RESOURCE ALLOCATION BY RICE FARMERS IN SRI LANKA: A DECISION THEORETIC APPROACH

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[Read by Paul G. Webster.]

Too often, tests of economic rationality of agricultural producers are based on the assumption of profit maximization and certainty of outcomes of production decisions (Hopper; and Yotopoulos). However, multiple goals and uncertainties may be relevant to the decisionmaker. Consequently, single goal models under certainty are not always a realistic approach to the decision process and may not provide a farmer with an acceptable solution.

Progress in using multiple goals and uncertainties in decision models has been slowed by the difficulty of incorporating multiple goals and uncertainties into analytical models. However, with the development of decision theory, procedures became available that permit explicit incorporation of uncertainties and multiple goals. Decision theory describes how a rational decisonmaker ought to behave given his beliefs and preferences. Whether or not the model explains the behaviour of peasant farmers can only be answered by empirical tests.

The objectives of this study are: (1) to compare alternative theories of choice (single attribute utility maximization, multiattribute utility maximization, and expected profit maximization in terms of their abilities to explain and predict actual resource allocation decisions of producers, and (2) to explore implications for policy decisionmakers of the impact of and uncertainty on farmers' choices. The present research was conducted on a sample of rice farmers in Sri Lanka.

Approach

If $x = (x_1, x_2, ..., x_n)$ is the vector of resource allocations, then the decision problem is to select the best value of x. If the axioms of rational choice (Keeney and Raiffa) are to be met, then the decisonmaker should select that value of x which maximizes his expected utility:

$$(1) \quad \int_y u(y)f(y|x)dy,$$

where $y = (y_1, y_2, ..., y_n)$ represents a vector of attributes, f is the decisionmaker's probability density function over y given the value of x, and u is his utility function.

Feasible Land Allocation

After discussions with farmers, it was felt useful to concentrate on the allocation of scarce land resources under uncertainty. Preliminary observations indicated that many farmers allocated land to mixtures of two varieties of rice. The most important observation made was that these two varietal mixtures contained one high yielding (HYV) and one traditional variety (TV). Thus, for examining this decision to allocate land between the HYV and the TV, the allocation was specified by $x = (x_1, x_2)$, where x_1 is the proportion of land of the HYV and x_2 is the proportion of land of the TV. The problem can now be stated as:

$$(2) \quad \text{maximize} \int_y u(y)f(y|x)dy,$$

$$(3) \quad \text{subject to } x_1 + x_2 = 1.$$

Attributes

Discussions with farmers indicated that subsistence consumption y_1 and net cash income y_2 are the main goals in rice production. To analyze the above decision problem using multiattribute utility theory, a set of measures of effectiveness for y_1 and y_2 need to be developed. Net cash income could be measured in Sri Lankan rupees. For y_1, however, the volume of farm produced rice consumed by the farm family was used as a simple measure because of the need to make probability and utility judgments.

Probability Distributions: Performance-Allocation Relationships

To evaluate all feasible allocation plans, a large number of probability distributions need to be derived. However, to simplify data acquisition and subsequent analysis, this optimization was represented as a one period, two investment portfolio model as follows:

$$(4) \quad \text{Max EU} = \text{Max} \int\int u[x_1q_1 + (1 - x_1)q_2]Ldf(q_1, q_2),$$

where q_1 is the yield of HYV, q_2 is the yield of TV, L is the total land allocated to HYV and TV, and f is the joint probability distribution of yields per acre between the two varieties.

To simplify the analysis, the joint distribution of yields was assumed to be bivariate normal. The assumption of normality permits the specification of the joint distirbution of n variables using the means and the standard deviations together with the values of the $n(n - 1)/2$ conditional means and the standard deviations (Anderson and others). If q_1 and q_2 are jointly normally distributed with means $E(q_1)$ and $E(q_2)$, standard deviations s_1 and s_2 respectively, and correlation p_{12}, then the conditional distribution of q_1 given $q_2 = q_2^*$, is characterized by mean and variance, as follows:

$$(5) \quad E(q_1|q_2 = q_2^*) = E(q_1) + p_{12}(s_1/s_2)[q_2^* - E(q_2)], \text{ and}$$

$$(6) \quad Var(q_1|q_2 = q_2^*) = s_1^2(1 - p_{12}^2),$$

respectively. Equations (5) and (6) provided a method of estimating the parameters of the bivariate yield distributions in this study.

Utility Function Structure

Keeney has developed two main assumptions, namely preferential and utility independence, which simplify the assessment of multiattribute utility functions. In the case of only two attributes, it has been shown by Keeney that if these two attributes are mutually utility independent (that is, if y_1 is utility independent of y_2 and vice versa) then either:

$$(7) \quad u(y_1, y_2) = \sum_{i=1}^{n} k_iu_iy_i, \text{ or}$$

$$(8) \quad u(y_1, y_2) = \prod_{i=1}^{n} [(1 + Kk_iu_iy_i) - 1]/K$$

where u and u_i are utility functions scaled from zero to one, the k_i are the scaling constants with $0 < k_i < 1$, and $K > -1$ is a nonzero scaling constant.

Data Assessment

Probability Distributions

Two samples of rice farmers--one from the wet zone and the other from the dry zone--were selected for this study. Two marginal distributions and one conditional distribution were assessed for each farmer using the visual impact method (Anderson and others) in order to specify the bivariate distribution of yields using (5) or (6). These distributions were checked for normality using the Kolmagarov test. Most of the distributions approximated the normal distribution very well. The distributions which were not normal were symmetrized using a generalized power transformation of the form:

(9) $z = (q^w - 1)/w, \quad w \neq 0,$

where w is the transformation parameter and z is the transformed value of the variable. The value of w was varied over a reasonable range in order to obtain the value which best symmetrizes the distribution.

A test of symmetry was made by computing the value of T where

(10) $T = [z_{(\alpha)} + z_{(1-\alpha)}]/2z_{(0.5)}, \quad 0 \leqq \alpha \leqq 1,$

where α is a given fractile value. The best w gives a value of 1 to equation (10).

For single attribute utility maximization, the joint yield distributions were transformed into distributions of net income (defined as gross income less variable costs) by the use of a linear transformation (Herath).

Utility Functions

The utility independence assumption was not tested rigorously in this study. It was considered a reasonable assumption (Herath). The multiattribute utility function was specified using the individual utility functions for y_1 and y_2 derived using the equally likely certainty equivalent method (Anderson and others) and the scaling constants k_1 and k_2 for y_1 and y_2 respectively. Most of the utility functions showed risk aversion. Several different functional forms such as the cubic, the spliced cubic, and the negative exponential were fitted to the elicited data. The negative exponential function was found to approximate the shape of most of the curves. This function also shows constant absolute risk aversion and has found favour in many multiattribute situations (Keeney and Raiffa). Consequently, the negative exponential function was fitted for all farmers for both y_1 and y_2 using procedures developed by Buccola and French.

Scaling Constants

The scaling constants k_1 and k_2 were assessed using a lottery technique (Keeney and Raiffa). In all cases, the sum of the k_i for i = 1 to i = n was not equal to one, and hence the multiattribute utility functions were multiplicative. The value of K in (8) was determined from the elicited value of k_1 and k_2 (Keeney and Raiffa). In a majority of the cases, k was found to be negative, indicating multivariate risk aversion (Richard).

Optimization Procedure

The optimal solutions under the three criteria were computed using a Monte Carlo approach. Here, x_1 was varied between zero and one in increments of 0.1, and the value among these that maximized the objective function was chosen as the optimal solution.

For single attribute utility maximization, a level of net income for each variety was generated randomly from the bivariate normal distribution of net income, truncated at plus and minus three standard deviations from the expected value, for a given value of x_1. The output variables were calculated according to the following sequence:

$$(11) \quad y_2' = [x_1 r_1 + (1 - x_1) r_2]L,$$

where y_2' is total net income, $(1 - x_1)$ is the proportion of land allocated to TV, r_1 is the random net income from HYV, and r_2 is the random net income from TV.

Then, y_2' was substituted in the utility function derived for net cash income to compute the total utility. The above sequence was repeated 1,500 times. Finally, the mean (expected) utility was calculated for a given value of x_1 for the total number of iterations. The adequacy of 1,500 iterations was determined by trial and error. The use of the utility function for y_2 as a proxy for the utility function for net income is only approximate. However, the use of a negative exponential assumption provides some justification for the approximation (Herath). The computation was repeated for each successive value of x_1. The output obtained in the simulation is the expected utility for different allocations of land to the HYV for proportions varying from zero to one. The proportion giving the highest expected utility was approximated as the theoretically optimal solution.

The structure of the simulation was slightly modified for multiattribute utility maximization, as follows. A random yield from each variety was generated from the bivariate normal distribution of yields. The output variables were then calculated according to the following expressions:

$$(12) \quad Q = [x_1 q_1 + (1 - x_1) q_2]L,$$

where Q is total random yield, q_1 is the random yield from HYV, and q_2 is the random yield from TV.

The Q obtained from the two varieties was allocated between y_1 and y_2 to maximize the utility according to:

$$(13) \quad u = [(1 + Kk_1 u_1 y_1)(1 + Kk_2 u_2 y_2) - 1]/K.$$

Making use of the fact that:

$$(14) \quad y_2 = (Q - y_1)p - t,$$

where p is the price of a bushel of rice and t is the total cost of production, equation (13) can be written as:

$$(15) \quad \{(1 + Kk_1 u_1 y_1)(1 + Kk_2 u_2 [(Q - y_1)p - t] - 1\}/K.$$

The allocation of Q between y_1 and y_2 can be determined by maximizing (15) with respect to y_1. The associated optimal value of y_2 can be found from (14). The utility maximizing solution in terms of y_1 was established using the Newton-Rhapson technique (Hartree). This procedure was repeated 1,500 times and expected utility was computed by averaging the total over the number of iterations.

For expected profit maximization, a formal optimization procedure was not required. Here the choice for each farmer is to grow either the HYV or the TV depending upon which of the two varieties has the highest (subjective) mean yield.

Comparison of Optimal Solutions with Actual Allocation

The main aim of this study was to determine which is the best predictor of farmers' behaviour: (1) expected profit maximization, (2) expected utility maximization (single attribute), or (3) expected utility maximization (multiattribute).

An evaluation of the closeness of prediction was made by computing the mean absolute deviation of the predicted area of HYV form the actual grown. The mean absolute deviation was computed using the following:

$$(16) \quad \left(\sum_{i=1}^{n} |PA - AA|\right)/n$$

where PA is predicted area, AA is actual area, and n is the number of farmers in the sample.

The mean absolute deviation so computed is then expressed as a percentage of the mean actual area under the HYV. This indicates the percentage deviation of predicted area from the actual area.

The percentage deviations for single attribute utility maximization were about 10 to 7.7 for the wet and dry zone samples respectively. For multiattribute utility maximization, the corresponding deviations were 34 and 15. For expected profit maximization, the deviations were very high, of the order of 49 and 29 percent for the wet and dry zones respectively. These figures indicate that the deviations in the prediction were smallest for single attribute utility maximization, which performed better than either of the other two. It can thus be concluded, at least in this study, that single attribute utility maximiation is the more appropriate model to explain the behaviour of peasant farmers over the conventional profit maximization hypothesis.

Policy Implications and Concluding Remarks

This study suggests that risk is an important factor in the adoption of new technology by peasant producers. An obvious implication is to introduce policy measures, to reduce the subjective uncertainties felt by farmers by improving communciations and making local demonstration plots, both of which could reduce the perceived risks of new technology. The development of infrastructure such as irrigation could also minimize the variability of yields, thereby reducing risk in adoption of innovations.

In addition to reducing risks, farmers must be helped to bear risks. Programmes to reduce price variability and schemes of crop insurance against undue losses help bear some of the risks in agricultural production. Another important implication is that plant breeders must focus not only on yield potential in breeding but also on those features which help reduce the yield variability. These policies could encourage adoption of new technology by small farmers, thereby reducing the disparity of incomes between the rural and the urban sector--a primary aim of rural development.

In conclusion, the usefulness of studying the decisionmaking process with explicit consideration of risk and uncertainty has been illustrated in this study. There appears to be greater merit in a decision analysis approach to study allocation decisions of peasant producers. Such decisions, in the aggregate, impinge in a substantial way on the well-being of large numbers of people and have a crucial impact on the success or failure of important aspects of rural development planning.

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OPENER'S REMARKS--Deryke G. R. Belshaw

Richardson, Hardaker, and Anderson foresaw that the use of decision modeling techniques would be confined to developed agriculture where their application would depend on the number of very large farms with computers or computer terminals in their offices. Heady took the view that the work on decision theory represented a large leap forward for understanding farm decisions in developed countries, but nevertheless believed that "we have a considerable distance to go in (a) meaningfully measuring risk reference, utility curves, subjective probability distributions and related phenomena, and (b) using them either to better understand decisionmaking under uncertainty or applying them in manners useful to farmers in the actual decisionmaking process" (p. 39).

Decision modeling has not been generally envisaged in the profession as a useful tool for application to small scale or peasant agriculture. In the light of the quoted discussion, it is clear that the research undertaken by Herath—applying decision theory to illuminate peasant farmer decisionmaking processes--is an imaginative and pioneering extension of previous work.

How well has the author succeeded in this attempt? In this case, we are probably close to the technique in search of a problem situation. Although subject to denigration, such research can be justified in the early phases of development of a new methodology as long as a critical assessment is made by the researcher of the wider social utility of the approach. In practice in the research "industry," the tendency is usually to advocate further applications of the new methodology irrespective of its utility or potential demand by decisionmakers for the information it generates.

It will be clear from these remarks that the evaluative criteria adopted here concern the value of the insights and data for advisors and planners responsible for formulating agricultural development strategies in developing countries. Indeed, in the final section of his paper, the author claims that precisely such benefits follow from his research. Are the claims soundly based? Does much wider use of decision theory in the investigation of peasant agriculture appear justified? Should decision theory be inserted in standard curricula for training agricultural economists in developing countries?

There are several difficulties in understanding the precise methodology employed from the description supplied in the paper. This is not necessarily the author's fault, as he is summarizing the contents of a Ph.D. thesis within the very severe paper length constraints imposed by the Confernece organizers. Nevertheless, there are important aspects of the data collection procedures about which we should be informed. How was the farmer sample chosen? How representative is it? What is meant by farmers?--Heads of households, accessible informants, key decisionmakers, or members of the family labour force? The opportunity was apparently not taken to record objective features of the farmer's environment which might account for differneces in risk bearing capacity, nor to suggest additional or alternative objective functions pursued by some, if not all, of the farmers in the sample. Interfarmer variation in risk aversion is now recognized as an important variable accounting for differential adoption of HYV technology and the associated weak equity impacts in terms of raising labour productivity of poorer farm families. Additional objective functions which in general might improve the explanatory power of multi-attribute utility maximization functions include reduction of normal labour inputs, improvement of social standing, and reduction of social risk. A potentially powerful explanation of differential decisionmaking by peasant farmers appears to be offered by Chayanov's model of the developmental cycle of domestic groups. This framework suggests that farmers will switch from one utility maximization function to another at different points in the cycle of family growth and decline--a feature which would have important implications in terms of the identification of target groups and the design of appropriate technological and institutional packages.

The particular decision problem selected for study--the areas planted to high yielding and traditional varieties of the dominant food crop--is an important aspect of the Green Revolution situation. But other types of decisions are also presented and may be more fundamental--the combination of variable inputs, changes in product risk, and long run investment decisions, for example. What light can decision theory throw on these areas?

An important consideration which is glossed over in the paper is the assumption of utility independence. This was not tested rigorously, and it seems likely that the savings potential of increased cash income would reduce the utility of a given level of self-sufficiency in staple food supply. The absence of utility independence, of course, would weaken the explanatory power of the multiattribute utility function.

Finally, the policy insights of the research results presented in the final section of the paper appear unremarkable. The general significance of risk as a factor affecting technology adoption in peasant agriculture has long been appreciated by agricultural economists. Qualitative analyses by Raeburn and by Lipton--the latter a powerful critique of Schultz's "efficient but poor" hypothesis central to his seminal book on transforming traditional agriculture--come to mind. The ingenuity of the quantitative decision theory techniques applied in this study have added nothing to our knowledge at this level, although perhaps they would have done so had they been concentrated on the search for significant variation in objectives and attributes between farmers operating in the same development environment. It is, therefore, too early to conclude from this study that decision theory has no potential social utility when applied to peasant agriculture; only that the claimed insights of the particular application carried out by the author would not seem to justify the replication of similar work in other farmer populations. The case for including decision theory in training curricula is certainly a long way form being convincingly demonstrated.

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RAPPORTEUR'S REPORT--Lorraine C. Bassett

The assumption of utility independence between attributes was discussed. It was posited that the incorporation of this assumption could possibly explain why the multiattribute utility maximization approach to predicting the actual behaviour of Sri Lankan rice farmers was poorer than the single attribute utility maximization approach. Further discussion on the assumption of utility independence between attributes was recommended. It was noted that the utility functions derived in the study were based on a hypothetical gambling procedure. Because past studies have indicated that utility functions derived from hypothetical gambling or lottery games are not indicative of an individual's real utilities, it was suggested that the utility functions derived for subsistence consumption and net cash income could be biased.

The point was raised that the use of different data sets in studies which introduce small variations to the main body of utility theory makes it difficult to evaluate models, such as the model presented by Herath. In response to this point, it was stressed that an alternative approach to utility analysis such as employing one set of data and testing different theories is a viable alternative and had been undertaken by the author.

Contributing to the discussion were Allen N. Rae and Inderjit Singh.