Pertanika 5(2): 141–153 (1982)

Small Farmers' Decisions: Utility Versus Profit Maximization

MOHD. GHAZALI MOHAYIDIN
Faculty of Resource Economics and Agribusiness
Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia.

Key-words: Risk; decision making; crop selection; quadratic programming; mean-variance; expected uility.

RINGKASAN

Sikap petani terhadap risiko dimodel dengan menggunakan fungsi-fungsi nilai-faedah Cobb-Douglas, transendental, exponensial negatif, dan ukuran-bersama. Pengamatan petani-petani mengenai risiko tanaman-tanaman alternatif juga disukat dan algorithm programan quadratik digunakan untuk mendapat sempadan jangkaan min-varians (E-V) paling cekap bagi tiap-tiap petani. Sempadan E-V ini, seterusnya, digunakan bersama-sama fungsi-fungsi nilai-faedah untuk menentukan rancangan ladang yang optimum. Rancangan-rancangan ladang yang memaksimumkan jangkaan-untung juga ditentukan. Keputusan analisis menunjukkan bahawa model ukuran-bersama membuat ramalan yang hampir tepat dengan gelagat petani yang sebenarnya. Modal jangkaan-untung sebaliknya ialah peramal yang paling lemah sekali. Ini membuktikan bahawa risiko memainkan peranan di dalam membuat keputusan dan petani-petani bertujuan memaksimumkan nilai faedah dan bukan keuntungan sahaja. Oleh yang demikian, program-program yang lebih berkesan adalah program-program yang mengurangkan risiko dan ketidakpastian yang dihadapi oleh petani-petani.

SUMMARY

Farmer's risk attitudes are modelled using the Cobb-Douglas, transcendental, negative exponential, and conjoint measurement utility functions. The farmers' perception of the riskiness of alternative crops are also measured and a quadratic programming algorithm is used to derive the most efficient expected mean-variance (E-V) frontier of each farmer. The E-V frontiers are then used in conjunction with the utility functions to determine the optimal farm plans. Farm plans that maximise expected profit are also determined.

The results reveal that the conjoint measurement utility model predicts actual behaviour better than the other models. The expected profit model, on the other hand, is the worst predictor. This indicates that risk does play a role in decision-making and that the farmers are utility maximizers rather than profit maximizers only. Therefore, more effective programs would be those that tend to reduce risks and uncertainties faced by the farmers.

INTRODUCTION

Agricultural production in Malaysia is undertaken mainly on smallholdings ranging from less than one-half hectare to about 25 hectares. The situation in agriculture is very complex. The soil characteristics and the area topography vary modestly from farm to farm and vary more importantly among farms in different villages, districts, and states; the labour supply and credit availability vary from farm to farm; the input and product prices vary from place to place; and the farmers have differing experience with new technologies and new practices. The farmers are also faced with differing market conditions. Thus the technical production coefficients of each farmer and the economic relationships among factors and products confronting him

Key to author's name: M. Ghazali

differ to some degree – perhaps modestly, perhaps greatly – as each of these farmers considers the adoption of new technology brought to his attention or made available to him by government programs or policies. The entire scenerio is further confounded by the differences in attitudes of each farmer towards the risk of adopting the new technology and his perception of the riskiness of the new innovation. Thus, almost every development program or policy that may be conceived for agriculture cannot be appraised as to its profitability or productiveness within itself. It can only be done in terms of the response it evokes among the farmers who come in contact with the program or policy.

In the present study, the basic concern is whether risk and uncertainty affect the process of decision-making regarding crop selection, which in turn may affect policy prescriptions and the effectiveness of policy tools. Since the major actors of this study are the small farmers, attention is concentrated on analysing their risk preferences and their perceptions of risk. The study was carried out in the districts of Muar and Perak Tengah in the Malaysian Peninsula. Even though both districts are major fruit producing areas, the local agriculture is still dominated by rubber.

An accurate estimate of the domestic consumption of fruits and fruit products is extremely difficult because of the lack of data. A projection on the demand for and supply of fruits indicates that there is and will be a shortfall in the supply for many more years to come unless domestic production is stepped up vigorously. At present, the country is importing large quantities of fruits and fruit products to supplement the local market.

Realizing that there is a good market potential for local fruit, the government has taken several significant steps to promote the development of the fruit industry. Some of the steps taken include raising the amount of financial assistance to farmers and raising tariffs on imported fruits. The government also provides some of the essential supporting services, such as extension and marketing.

Despite these programs, most of the farmers are still hesitant to commit themselves to fruit production. The reasons are diverse; however, it is hypothesized that one of the major factors inhibiting the farmers from participating in the government programs is risk and uncertainty. In other words, the hypothesis is that the farmers are maximizing utilities rather than profits.

ANALYTICAL FRAMEWORK

Farmers' Utility Functions

Perhaps the most widely accepted model of individual behavior under uncertainty is based on the expected utility theorem (Anderson et al., 1977), which takes into account the risk attitudes and beliefs of the decision-maker. There are several methods of eliciting farmers' utility functions. In this study, two methods were used: (i) certainty – equivalent (Francisco and Anderson, 1972) and (ii) conjoint-measurement (Garrod and Miklius, 1981).

In the certainty-equivalent technique, the risk attitude of each farmer was ascertained within the range of losing his entire annual income and gaining twice the amount of income. The farmer was confronted with a hypothetical decision problem which was set to present a real-world situation faced by him in his agricultural environment. An example of the hypothetical problem is as follows:

> The farmers' crop is maturing well and by the next month it will be ready for harvest. While the farmer is waiting anxiously for the harvest, an agricultural officer breaks the news that a particular type of disease is spreading very rapidly and is expected to reach his area very soon. At the speed the disease is spreading, he has a fifty-fifty chance of harvesting his crop. If the disease strikes before the crop can be harvested he will lose the entire crop and thus his annual income (assume sunk costs equal zero). However, if he manages to harvest before the disease strikes, he will be able to sell his crop at a higher price (say double the normal price) because many other farmers' crops would have been completely destroyed. While he is in this uncertain situation, somebody comes to "pajak" his crop, that is, offers to pay cash now in return for the rights to harvest the crop. What will be the sum of money offered at which he would find himself indifferent between selling and not selling?

If the farmer found it difficult to answer, the interviewer would act as the "pemajak" and start to bargain with the farmer until a point was reached where the farmer was just willing to sell his crop. This value x_1 was recorded as the certainty-equivalent of the uncertain prospect of losing this entire income 'a' and gaining twice this annual income 'b' *(Figure 1)*.

Once the first set of information was obtained, a new problem with equally-likely outcomes was set-up using x_1 as one of the uncertain outcomes and one of the previously mentioned extremes (a or b) as the other. If 'a' was selected first, then the certainty-equivalent for the uncertain prospect of 'a' and 'x_1' was determined using the above procedure. Taking this as problem 2 (Q.2), the process was repeated until Q.7 was answered by the farmer.

crops and their associated riskiness, measured in terms of variance. Specifically, the main concern was to evaluate the joint effect of the two variables, mean and variance, on the ordering of the dependent variable, utility. The analysis could be extended to include other attributes, but this was not within the scope of this study.

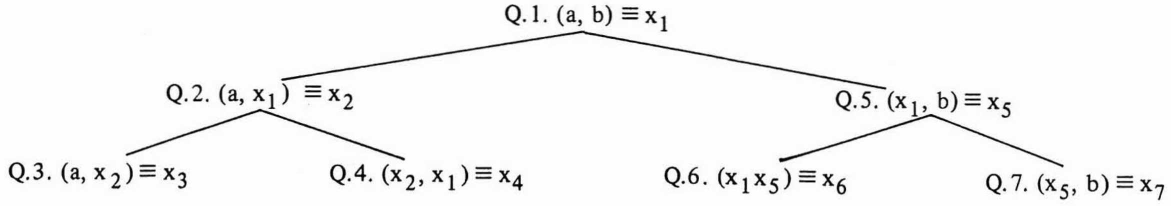

Fig. 1. Questioning Procedure for Obtaining Certainty-Equivalents.

Cross-check questions were also asked to ascertain whether the farmer's answers were internally consistent. This was done by finding the certainty-equivalent of the uncertain prospects of x_2 and x_5. The value of the certainty equivalent should be x_1 or very close to it. These data were then used in a regression model to estimate Bernoullian type utility functions. Alternative forms of the utility function were specified, i.e., Cobb-Douglas, transcendental, and negative exponential.

The conjoint measurement technique, which was the second technique used to estimate utility functions, has shown a lot of promise in marketing research. This technique "starts with the consumer's overall or global judgements about a set of complex alternatives. His or her original evaluations are then decomposed into separate and compatible utility scales by which the original global judgements (or others involving new combinations of attributes) can be reconstituted" (Green and Wind, 1975). Once the overall judgements are separated into their psychological components, a decision-maker would have valuable information about the attributes of a product. He would also have the information about the value of various levels of any single attribute. Conjoint measurement, which is concerned with the joint effect of two or more independent variables on the ordering of a dependent variable, was used to explain the decision-makers' selection of crops.

The major attributes of concern in this study were the expected net incomes derived from the

Five cards were used to elicit the information required to apply conjoint measurement. Different net income levels from a hectare of fruit holding over a period of four years and their chances of occurence were written on each card:

Card 1 : 2 out of 4 years, the net income is \$4500 and
2 out of 4 years, the net income is \$5500

Card 2 : 2 out of 4 years, the net income is \$4000 and
2 out of 4 years, the net income is \$6000

Card 3 : 1 out of 4 years, the net income is \$2000 and
3 out of 4 years, the net income is \$7500

Card 4 : 1 out of 4 years, the net income is \$3000 and
3 out of 4 years, the net income is \$7000

Card 5: 1 out of 4 years, the net income is − \$500 and
3 out of 4 years, the net income is \$8000

Each farmer was asked to rank these cards according to his preference. The reasons for the possibility of variations in income from different farms growing the same crops in the same area were explained to farmers before ranking of the cards. Some of the reasons given were pest, diseases, weather, and theft. The interviewers were instructed to make sure that the ranking was based on the farmer's preference concerning the mean and variance of income.

Computation of the utility scales of each attribute was carried out by a mathematical programming formulation of monotonic (or order-preserving) regression (Garrod, 1979). Monotonic regression has been applied to all conjoint measurement and also to certain types of multidimensional scaling problems. Pekelman and Sen (1974) developed models that minimize the number of discordant pairs; Srinivasan and Shocker (1973) used a linear programming formulation to minimize the sum of the differences between discordant pairs; and both Johnson (1975) and Kruskal (1965) used squared differences between discordant ranks in their loss functions. Concordance in this case was defined as "the event where the sign of the difference between the estimated rank order of any pair of observations is the same as the sign of the difference between the true or initial ranks." Garrod (1979) has proved that the mathematical programming formulation of monotonic regression generally yields more concordant results than the other techniques and that it will always yield results at least as concordant. For this reason, this formulation was used in the analysis.

Farmers' Perception of Risk

In the second stage of the analysis, the farmers' degree of beliefs or subjective probabilities were quantified and their perception of the most efficient production frontiers were developed in the form of Mean-Variance (E–V) frontiers using a quadratic programming algorithm.

Probability distributions are used to describe the stochastic or probabilistic behavior of random variables. The states of nature depend on one or more random variables. Hence, an assessment of the subjective probabilities of states usually requires knowledge of the decision-maker's degree of belief about the underlying random variables. A variety of methods are available for estimating these probabilities. Anderson et al., (1977) recommend the 'gross method' of eliciting subjective probabilities of income levels directly from the decision-maker. However, this method is quite sensitive to interview technique. This often results in inconsistencies in the decision-makers' responses. Many decision-makers, particularly farmers, do not think in terms of probabilities. Thus they may not be able to implicitly evaluate production responses of different enterprises under various environmental conditions, consider their price expectations, and combine all this information to come up with probability distributions.

The technique adopted for the purpose of estimating the farmer's perception of risk in this study was to elicit the components for the approximation of the frequency distributions of incomes from various crops. Problems of pest and weather that the farmer perceived as being associated with major and moderate crop damage were first discussed. 'Good,' 'medium,' and 'poor' seasons were then defined according to the extent of damage. The farmer was then asked to respond to the question: "How many years out of ten do you expect the seasons to be good, medium, and poor?" He was also asked to indicate the output and prices he expected to get in each of these seasons. The data obtained from this technique were then used to calculate means, variances, and covariances of different crops to be used as input data for quadratic programming to derive E–V frontiers.

Programming Framework

Attempts to incorporate risk in mathematical programming formulations in a whole-farm planning problem include quadratic risk programming. Risk is considered only in relation to the activity net revenues that are assumed to follow a multivariate normal distribution. Choice of the utility-maximizing set of x_j values is a type of portfolio analysis where the optimal portfolio is some vector of $X = x_i, \ldots, x_j, \ldots x_n$ that maximizes utility subject to the following resource constraints:

$$\sum_{j=1}^{n} a_{hj} x_j \{ \leqslant = \geqslant \} b_h, (h = 1, \ldots, m),$$

where b_h = the quantity of the h^{th} resource, and

a_{hj} = the technical input-output coefficient specifying the amount of the h^{th} resource required to produce a unit of the j^{th} activity.

A more common approach like the one developed by Wolfe (1959) is to divide the analysis into two stages. The first stage is to make use of a parametric programming procedure to determine the efficient E–V set of portfolios or the E–V frontier. The second stage is to ascertain the utility maximizing member of this set.

In this study, the objective function was to minimize

$$V = \sum_{i=1}^{n} \sum_{j=1}^{n} \sigma_{ij} x_i x_j$$

subjected to a parametric expected profit constraint

$$\sum_{j=1}^{n} E(c_j)x_j - F = \beta, \ (\beta = -F \text{ to Emax}),$$

$$\sum_{j=1}^{n} a_{hj}x_j \ \{\leqslant = \geqslant\} \ b_h, \ (h = 1, \ldots, m), \text{ and}$$

$$x_j \geqslant 0;$$

where:

σ_{ij} = covariance of the per unit net revenues of activities i and j,

V = variance of profit of current plan,

$E(c_j)$ = expected net revenue per unit of activity j,

F = fixed costs, and

β = parameter which measures the expected profit of current farm plans for the values ranging from −F to Emax (the maximum possible expected profit regardless of variance).

An optimal solution vector X_o^* was initially obtained when $\beta = -F$. As β was increased, the levels of activities in the optimal solution changed linearly with β until one of the constraints was met or one of the activities was driven to zero. The "change-of-basis" occurred at this point. When β was further increased, the levels of activities would also vary with β. This change was also linear until another change-of-basis was met. In this way a sequence of critical values of β denoted as β_1, β_2, ... were obtained along with a sequence of change-of-basis solutions. For the k^{th} change-of-basis solution, the expected value E_k and the variance V_k of the total net revenue were computed respectively as follows:

$$E_k = \sum_{j=1}^{n} c_j x_{kj}^* - F$$

$$V_k = \sum_{i=1}^{n} \sum_{j=1}^{n} \sigma_{ij} x_{ki}^* x_{kj}^*$$

where: x_{kj}^* = value of x_j at the k^{th} change-of-basis solution.

For the value of β between any two change-of-basis solutions, the corresponding activity levels were determined by linear interpolation.

The above parametric procedure was used to obtain the set of solutions that yielded minimum variance for given levels of expected income subjected to the specified constraints. The solutions then represented the E-V efficient set. The optimal solution could either be left to the decision-maker's discretion or could be determined if utility function expressed in terms of mean-variance was determined *(Figure 2)*.

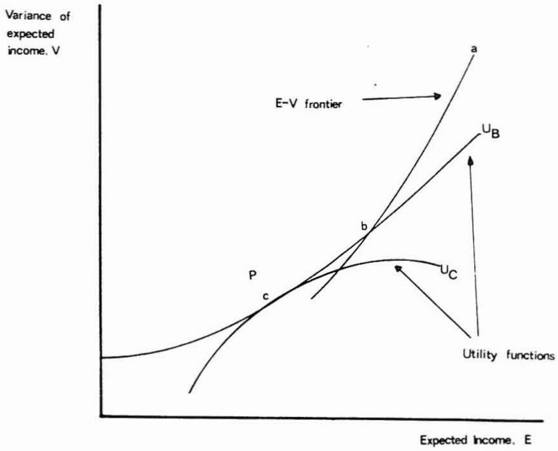

Figure 2: Expected Utility Maximization.

Predicting Actual Behavior

In the third stage of the analysis, the farmers' attitude toward risk and their perception of risk were brought together in the E-V space (Figure 2). The ability of the behavioral models or the utility functions were then tested to determine how close they were in predicting the actual behavior of the farmers in terms of selecting various crops. A chi-square test was used to test the performance of each models. In Figure 2, suppose point p represents the mean and variance of the actual income obtained from the present plan, the test is to determine how well points c, b, and a (which represents profit maximization point) predict point p – the closer the better.

RESULTS OF ALTERNATIVE SPECIFICATIONS OF THE DECISION MODELS

The Certainty-Equivalent Technique

The method of eliciting risk preferences of the farmers using the certainty-equivalent technique was described in the preceding section. The farmers were asked a set of hypothetical decision problems and the certainty-equivalents for a series of risky prospects were ascertained. These values were then used to derive the farmers' utility functions.

Arbitrary utility values were first assigned to the two extreme income values of 'a' and 'b'. The utility values adopted for this case was 0 and 100. Using the expected utility rule, the expected utility of each certainty-equivalent was obtained. As an example, suppose $U(x_1)$ is the utility of x_1, the uncertainty-equivalent of the risky prospect with equally likely outcomes of 'a' and 'b', then

$$U(x_1) = P(a)U(a) + P(b)U(b)$$

where P(a) and P(b) are the probabilities of 'a' and 'b' occurring. With a fifty-fifty percent chance,

$$U(x_1) = ½(100) + ½(0) = 50$$

Similarly, the expected utility of x_2 *(Figure 1)* is calculated to be

$$U(x_2) = ½ \left\{U(a)\right\} + ½ \left\{U(x_1)\right\}$$

$$= ½(100) + ½(50) = 75$$

The expected utilities of all the other certainty-equivalents were calculated in a similar manner. The expected utilities, including the two extreme values, were then regressed on the corresponding certainty-equivalents, using several functional relationships[1] that include:

a. The Cobb-Douglas function : $U(W) = AW^c$

b. The transcendental function : $U(W) = AW^b e^{cW}$

c. The negative-exponential function : $U(W) = 1 - e^{-cW}$

where U(W) is the utility of wealth, W.

The Conjoint Measurement Technique

The questioning procedure for obtaining the raw data has already been presented. An example of the ranking of the raw data by the farmer is shown in Table 1. The alternative or stimulus with mean 5875 and standard deviation 3681 is the most preferred, followed by the alternative with mean 5000 and standard deviation 1000, and so on down the columns. These results become the input data for monotonic regression.[2]

In this analysis, the following values were chosen: $\epsilon = 1$, $b_1 = 1$, and the initial value of $b_2 = 0$.

TABLE 1
An example of raw data and ranks for the monotonic regression problem

Alternative Stimuli		Rank as Given by a Farmer
Expected Average Income	Standard Deviation	
5875	3681	1
5000	1000	2
6125	2382	3
6000	1732	4
5000	500	5

In the first function where the slopes $b_1 = 1$ and $b_2 = 0$, the value of the objective function is 2.00; the optimal weight for the first attribute (mean) is 0.0366, and for the second attribute (standard deviation) the optimal weight is −0.0227 (Table 2)[3]. These values indicate that this particular farmer preferred a higher mean income and a lower variance. These results are characteristic of a risk-averse individual.

Kendall's tau coefficient of rank order correlation and the Spearman's coefficient or rank correlation (rho) were used to measure the degree

TABLE 2
An example of results of monotonic regression when $b_1 = 1$ and $b_2 = 0$

Ranks Given by a Farmer	*Predicted Ranks*
1	1
2	2
3	4
4	5
5	3

Optimal weights $w_1 = .0366$; $w_2 = -.0227$
Value of loss function (objective function) = 2.00

Measure of Concordance

1. Spearman's coefficient of rank correlation = .7
2. Kendall's tau coefficient = .6
3. Number of concordant pairs = 8
4. Number of pairs with ties = 0
5. Number of discordant pairs = 2

[1] The utility functions for all the farmers are shown in Table 3.
[2] A detail discussion on monotomic regression can be found in Garrod (1979).
[3] The conjoint measurement functions for all farmers are shown in Table 3.

TABLE 3
Utility functions of farmers

Farmer No.	Cobb-Douglas Utility $U = AW^b$			Transcendental Utility Function $U = AW^b e^{cW}$					Negative Exponential Utility Function $U = 1 - e^{-cW}$			Conjoint Measurement Utility Function $U = w_1\overline{W} + w_2(SW)$						
	b	t-ratio	R^2	b	t-ratio	c	t-ratio	R^2	C	t-ratio	R^2	W_1	W_2	C	T	D	rho	tau
1	.8650	7.7517	.9092	1.1448	4.9930	–.0029	– 2.3701	.9340	.7235	1.2540	.1013	.0366	–.0227	8	0	2	.7	.6
2	.7440	6.5135	.8761	1.2800	18.3910	–.0885	– 8.6286	.9922	.7789	2.3622	.1857	.1636	–.0500	10	0	0	1.	1.
3	.7632	11.7590	.9584	2.6951	6.8892	–.0202	– 3.4588	.9877	.4151	1.0250	.2101	.0082	–.0250	10	0	0	1.	1.
4	.9315	9.1570	.9331	1.5495	9.7121	–.1607	– 4.1096	.9847	1.3965	2.6612	.0067	.0980	–.0112	8	0	2	.7	.6
5	3.6109	10.0840	.9443	11,6480	6.2190	–.5358	– 4.3112	.9882	.0625	.0723	.1460	.0038	+.0084	9	0	1	.9	.8
6	.8733	7.2871	.8985	14.5660	12.5790	–.3038	– 9.7964	.9950	.7912	2.1135	.2017	.0648	–.0250	9	0	1	.9	.8
7	.8745	10.6000	.9493	.3503	1.5876	.0694	2.4712	.9772	.1800	.9832	.0160	.2174	–.0589	9	0	1	.9	.8
8	.6874	9.4670	.8871	6.5050	11.5310	–.1598	–10.4210	.9730	1.4149	2.2457	.3702	.2174	–.0589	9	0	1	.9	.8
9	.8960	10.6750	.9500	1.3666	4.6776	–.0096	– 1.6635	.9678	1.0724	2.0527	.0014	.0196	–.0115	9	0	1	.9	.8
10	3.0447	23.9360	.9948	2.9997	3.1916	.0021	.4817	.9948	.3738	.9625	.1244	.0196	+.0115	9	0	1	.9	.8
11	.8517	16.0470	.9772	.8378	5.7201	.0003	.1034	.9773	.7430	1.9935	.1650	.0648	–.0250	9	0	1	.9	.8
12	.9607	10.2870	.9463	1.5114	12.2790	–.1469	– 4.7802	.9904	.8071	2.0253	.5186	.0082	–.0250	10	0	0	1.	1.
13	3.8421	18.1090	.9820	1.0318	.3034	.0898	.8581	.9843	.8949	2.2428	.0143	.0038	+.0084	9	0	1	.9	.8
14	3.1687	10.0320	.9437	9.4871	10.2400	–.0881	– 6.8750	.9946	.3654	1.5569	.0655	.0011	+.0079	10	0	0	1.	1.
15	.9612	4.6927	.7859	2.0727	7.0240	–.0935	– 4.0502	.9500	.2626	.8843	.1055	.1700	–.0250	10	0	0	1.	1.
16	.8471	8.3734	.9212	1.2020	6.6745	–.0320	– 2.1940	.9598	.7845	1.7877	.2076	.0082	–.0250	10	0	0	1.	1.
17	.6875	5.8214	.8496	.9703	4.9873	–.0351	– 2.7120	.9052	.0266	.0836	.1006	.0366	–.0227	8	0	2	.7	.6
18	.8082	4.6719	.7844	1.7152	10.4500	–.0865	– 6.0332	.9740	.5438	1.5522	.4819	.0263	–.0223	6	0	4	.5	.2
19	.9445	5.4367	.8313	2.0178	18.5450	–.0927	–10.5810	.9928	.0177	.0133	.0045	.0082	–.0250	10	0	0	1.	1.
20	.8800	4.0716	.7290	2.4663	7.8264	–.0842	– 4.8301	.9404	2.2456	2.2456	.5601	.0082	–.0250	10	0	0	1.	1.

C = No. of concordant pairs: T = No. of discordant pairs: D = No. of ties.

W = level of wealth

w_1 = weights attached to the mean $\overline{W}$

w_2 = weights attached to the standard deviation SW

rho and tau = both are measures of associations between the mean and standard division of association between the actual and predicted ranks. The values of .7 and .6 for the Spearman's rho and Kendall's tau respectively indicate that there was a moderately strong association between the initial ranks and the estimated ranks. Also presented in the table is a count of the number of concordant, discordant and tied pairs. There are eight concordant pairs and two discordant pairs; none of the pairs are tied.

The problem of multiple vectors of w corresponding to the same minimum value of the loss function was partially alleviated by parametrically varying the initial value of b_2 from 0 to $b_2 = b_1$. The values selected were 0, .1, .5, and 1. Parametrically varying b_2 did not show any improvement in the number of concordant pairs or in the value of the optimal weights in this example. This also held true for most other cases.

The Probability Distributions

The response functions were estimated for individual crops rather than for a heterogeneous aggregate for the total farm. Price and yield expectations were combined to get an estimate of the expectation of gross returns per hectare for the individual crops. An illustration of this technique is shown in Table 4.

The average yields and prices in the three different seasons were calculated for all crops belonging to each of the farmers. Rubber was considered the least risky crop. Farmers expected no fluctuation in the income level generated by this crop over the years. They did, however, expect some monthly fluctuation. In the course of the interview, the farmers were also asked to give their opinion on inflation. The general response was that even though they expected an increase in the price level, as far as their products were concerned, prices would remain fairly stable. Regarding the price of inputs, particularly fertilizer and planting materials, they believed that prices would increase but they expected the government to step in and stabilize the prices they would have to pay.

TABLE 4

Expected output, prices and incomes of one crop per hectare

Seasons Classification	*No. of Year out of ten*	*Expected Output* (Kilograms)	*Expected Price* (M$/Kilogram)	*Expected Income* (M$)
Good	3	5990	.55	3295
Medium	4	1122	1.10	1234
Poor	3	625	1.65	1031
Average*		2433	1.10	2676

*Average expected output is computed using the formula

$E(Y) = Y_jP_j$ where Y_j = output in j^{th} season

P_j = probability of the j^{th} type of season

Average expected price and average expected income are computed in similar manner.

TABLE 5

Activity gross margin per hectare (M$)

Type of growing seasons	Cropping Activities*			
	Durian (X_1)	Duku (X_2)	Rambutan (X_3)	Rubber (X_4)
Good	3295 (n = 3)	1754 (n = 1)	2377 (n = 3)	–
Medium	1234 (n = 4)	1261 (n = 7)	1373 (n = 4)	1266 (n = 10)
Poor	1031 (n = 3)	1124 (n = 2)	589 (n = 3)	–
Average	1791	1283	1439	1266

*n = number of years out of ten.

The E-V *Frontier*

The farmer's subjective probability distribution of prices and yields were incorporated in the estimation of the expected net returns and the variances. The figures were obtained by the technique discussed in the preceding section and an example of the elicited gross margins per hectare from one farmer are shown in Table 5.

A closer look at Table 5 reveals that this particular farmer perceived the presence of good, medium, and poor seasons for all the fruit crops but not for rubber. He believed that the income from rubber was not subjected to annual fluctuation even though he expected monthly variations.

A quadratic programming model was used to estimate the E-V frontier for each farm.[4] The size of operation was limited by the total amount of land available. The total labor available for farm work was computed by summing the number of days per year each family member was expected to contribute. Fertilizer was limited by the maximum amount of funds the farmer was willing to commit to fertilizer. The amount of non-farm income the farmer received was also incorporated into the quadratic programming. Inclusion of the non-farm income did not alter the shape of the E-V frontier, but it could affect the optimal farm plan since it did shift the frontier. Fixed costs were not included in the analysis because the values were negligible for this type of farming operation. Table 6 shows examples of the input data used in the quadratic programming framework. Means and variances of income for individual crops on each farm were estimated subjectively, but it proved impossible to obtain subjective estimates of covariances (or correlations) directly from the farmers. It was also not possible to use historical covariances among crops since data were not available. Therefore, an assumption was made that the income correlation among different fruits was .5. It was also assumed that rubber income was not correlated with those of various fruits.

Optimal Farm Plans

Each of the alternative behavioral models and the profit-maximization hypothesis was then used in conjunction with the E–V frontier, described in the preceding section, to derive the optimal farm plans.

Utility functions (except the conjoint measurement function which was already defined in terms of mean and variance) were respecified as func-

TABLE 6

The quadratic programming data requirement (for one farmer)

The Objective Function (covariance metrix):

	X_1	X_2	X_3	X_4^a
X_1	1084427	91146	381218	0
X_2	91146	30643	64082	0
X_3	381218	64082	536051	0
X_4	0	0	0	1

[a]A small number, 1, is used as variance of rubber income for operational purposes.

The Technical Coefficients and Constraints:

	X_1	X_2	X_3	X_4	
Land (hectares)	1	1	1	1	$\leqslant$ 5.25
Labor (man-days)	203	175	67	423	$\leqslant$ 1500
Fertilizer (Kilograms)	80	27	9	19	$\leqslant$ 567
Miscellaneous ($)	64	40	30	40	$\leqslant$ 500
Expected income ($)	1791	1283	1439	1266	$= \lambda$

[4] The E–V frontier solutions were obtained using a quadratic programming routine developed by Dr. Peter V. Garrod, Department of Agricultural and Resource Eonomics, University of Hawaii at Manoa.

tions defined in terms of the mean and variance to estimate the optimal farm plans. Assuming a normal or approximately normal distribution, the Cobb-Douglas utility function was written use:

$$U = \{W_0 + E(w)\}^{b} + b(b-1)\{W_0 + E(w)\}^{b-2} \quad Var(w)/2;$$

the transcendental utility function as:

$$U = \{W_0 + E(w)\}^{b} e^{c\{W + E(w)\}} + U\left\{\frac{b(b-1)}{\{W_0 + E(w)\}^2} + \frac{2bc}{\{W + E(w)\}} + C^2\right\} Var(w)/2;$$

and the negative exponential utility function as:

$$U = \{W_0 + E(w)\} - cVar(w)/2,$$

where:

W_0 = initial wealth,

$E(w)$ = expected gain or loss of wealth, and

$Var(w)$ = variance of wealth.

Profit maximization implies a linear utility function. This implies vertical indifference curves. Therefore, the profit maximizing farm plan was the extreme right of the E–V frontier (point a in Figure 2).

TABLE 7

The Chi-square goodness-of-fit and the estimated probability of income profile of actual and predicted plan being equal

	Calculated Chi-Square Value[f]					Estimated Probability[g]				
Farmer No.	CD[a]	TR[b]	BW[c]	CM[d]	PM[e]	CD	TR	BW	CM	PM
1	3.084	3.088	3.082	3.088	3.090	.0835	.0833	0.836	.0833	.0832
2	.628	.628	.628	.628	.850	.7182	.7182	.7182	.7182	.6523
3	3.579	3.580	3.578	3.580	3.582	.0615	.0615	.0161	.0615	.0614
4	3.072	3.037	3.078	7.137	7.137	.0840	.0855	.0837	.0080	.0080
5	.796	.798	.786	.646	.798	.6683	.6682	.6713	.7129	.6682
6	7.621	7.621	7.621	7.628	7.628	.0060	.0060	.0060	.0060	.0060
7	12.645	12.650	12.624	12.650	12.652	0	0	0	0	0
8	3.770	3.793	3.793	3.794	3.794	.0214	.0213	.0213	.0213	.0213
9	66.936	66.936	66.973	66.936	69.363	0	0	0	0	0
10	6.266	6.270	6.266	6.270	6.270	.0314	.0134	.0314	.0134	.0134
11	10.693	10.690	10.678	6,220	10.690	0	0	0	.0138	0
12	9.345	5.993	5.990	5.990	9.345	0	.0159	.0160	.0160	0
13	16.135	16.132	16.132	16.135	16.135	0	0	0	0	0
14	3.081	.728	3.070	3.081	3.081	.0836	.6885	.0841	.0836	.0836
15	7.341	2.722	2.722	2.722	7.344	.0072	.0995	.0995	.0995	.0071
16	1.779	1.784	1.784	1.784	1.784	.3764	.3750	.3750	.3750	.3750
17	.328	.328	.311	.063	.328	.8073	.8073	.8123	.8860	.8073
18	12.761	12.763	12.761	12.761	12.763	0	0	0	0	0
19	1.022	1.022	.966	.742	1.022	.6012	.6012	.6719	.6844	.6012
20	5.648	5.652	5.650	5.648	5.652	.0191	.0191	.0191	.0191	.0191

a. CD = Cobb-Douglas utility model.
b. TR = Transcendental utility model.
c. BW = Negative exponential/Binswanger utility model.
d. CM = Conjoint Measurement.
e. PM = Profit maximization model.
f. underlined values show the best predictor of actual behavior.
g. underlined valued show the predictor with the higher probability that the actual and predicted plans are equal.

Prediction of Actual Behavior

The final step in this analysis was to test the ability of the models to predict actual behavior (i.e., the actual cropping pattern at the time of the study). It is obvious that the actual plan has many dimensions, including sizes of various crops, levels of various inputs, average income from different crops, etc. However, the income distribution for each plan — i.e., its mean and variance — is perhaps the best factor to characterize the plan. So, the test to determine which models best describe actual behavior was made within the E–V space. The Chi-square goodness-of-fit test was used. It was calculated by comparing the mean and variance of the income from the optimal plan predicted by each of these models with that of the actual plan. The results of the Chi-square test are shown in Table 7.

The Chi-square values were then used to calculate the probability of obtaining the two different distributions at random when in fact they have the same mean and variance. This means the higher the probability level, the better is the prediction.

The conjoint measurement model was the best predictor in seven cases. The next best predictor of the actual farm plan were the transcendental, the negative exponential, and the Cobb-Douglas utility models; and finally the profit maximization model. For the classical behavior assumption of profit maximization, the probability of "correctly" predicting actual behaviour is essentially or very close to zero in 15 of the 20 cases analysed.

Therefore, the results of the analysis show that Bernoullian utility maximization explains actual farmer behavior more accurately than profit maximization.

POLICY IMPLICATIONS AND AREA FOR FURTHER RESEARCH

What is the best way to get the numerous small farmers to participate in the programs of the fruit development plan in the prescribed way so as to contribute to the attainment of the plan goals and targets? It has been observed on many occasions that a significantly large number of farmers still fail to participate in government programs to develop the fruit industry when it appears that it is to the economic advantage of the farmers to participate. Hence a conventional wisdom has gained widespread acceptance among some people that the small farmers stubbornly and irrationally resist change. This, of course, may not be true. Firstly, a small farmer typically lacks technical information concerning the technical change that may be involved, and he has had little or no experience with it; hence he is inclined to move slowly with respect to adopting the technology. Secondly, adoption of new technology may, in fact or in the mind of the farmer, involve considerable risk, and often, he can not afford to take the chance. For both of these reasons one could not say that the farmer acts irrationally.

It would be ideal if the government programs could reach the individualized operation of thousands of farms and direct the pattern of operation in each of these farms so as to maximize the expected utility of each farmer. This, of course, is next to impossible. However, it is believed that the attainment of development goals and targets can be achieved via the inducement approach; it would be far easier and more productive to provide a general incentive in terms of a temporarily increased price, or factor subsidy, etc. aimed at increasing farm profit and to let each farmer, with the aid of a good information program, work out the most efficient pattern of operation for his particular farm according to his preference.

In light of the above, a consideration of a fruit development plan must contain within it a relatively large and effective production education program to convey to farmers relevant and reliable technical information concerning the new technology or production program so that they make rational decisions with respect to adoption or participation. Where research for technological development is concerned, effort has been concentrated on propagating and developing fruit clones that are high yielding and at the same time have shorter maturity periods. Another important feature of these crops that has not been researched is the variability in production which is irregular and unpredictable. Research on developing clones that have lower variability and irregularity of production but at the same time provide an acceptable yield and a short maturity period is highly relevant for the development of the fruit industry.

The fruit development plan may be complemented by economic programs which provide better marketing and credit facilities, input subsidies, planting materials, technical information, and non-farm job opportunities which allow greater pooling of risks at the household level.

Agricultural price support has been used quite successfully in the production of rice as part of an incomes policy. This policy is likely to be more appropriate in cases where price uncertainty dominates. In this study, however, the extent of price and yield uncertainties are not examined individually; thus it would not be appropriate to recommend price support policy. This issue, therefore, requires further research before any form of conclusion can be made.

In the area of crop insurance as a policy alternative to dealing with the undesirable consequences of risk aversion, various studies have shown that pure insurance schemes based on individual loss assessment are likely to have low benefit-cost ratios, particularly in countries with low levels of income and small landholdings because the administrative costs of assessing individual losses become very high (Roumasset, 1978). Furthermore, the relevant efficiency issue is not whether risk preferences change the allocation of resources, but whether risks are appropriately spread throughout the economy (Arrow, 1971). There is also the possibility that where risk preferences are derived from market imperfections like the differences in buying and selling prices, they serve a positive role in the efficient allocation of resources (Roumasset, 1978). In developing countries where the insurance schemes seemed to have worked, they are better described as income support and distribution schemes towards poor areas rather than insurance schemes (Binswanger, 1979). The prospect of crop insurance at this moment appears bleak; however, to the extent that one believes that it may be an affective tool to reduce risk, further research is warranted.

The biggest problem encountered during the survey was related to the process of eliciting the subjective risk preferences of the farmers, and this may have some effect on the results. If similar techniques were to be used in future research work, the problem could be alleviated by providing more intensive training to the interviewers so that they could explain more clearly the nature and requirement of the scheme to the farmers and become more alert in recognizing inconsistent answers.

The conjoint measurement utility function appears to work quite well in explaining farmers' attitudes towards risk and thus may be considered a good prospect for similar work in the future. The conjoint measurement if carried out in more detail, may become a good tool in explaining the decision-making process of small farmers.

Research dealing with subjective probability distribution has gained momentum in recent years. In this study, an approach combining personal probabilities of certain 'disasters' such as pest outbreaks with expected outcomes of yield and prices is used. This approach appears to work quite well, i.e., most farmers are able to specify the number of good, medium, and poor years out of ten as well as the associated yields and prices. Future studies dealing with subjective probability distributions may consider using and improving this approach.

Because it considers only two moments of the distribution of returns, there has been strong criticism of the E–V approach. However, a crude representation of risk may be better than ignoring it altogether. The analysis can be extended to higher moments if required, though at some computational cost.

In the final analysis, planners for the fruit industry must develop methodological innovations for dealing with uncertainty in complex cropping situation and formulate research, projects, programs, and policies that are tailored to its special characteristics but which constitute tolerable solutions to the difficult issues of its development. It is hoped that a recognition and understanding of these special characteristics and issues will lead to a more effective development plan for the fruit industry.

REFERENCES

ANDERSON, J.R., DILLON, J.L. and HARDAKER, J.B. (1977): Decision Analysis in Agricultural Development. Ames. Iowa State University Press.

ARROW, K.J. (1971): Essays in the Theory of Risk Bearing. Chicago. Markham Publishing Company.

BINSWANGER, H.P. (1979): Risk and Uncertainty in Agricultural Development: An Overview. In Roumasset, J.A., Boussard, J.M. and Singh, I. (Eds.). "Risk, Uncertainty and Agricultural Development." Laguna. Southeast Asian Regional Centre for Graduate Study and Research in Agriculture.

FRANCISCO, E.M. and ANDERSON, J.R., (1972): Chance and Choice West of the Darling. *Aust. J. agri. Econ.* **16(2):** 82-93.

GARROD, P.V. (1979): A General Program for Monotonic Regression. (mimeograph). University of Hawaii.

GARROD, P.V. and MIKLIUS, W. (1981): A Method for Estimating the Value of Transport Service Attributes. Paper presented at WAEA Annual Meeting of Lincoln. Nebraska. July 19-21, 1981.

GREEN, P.E. and WIND., Y. (1975): New Way to Measure Consumers' Judgements. *Harvard Bus. Rev.* **54:** 107-117.

JOHNSON, R.M. (1975): A Simple Method for Pairwise Monotone Regression. *Psychometrika.* **40,(2):** 163-168.

KRUSKAL, J.B. (1965): Analysis of Factorial Experiments by Estimating Monotone Transformations of the Data, *J.R. statist. Soc.* Series B. **27**: 251-263.

MALAYSIA MINISTRY OF AGRICULTURE. (1975): Report of the Committee on Fruits and Vegetable. Vol. 1. Kuala Lumpur. Ministry of Agriculture Printing Office.

PEKELMAN, D. and SEN., S.K. (1974): Mathematical Programming Models for the Determination of Attribute Weights. *Management Science.* **20(8)**: 1217-1229.

ROUMASSET, J.A. (1978): The Case Against Crop Insurance in Developing Countries. *Philippines Rev. Bus. and Econ.* I.

SRINIVASAN, V. and SHOCKER, A. (1973): Linear Programming Techniques for Multidimensional Analysis of Preferences. *Psychometrika.* **38(3)**: 337-369.

(Received 2 February 1982)