of money which makes it infeasible for the present study. Besides, it only gives risk aversion for a relatively small increase on the utility function. The ELRO approach overcomes the interviewing bias but is relatively difficult to handle because of its complexity. Thus the ELCE interview technique with imaginary payoffs was used in the present study to elicit the utility functions of farmers.

Data and Empirical Procedure

The data used in this paper come from a random sample of 90 farmers. The survey was conducted in Kavar district of Fars province in 1995-96. The sample farmers came from four villages. Further, time-series data on yield per ha of various crops were gathered from records held at the Regional Branch of the Rural Service Center at Kavar. Data on costs of inputs and prices of outputs, as well as information regarding hired-labor wage rates were obtained from secondary sources such as various publications of the Ministry of Agriculture, the Budget and Planning Organization and also the Annual Report and Balance Sheet of the Central Bank of Iran.

As the first step, following Buckwell and Hazell (8) and Hazell and Norton (15), cluster analysis was used to classify the sample farms on the basis of farm size. The cluster analysis divided the sample farms into three size classes: i.e., 4.5 ha and smaller (small farms), larger than 4.5 and smaller than 10 ha (medium farms), and 10 ha and larger (large farms). Then, a possible range was established for each individual farmer's annual cash income based on performances in past years which were more convenient for farmers to remember. The preference levels of 1 and 0 were assigned to the highest and lowest value of the above range, respectively. Each farmer was then asked to indicate the certain amount he or she would need to be indifferent between receiving this amount and a lottery with consequences of the highest and lowest values of the possible outcome each with probability of 0.5. The utility level of 0.5 was attached to this first certainty equivalent. The procedure was then repeated twice with the lowest and highest value and the above certainty equivalent, respectively, as the new possible ranges to find the second and third certainty equivalents. The preference levels of 0.25 and 0.75 were assigned to the second and third certainty equivalents, respectively. Consequently, the elicitation procedure yielded 5 points on the utility function of each farmer. A curve smoothed through these points represents the preference function of each individual farmer. Finally, a 'check' question was asked in order to gauge the consistency of farmers' responses and, when necessary, the procedure was repeated to achieve consistency.

The next step was to specify an appropriate mathematical expression for the utility function. There are a number of algebraic forms which can be fitted to the elicited data (1, 16, 18). However, quadratic and cubic polynomials, and exponential functions are the most popular and have been used in many previous empirical investigations.

The quadratic utility function is easy to handle and has been used in many previous studies (1, 13, 15). However, it is not monotonically increasing everywhere but only over some hopefully relevant range. Moreover, the quadratic utility function exhibits increasing risk aversion as income increases. The unappealing characteristic of increasing risk aversion may also happen for higher polynomials such as cubic functions.

The negative exponential utility function has the form :

$$U(x) = 1 - \exp(-r_A x)$$

where r_A is a measure of risk aversion (11). A positive and non-zero value for r_A means that the farmer is risk-averse, while $r_A < 0$ means that the farmer is risk-preferring.

The negative exponential utility function exhibits constant absolute risk aversion which may be regarded as a major limitation. However, it has several attractive features. Negative exponential functions have decreasing marginal utility with respect to income. Moreover, the function is defined by only r_A, which makes it easy to work with. This latter characteristic makes it particularly convenient in empirical work (2). It has been demonstrated by Zuhair *et al.* (30) that negative exponential utility functions can better predict the farmers' behavior compared to cubic and quadratic utility functions. Consequently, based on the above arguments, the farmers' utility functions were assumed to be negative exponential in form.

A Lotus spreadsheet was developed to estimate the level of r_A based on the definition of a certainty equivalent (i.e., CE(Xi) = E[U(Xi)]). Then fitting the above function to each set of data points, the estimates of the risk aversion coefficient for each of 90 farmers were obtained.

Finally, in order to investigate the extent to which risk aversion may act as a friction on farmers' income, the farmers' existing cropping patterns were compared to the results of the models of expected utility maximization and expected profit maximization (i.e., models with a linear utility function which implies risk neutrality). Following Lambert and McCarl (16), optimal farm plans for the representative small, medium and large farms were estimated using the direct expected mathematical programming (DEMP) method. They applied non-linear programming techniques to maximize directly expected utility. Their formulation is consistent with traditional risk theory and overcomes the main theoretical criticisms of the E-V analysis and likewise MOTAD as an approximation to it (16).

A DEMP model may be specified in a whole-farm context in the form:

maximize $E(U) = p'u(z)$

subject to:

$$Ax \le b; \quad Cx\text{-}Iz = uf$$

and $$x \ge 0$$

where z is a vector of net incomes;

u(z) is a vector of utility of net revenue by state;

A is a matrix of technical coefficients;

p′ is a vector of state probabilities;

C is a matrix of activity net revenue;

I is an identity matrix;

u is a vector of ones;

x is a vector of activity levels;

f is fixed costs; and

b is a vector of resource stocks.

The DEMP model of the study was solved by using the GAMS/MINOS non-linear maximization option (7).

RESULTS AND DISCUSSION

The distribution of the risk aversion coefficient is presented in Table 1.

Table 1. Pratt absolute risk aversion coefficient, r_A, for different farm sizes.

Risk aversion	Farm size		
	Small	Medium	Large
Low	0.00005240	0.00003321	0.00001030
Medium	0.00016120	0.00009170	0.00003425
Large	0.00048900	0.00021860	0.00009811

The r_A values ranged from 0.00005240 to 0.00048900, 0.00003321 to 0.00021860 and 0.00001030 to 0.00009811 for the representative small, medium and large farms, respectively. So, it was found that all farmers were risk averse. Close examination of the risk aversion coefficient revealed that there existed no higher risk takers in any particular village. Also, it can be seen that r_A declines with farm size, which is consistent with expectations (3, 20).

Detailed cropping pattern of models of utility maximization, and expected profit maximization are presented in Tables 2 to 4 for small, medium and large representative farms, respectively. Major crops in the region are wheat and barley in the winter (sheta) season, and corn, sugar beet and tomato in the summer (saif) season. Wheat and barley are harvested by combine harvester. However, harvesting of sugar beet and tomato, on most farms, takes place manually without mechanization. Weed control is a major concern in sugar beet production and manual weed control is the common practice.

Table 2. Cropping patterns for allocatively efficient farm plan and existing situation (small farm)†

	Activity levels					
	Barley (ha)	Maize (ha)	Sugar beet (ha)	Tomato (ha)	Wheat (ha)	ETNR§ (1000 Rials)
EFP¶	0.75	0.50	1.00	0.00	1.00	3587.50
UMFP††	0.50	0.40	1.18	0.30	0.82	3806.25
PMFP§§	0.15	0.40	1.14	0.75	0.79	4080.80

† The small representative farm has 3.5 ha of operated land.

§ ETNR stands for expected value of total net revenue.

¶ EFP represents existing farm plan.

†† UMFP represents expected utility maximizing farm plan.

§§ PMFP represents expected profit maximizing farm plan.

It is evident from Tables 2 to 4 that farmers' actual total net revenues are different from those of both risk-averse and risk-neutral models. According to the data in above tables, total net revenues of the representative small, medium and large farms can increase as much as 218.75, 294.7 and 397.92 thousand Rials, respectively, by adopting the utility maximization models. The differences between the total net revenues of the existing situations and the utility maximization models may be attributed to the possibility of increasing farmers outcome through allocatively efficient use of resources. However, the differences between the total net revenues of models of utility maximization and profit maximization indicate the impacts of risk aversion on farmers behavior. These differences are larger in the case of the representative small and medium farms compared with the representative large farm when calculated on per ha basis. This demonstrates the importance of risk aversion for small and medium farms as compared to large farms.

Table 3. Cropping patterns for allocatively efficient farm plan and existing situation (medium farm)†

	Activity levels						
	Barley (ha)	Maize (ha)	Tomato (ha)	Sugar beet (ha)	Sunflower (ha)	Wheat (ha)	ETNR§ (1000Rials)
EFP¶	1.00	0.00	0.50	1.00	0.00	4.00	6406.00
UMFP††	0.35	0.50	1.05	1.20	1.00	2.30	6700.70
PMFP§§	0.00	0.56	1.34	1.65	1.37	1.50	7128.50

† The medium representative farm has 6.5 ha of operated land.

§ ETNR stands for expected value of total net revenue.

¶ EFP represents existing farm plan.

†† UMFP represents expected utility maximizing farm plan.

§§ PMFP represents expected profit maximizing farm plan.

Further research is needed before these results can be generalized. However, based on the technological and institutional constraints and also the risky nature of the environment within which decisions are made, it seems likely that Iranian farmers would behave in a risk-averse way. Accordingly, they may be reluctant to shift from a traditional technology and crop pattern that they have come to know and understand over years to a new one that promises higher returns but may entail greater risks of crop failure. This reluctance, in the main, can be attributed to two factors: (a) farmer's aversion to risk, and (b) imperfect information

Finally, Iran has a high proportion of small farms. About 87 percent of farms are below 10 ha and these represent around 43 percent of the farmed land. Thus, understanding of risk aversion is important in proposing policies for the government. The measures that can reduce risk and change farmers' behavior could lead to improvements in both farming efficiency and in the rate of diffusion of new technologies. Besides, policy intervention is needed to improve information and reduce its cost to farmers. The policy implications include improving education and extension services and adoption of risk-mitigating strategies such as agricultural insurance, and providing more credit facilities.

Table 4. Cropping patterns for allocatively efficient farm plan and existing situation (large farm)†

	Activity levels					
	Maize (ha)	Tomato (ha)	Sugar beet (ha)	Sunflower (ha)	Wheat (ha)	ETNR§ (1000 Rials)
EFP¶	2.00	1.40	3.00	2.00	5.00	12275.50
UMFP††	2.20	1.55	2.94	2.10	4.52	12643.42
PMFP§§	2.35	1.85	3.10	2.19	3.95	13211.00

† The large representative farm has 13.5 ha of operated land.

§ ETNR stands for expected value of total net revenue.

¶ EFP represents existing farm plan.

†† UMFP represents expected utility maximizing farm plan.

§§ PMFP represents expected profit maximizing farm plan.

ACKNOWLEDGEMENT

This research was supported by a grant from the Research Council of Shiraz University (Project No: 74-AG-881-513).

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