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COMPARISON OF THE PROGRAMMING MODELS FOR CONSIDERING RISK IN FARM PLANNING: APPLICATION OF UTILITY-EFFICIENT PROGRAMMING

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ABSTRACT

Farmers, particularly in developing countries, operate in an uncertain decision making environment. Variations in crop yields and fluctuations in input and output prices are important elements of risk in agriculture. Various risk -programming techniques have been developed to model risk in decision making under uncertainty. The purpose of this study was to examine and evaluate major alternative methods of incorporating risk in decision models. An extension of the method of direct utility maximization then was used to generate an efficient set of farm plans for the small, medium and large representative farms, using the concept of stochastic dominance with respect to a function. The model incorporates farmers' risk preferences, revenue fluctuations and resources restrictions in agricultural planning. Results of this study demonstrated the merits of this technique particularly when sufficient information is not available to estimate the individual utility function for each representative farm. The optimum plans identified the changes in crop activities to seek a trade-off between maximizing expected value of total net revenues as well as minimizing the risk of undertaking crop activities.

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Key words: Risk programming methods, Risk preferences, Utility-efficient programming technique.

تحقیقات کشاورزی ایران

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مقایسه مدل های برنامه ریزی ریاضی دخالــت دادن مخــاطره در برنامه مزرعه: کاربرد روش برنامه‌ریزی بازده مطلوبیت

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چکیده

کشاورزان، به ویژه در کشورهای در حال توسعه، در محیطی توأم با عدم حتمیت فعالیت می‌کنند. نوسان در تولید و قیمت داده‌ها و ستاده‌ها از اجزای اصلی مخاطره در کشاورزی است. برای تصمیم‌گیری در شرایط عدم حتمیت، چندین روش برنامه‌ریزی توأم با مخاطره پیشنهاد شده است. در این مطالعه، روش های عمده دخالت دادن مخاطرات در مدل های تصمیم‌گیری، بررسی و ارزیابی شد. سپس، با توجه به مفهوم برتری تصادفی و با توجه به فرم یک تابع، از نوع گسترش یافته روش بیشینه‌کننده فایده مستقیمَ برای ایجاد مجموعه کارای برنامه‌های بهره‌برداری های نماینده گروه های کوچک، متوسط و بزرگ استفاده شد. این مدل، اولویت های مخاطره‌ای کشاورزان، نوسان های درآمدی و محدودیت های مربوط به منابع را در برنامه‌ریزی کشاورزی دخالت می‌دهد. یافته های این مطالعه، نمایانگر مزایای استفاده از این روش، به ویژه در صورت عدم دسترسی به اطلاعات لازم، برای تخمین تابع مطلوبیت انفرادی زارع، است. برنامه‌های بهینه

ایجاد شده نشان دهنده تغییرات لازم در ترکیب فعالیت های زراعی کشاورزان نماینده برای ایجاد مبادله بین اهداف حداکثر کردن ارزش انتظاری درآمد خالص و حداقل نمودن مخاطرات است.

INTRODUCTION

Most of the agricultural production activities are exposed to risk. The immediate implication of this risk for economic agents is that many possible outcomes are usually associated with any one chosen action. Plans have their outcomes in the future and farmers can never be absolutely sure what the future will bring. So, agricultural producers, particularly in developing countries, operate in an uncertain decision making environment (1, 2, 7, 10).

A major criticism of the conventional production theory concerns its omission of risk and risk aversion (10, 11, 14, 19). Risk can be defined as any fluctuations in farmers' outcomes. Variations in crop yields and fluctuations in input and output prices are important elements of risk in agriculture. The most typical example of risk in agricultural production is that associated with climatic variables. Yield depends on random climatic variables, thus becoming random itself. Another major source of risk in agriculture is market prices. So, risk may be summarized, usually, as uncertainty in farmer's outcome (5, 8, 20).

Since the risk attached to outcome of farm income affects farmer's decision making, it is desirable to incorporate risk into the analytical framework for farm management research and extension purpose. The desire to reflect risk of future events within decision making problems has led to a number of risk models (3, 6, 12, 13, 23). A class of these risk models, for incorporating stochastic parameters into the framework of decision analysis, has arisen within the mathematical programming literature. In this class of models, risk and uncertainty are equivalent and mean some variables in the objective function are random variables. Thus, incorporating risk in production analysis means incorporating random variables in production models and in the decision problems faced by farm managers (15, 16, 18).

Various risk programming techniques have been developed to model risk in decision making under uncertainty (3, 10). These methods include linear risk programming, such as minimization of total absolute deviations (MOTAD) and Target MOTAD, and nonlinear risk programming such as quadratic risk programming (QRP), direct expected mathematical programming (DEMP) and utility-efficient programming (UEP) (3, 9, 10). The above analytical tools have been mainly developed to apply expected utility hypothesis (EUH) to the decision problems faced by managers. The assumptions and axioms associated with the EUH have been reviewed by several authors (14, 17, 24).

The first objective of this study was to evaluate some alternative methods of incorporating risk in decision models and the second objective was to demonstrate an application of the technique of UEP to a practical farm planning problem. The guiding hypothesis was that uncertainties in activity costs, yields, and prices affect expected productivity and expected income of the study farmers.

This paper provides a brief evaluation of some alternative risk programming models. This is followed by the report of empirical results obtained from application of the UEP technique.

METHODOLOGY

Lambert and McCarl in 1985 reviewed deficiencies of the quadratic risk programming (QRP) and proposed, as an alternative, a mathematical programming model which involves direct maximization of expected utility (10, 11, 19).

QRP model is the most widely used method of accounting for risk in the objective function (12). It is based on the assumption that the farmer has a utility function which can be expressed in terms of expected income (E) and income variance (V). It assumes that the farmer is risk-averse so that the iso-utility curves are convex (10). That is, along every iso-utility curve the farmer would prefer a strategy with higher V only if E were also greater. Markowitz in 1952 used a quadratic formulation to generate an efficient E-V frontier while Freund in 1956 used it for including risk in a farm programming model (3, 9). Tsiang (23) has provided a justification for E-V analysis. The model is typically formulated as:

$$\text{Maximize} \quad E(U) = \pi' x - \lambda(x' \sigma x)$$

Subject to:

$$Ax \leq b \qquad \text{and} \qquad x \geq 0$$

where E (U) = the expected utility; π = the vector of activity net revenue; x = the vector of activity levels; σ = the variance-covariance matrix of activity returns; A = the matrix of technical coefficients; b = the vector of resource stocks; and λ = the risk aversion coefficient. λ varies form zero to one to derive the efficient frontier. When λ and/or $\sigma = 0$ the problem is reduced to a linear programming.

QRP has been criticized for its restrictive assumptions (3, 10). These assumptions are expressed as follows: 1) the farmer's utility function has quadratic form, and/or 2) the distribution of total net income is normal. The first assumption implies that a) marginal utility is positive only within a bounded range, since a quadratic utility function is not everywhere increasing (10), and b) increasing risk aversion so that it fails to meet the intuitive requirement of decreasing risk aversion with increasing wealth (3). Both properties are inconsistent with the expected nature of true preferences and generally are not acceptable. It has been argued strongly against the use of the quadratic function on the grounds that it is reasonable to expect that, as wealth increases, the coefficient of absolute risk aversion should decrease (9). Also, the symmetry implied by the normality assumption has been questioned on the grounds that the real world may be characterized by asymmetric distributions (3, 10, 21).

Lambert and McCarl's direct expected utility mathematical programming model is consistent with traditional risk theory (e.g. ability to allow decreasing risk aversion as wealth increases) and overcomes the main theoretical criticisms of E-V analysis and its linear approximations such as MOTAD (10, 22, 23).

DEMP model may be formulated as follows:

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

Subject to:

$Ax \leq b$ $\quad$ $Cx - Iz = uf$

and $\quad$ $x \geq 0$

where U(.) = a monotonic and concave utility function; u(z) = a vector of utility of net revenue by state; z = a vector of net incomes; A = a matrix of technical coefficients; p = a vector of state probabilities; C = a matrix of activity net revenue; I = an identity matrix; u = a vector of ones; x = a vector of activity levels; f = fixed costs; and b = a vector of resource stocks. The DEMP model can be solved by using a non-linear programming software such as GAMS with MINOS (4).

This model has been further developed by Patten, Hardaker and Pannell (19), and Hardaker Pandey and Patten (11). Patten *et al.* (19) reformulated Lambert and McCarl's approach using parametric objective programming. They called their approach UEP model. Their technique has a number of advantages. It needs less information about farmers' risk attitudes than Lambert and McCarl's approach. Further, it is applicable to a number of types of utility function. They applied both the sumex function and the exponential utility function to the same set of data, using a nonlinear programming algorithm. They reported very similar results in both cases (19).

Hardaker *et al.* (11) using a negative exponential utility function of parametric form proposed:

$$U = \exp[-\{(1-\lambda)a + \lambda b\}z], \qquad a, b \geq 0 \quad \text{and} \quad 0 \leq \lambda \leq 1$$

Variation in λ may be interpreted as variation in risk preferences when the coefficient of absolute risk aversion (r_A) varies between a and b. Thus, a and b can be set at the upper and lower limits of the range of risk aversion. r_A is equal to a when λ is zero and close to b when λ is large.

In this study, it was assumed that utility function has a negative exponential functional form, and the UEP models of the representative farms were solved by GAMS/MINOS non-linear maximization option (4).

The elicitation of farmers' risk attitudes is necessary for full specification of UEP models. The equally likely certainty equivalent (ELCE) interview technique with imaginary payoffs was used to elicit the utility functions of farmers' range of risk aversion (r_A) levels (11). 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. Thus empirically determined range of r_A was used in the UEP model to specify the range of risk aversion for the representative farm.

Data

Farm and household budget information, including farm resources, input levels, costs, yields and commodity prices, consumption and sale, and also other available data on levels of tractor, human labor supply and use in the study region, yield and price variability for the various cropping activities were collected from a sample of 95 farmers, who were selected by a two- stage cluster sampling from Korbal plain of Fars province, through structured questionnaires. In additional, asset ownership, off-farm work, credit use data on farmers' risk attitudes and their subjective beliefs regarding crop yields and prices were recorded. Time series data for the yields and prices of various crops were obtained for the 1988-1997 period from the regional branches of the rural service center.

Applying cluster analysis to classify sample farms into homogenous groups is likely to eliminate or at least minimize aggregation bias (14). Thus statistical cluster analysis was used to divide the sample farms into homogenous size classes. The median farm of each group then was chosen, following Hazell and Norton (14), as being representative after ranking the farms on the basis of their area, resulting in representative farms of the following sizes: small 2.5 ha, medium 7.8 ha and large 14.5 ha.

RESULTS AND DISCUSSION

The utility efficient solutions for three representative farms are presented in Tables 1 to 3, using the empirically estimated range of r_A values from 0.000005 to 0.0002. Results for selected r_A illustrate the trade off between cropping pattern and the farmers' risk preferences for the small, medium and large representative farms. In general, the model results and the cropping patterns show diversification of crops. Representative farms allocate their farm lands to crops which guarantee both household food security and income. Food security under the UEP models are guaranteed by the production of rice, wheat and barley. Household income also is ensured by producing sugar beet, sunflower and potential saleable surplus rice, wheat and barley.

Table 1. Efficient set of optimum solutions for the small representative farm[†]

	Activity levels (ha)						
r_A[§]	Barley	Corn	Rice	Sugar beet	Sunflower	Wheat	ETNR[¶]
0.200	0.60	0.20	0.34	0.00	0.00	1.35	3950.00
0.100	0.61	0.20	0.40	0.00	0.00	1.28	4080.00
0.050	0.60	0.17	0.43	0.05	0.10	1.15	4178.00
0.025	0.65	0.13	0.46	0.13	0.12	1.00	4202.00
0.012	0.70	0.00	0.50	0.20	0.20	0.90	4248.00
0.005	0.70	0.00	0.50	0.28	0.31	0.70	4289.50

[†] The small representative farm has 2.5 ha of operated land.

[§] r_A is the coefficient of risk aversion multiplied by 1000.

[¶] ETNR stands for expected value of total net revenue (1000 Rials).

Table 2. Efficient set of optimum solutions for the medium representative farm[†].

	Activity levels (ha)						
r_A[§]	Barley	Corn	Rice	Sugar beet	Sunflower	Wheat	ETNR[¶]
0.200	1.50	1.60	0.50	0.70	0.50	3.00	11361.50
0.100	1.50	1.53	0.60	0.71	0.55	2.90	11592.00
0.050	1.53	1.45	0.67	0.75	0.55	2.85	11870.00
0.025	1.60	1.28	0.70	0.88	0.63	2.70	12245.80
0.012	1.60	1.20	0.80	1.00	0.70	2.50	12604.00
0.005	1.50	1.07	0.84	1.12	0.15	2.10	13180.60

[†] The medium representative farm has 7.8 ha of operated land.

[§] r_A is the coefficient of risk aversion multiplied by 1000.

[¶] ETNR stands for expected value of total net revenue (1000 Rials).

However, large representative farm model, as compared to models of medium and small representative farms, allocate higher proportion of its farm land to high net return cash crops. Also, as r_A decreases, representative farmers select a farm plan which contains more high net return cash crops.

Furthermore, the model solutions for the small, medium and large representative farms show that expected value of total net return increases as aversion to risk decreases. These results are consistent with risk theory. Risk averse farmers typically prefer farm plans that provide a satisfactory level of security, even if this means sacrificing some income. Thus, the models' results confirm that households in the study region are risk averse, indicating that the risk aversion plays an important role in farmers' behavior.

Table 3. Efficient set of optimum solutions for the large representative farm[†].

	Activity levels (ha)						
r_A[§]	Barley	Corn	Rice	Sugar beet	Sunflower	Wheat	ETNR[¶]
0.200	3.50	2.00	1.00	2.00	1.00	5.00	21550.70
0.100	3.54	2.00	1.00	2.00	1.05	4.90	22140.00
0.050	3.68	1.83	1.07	2.08	1.13	4.70	22550.50
0.025	3.75	1.70	1.13	2.11	1.20	4.60	22890.00
0.012	3.80	1.40	1.40	2.27	1.42	4.20	23180.80
0.005	4.00	1.30	1.54	2.32	1.84	3.50	24880.50

[†] The large representative farm has 14.5 ha of operated land.

[§] r_A is the coefficient of risk aversion (multiplied by 1000).

[¶] ETNR stands for expected value of total net revenue (1000 Rials).

Results of this study demonstrated the merits of utility-efficient extension of the DEMP technique particularly when sufficient information is not available to estimate the individual utility function for each representative farm. The model incorporates farmers' risk preferences, revenue fluctuations and resources restrictions in agricultural planning. The optimum plans identified the changes in crop activities to seek a trade-off between maximizing expected value of total net revenues as well as minimizing the risk of undertaking crop activities, by placing limits on the decision maker's degree of absolute risk aversion.

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