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A study of economic efficiency of Iranian farmers in Ramjerd district: an application of stochastic programming

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Abstract

An extension of utility-efficient programming to the non-linear discrete stochastic programming method was developed and used in the analysis of the economic efficiency of a sample of farmers in Iran. The results indicate that it would be feasible to increase substantially farmers' total net revenue by increasing their economic efficiency in terms of technical and allocative efficiencies. The study further suggested that risk aversion plays an important role in farmers' behaviour. The sample farmers are risk averse and hence are likely to trade higher expected profits for lower risk. Understanding this characteristic is important for interventions intended to raise farm productivity and efficiency.

1. Introduction

The concept of efficiency is at the core of economic theory. The theory of production economics is concerned with optimisation, and optimisation implies efficiency (Baumol, 1977). Decision makers are presumed to be concerned with the maximisation of some measure of achievement such as profit or utility. The analysis of efficiency, in general, focuses on the possibility of producing a certain level of output at lowest cost or of producing the optimal level of output from given resources. Therefore, efficiency measurements that show the scope for improved performance may be useful in the formulation and analysis of agricultural policy (Russell and Young, 1983).

Since Schultz (1964)'s famous 'poor but efficient' hypothesis, there has been interest in assessing the efficiency of agriculture, especially in developing countries. Farm economic efficiency models used in these studies may be classified into four main categories, viz, production function, frontier function, profit function, and mathematical programming. Various approaches to measuring efficiency have been discussed and evaluated by Torkamani (1994).

Despite the many earlier studies, the concept of economic efficiency is not unambiguous and its usefulness as a measure of economic performance has been questioned. Pasour (1981) argued that efficiency measures derived by assuming profit maximisation are not appropriate standards to measure the performance of economic agents operating under imperfect information and whose objective functions involve elements other than profit. The applicability of rules of neoclassical economics to traditional agriculture has been criticised by many authors (e.g. Lipton, 1968; Dillon and Anderson, 1971; Upton, 1979).

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Analyses of economic efficiency are typically based on the assumptions that farmers strive to maximise profits given competitive input and output markets, and that they do so under certainty. However, considering the existence of imperfect information, and the socio-economic context within which farmers operate, the assumption of profit maximisation is unsatisfactory. Consequently, more realistic behavioural assumptions should be made in modelling peasant behaviour. Also, every farm is more or less a multi-output multi-input decision making unit and operates under technical, physical and socio-economic constraints. The farmer's decision making problem may therefore be regarded as one of constrained utility optimisation under uncertainty, suggesting that it is useful to look to a stochastic programming approach for modelling farm economic efficiency.

2. Stochastic programming approaches

Various methods for handling risk in mathematical programming models in agriculture are reported in the literature (e.g. Anderson et al., 1977; Hazell and Norton, 1986; Hardaker et al., 1991). Widely used methods of accounting for risk in the objective function include quadratic risk programming (Markowitz, 1952; Freund, 1956; Tsiang, 1972) and its linear approximations such as MOTAD (Hazell, 1971). However, in practice, a farmer may also face risk in the constraints. Programming methods that also account for uncertainty in the constraints are usually known as stochastic programming (Anderson et al., 1977; Hardaker et al., 1991). Various techniques to solve stochastic programming problems have been proposed.

Hardaker et al. (1991) argued that discrete stochastic programming (DSP) (Cocks, 1968; Rae, 1971a; Rae, 1971b) is the most useful approach to problems with embedded risk. Risk is embedded when decisions are made sequentially and later decisions may be influenced not only by earlier ones but also by the values of the random parameters that only become known after the earlier decisions have been taken. Most farm decision problems involve such embedded risk. Using the DSP formulation, the range of possible outcomes at each stage is reduced to a small number of representative cases. A mathematical programming matrix can then be constructed permitting simultaneous optimisation over these cases. For risk-averse farmers, the objective function for a DSP model may be specified as maximisation of expected utility (Lambert and McCarl, 1985).

3. The stochastic model specification

Assuming that the risk is to be represented by considering k states, then a DSP model for a two-stage sequential stochastic decision problem can be structured as follows

maximise $E[U] = p'u(z_{2k})$

subject to

$A_1 x_1 \leq b_1$

$-L_{1k} x_1 + A_{2k} x_{2k} \leq b_{2k}$

$c_{2k} x_{2k} - z_{2k} = f_{2k}$

and

$x_1, x_{2k} \geq 0, \qquad k = 1, \ldots, n$

where $U(.)$ is a monotonic and concave utility function; p is a vector of state probabilities for the k states; $u(z_{2k})$ is a vector of utility values of farm incomes for k states; A_1 is a matrix of technical coefficients of first-stage activities; x_1 is a vector of first-stage activity levels; b_1 is a vector of first-stage resource stocks; L_{1k} are matrices defining the status of the system at the end of stage 1 for each first-stage activity and each state; x_{2k} are vectors of second-stage activity levels for state k; A_{2k} are matrices of second-stage technical and tie-row accounting coefficients for state k; b_{2k} are vectors of resource stocks and right-hand side tie-row values for second-stage decision for state k; c_{2k} are vectors of per unit activity net revenues for second-stage activities for state k; z_{2k} are variables to measure farm income for state k; and f_{2k} is fixed costs for state k.

The DSP model can be solved using some non-linear algorithm or by approximating the utility function using linear segments. The former approach was adopted in this study by using the GAMS/MINOS non-linear maximisation option (Brooke et al., 1988).

The models built for representative farms in the study area included land and rotational constraints, seasonal constraints on labour and irrigation water, seasonal working capital constraints, credit limits, crop product inventories and minimum family food constraints. The working capital, crop product inventories and family food constraints were specified stochastically, reflecting the uncertainty in crop yields and prices. Activities in models included the main crops grown in the area, namely wheat, barley, maize, paddy, sesame, sugar beet and sunflower. Also included were activities to accommodate labour hiring (specified seasonally), borrowing working capital, and crop disposal for sale or to meet family food needs.

4. Study area and representative farms

The data used in the study were collected at several levels. Farm-level data were obtained from a sample of farmers in Ramjerd district of Fars Province, Iran. Sample farmers were selected in two stages. First, a cluster of three villages was purposively selected based on the recommendation of well-informed experts as being fairly typical of the study site. Second, 88 farmers were chosen at random in these villages, and interviewed to collect resource and production data. Data on farmers' risk attitudes and their subjective beliefs regarding crop yields and prices were collected from a sub-sample of 30 farmers drawn from the main sample. Time-series data covering 12 years on yields and prices of different crops cultivated in the study region were gathered from the Regional Branch of the Rural Service Centre at Ramjerd.

Statistical cluster analysis (Aldenderfer and Blashfield, 1984) was applied to the farm data such as farmers' total and cultivated land, land-to-labour and land-to-capital ratios as well as information on net returns to find homogeneous groups in the sample farms. The purpose in using cluster analysis to classify sample farms into homogeneous groups was to improve the selection of representative farms in an attempt to reduce aggregation bias (Hazell and Norton, 1986). The cluster analysis divided the sample farms into three size classes. The median farm of each group was chosen as being representative after ranking the farms on the basis of their area, resulting in representative farms of the following sizes: small (3.9 ha), medium (8.4 ha), and large (12.4 ha). The degree of representativeness of these median farms was tested by comparing the returns per hectare of each selected farm to the average of the corresponding size class.

Both farmers' subjective judgements and historical data on crop yields and prices were used as bases for the probability distributions used in the models. In order to preserve aspects of the stochastic dependency in the historical data, in particular, the correlations, as well as the general shape of the historical distributions, the following procedure was adopted. First, the historical data on crop yields and prices were detrended to remove the effects of inflation and technological change. Second, following Lin et al. (1974), a single elicitation method (i.e. the triangular distribution method) was used to obtain the marginal subjective probability distributions of crop yields and of prices for the sample farmers. Then the trend-corrected time-series data sets were reconstructed to have the same means and standard deviations as those obtained from the selected farmers, while preserving other statistic attributes of the detrended historical data such as the correlations.

This new set of data was estimated for each representative farm, based on the average subjective means and standard deviations for all farms in the related group. The subjectively adjusted time-series data were then used as alternative states of nature in the programming models for the representative farms.

5. Measuring risk preference

There are obvious difficulties in using utility-maximising MP as specified above to reflect the risk preferences of all the farmers in the defined clusters. In theory at least, each might have a different utility function requiring a different specification. To sidestep these difficulties, the utility-efficient (UE) programming approach of Patten et al. (1988) and Hardaker et al. (1991) was used since this method requires less information about farmers' risk attitudes. It integrates the concept of stochastic dominance with respect to a function (SDWRF) (Meyer, 1977a; Meyer, 1977b) into whole-farm programming to generate an efficient set of farm plans for those farmers whose absolute risk aversion functions are defined over a specified interval. Ogisi et al. (1994) have demonstrated that the resulting solutions are identical to those obtained using SDWRF. According to Meyer, this means that the efficient set will contain the preferred solution for any decision maker whose absolute risk aversion is in the defined range, regardless of the actual form of that decision maker's utility function.

The risk attitude of a decision maker is commonly derived by interviewing the subject using hypothetical choices or by an experimental method with real choices (Anderson et al., 1977; Binswanger, 1980). The ELCE interview technique with imaginary payoffs, described by Anderson et al., was used in the present study to elicit the risk attitudes of farmers. Thirty of the 88 sample farmers were randomly selected for this part of the study. A 'check' question was asked in order to gauge the consistency of each farmer's responses and, if necessary, the procedure repeated to achieve consistency.

Negative exponential utility functions of the form $U(x) = 1 - \exp(-r_A x)$ were fitted to each set of data points to yield estimates of the coefficients of absolute aversion, r_A, for each of the 30 farmers. The r_A values ranged from 0.0001 to 0.000001, thereby classifying all the sampled farmers as risk-averse. This empirically determined range was used in the programming model to specify the range of risk aversion for the three representative farms.

To implement the UE programming method, the DSP model specified earlier was modified to incorporate an objective function defined as a non-separable negative exponential function of parametric form

$$U_k = 1 - \exp[-\{(1-\lambda)r_1 + \lambda r_2\} z_k] \quad \text{for } 0 \le \lambda \le 1$$

where λ is a parameter, variation in which may be interpreted as variation in risk preference; r_1 and r_2 are upper and lower limits of the coefficient of absolute risk aversion (r_A), respectively; z_{2k} measures farm income for state k.

Note that:

$$r_A = (1-\lambda)r_1 + \lambda r_2 \quad \text{for } 0 \le \lambda \le 1$$

Hence, when $\lambda = 0$, the coefficient of risk aversion is at its upper limit and when $\lambda = 1$, it is at its lower limit. Thus, the level of risk aversion decreases as λ increases.

6. Efficiency analysis

Economic efficiency (EE) is the degree of ability of a farmer to produce a given level of output at least cost. EE may be divided into allocative and technical efficiencies (Farrell, 1957).

Allocative efficiency refers to the appropriate choice of input combinations. A farm is allocatively efficient if production inputs are allocated according to their relative prices. Consequently, price or allocative inefficiency results from suboptimal input combinations.

Technical efficiency refers to the proper choice of production function among all those actively in use by farmers. A farm is technically efficient if it produces the maximum obtainable level of output from a certain amount of inputs, given its technology. A farm is considered technically more efficient compared to other farms if it produces a larger output from the same quantities of inputs.

In a world where risk and risk aversion are recognised, the usual interpretation of these efficiency concepts needs some revision. In particular, the stochasticity of outcomes needs to be accommodated. Moreover, relative efficiencies cannot be assessed using expected utility values since utility is defined only up to a positive linear transformation. Alternative performance measures considered were certainty equivalents and expected values, with the latter being chosen on the grounds of greater familiarity and ease of interpretation.

6.1. Measuring the level of allocative efficiency

The following procedure was used.

(a) The expected total farm net revenues, E[TNR], for the existing resource allocations were estimated for the three representative farms.

(b) Then the potential levels of E[TNR] for the existing situations of the three representative farms were estimated by applying the DSP model, after model validation and verification. In other words, the above model provides the allocatively efficient level of E[TNR] with current technology, the existing level of resources of each representative farm and a specified degree of risk aversion. The level of allocative efficiency for each representative farm and degree of risk aversion can now be defined as

$$AE_i = E[\mathrm{TNR}_{ei}]/E[\mathrm{TNR}_{pi}]$$

where AE_i is the level of allocative efficiency of representative farm i; $E[\mathrm{TNR}_{ei}]$ is the expected value of total net revenue for the existing (denoted by e subscript) cropping plan of representative farm i, based on historical data for yields and prices adjusted to the average mean and standard deviation elicited from the farmers in the corresponding group; $E[\mathrm{TNR}_{pi}]$ is the expected potential (denoted by p subscript) value or allocatively efficient level of total net revenue of representative farm i, based on the mathematical programming results.

In order to eliminate possible errors due to selection of biased farmers as being representative, the efficiency analysis was conducted with the model on an average basis. Thus, the means and standard deviations used to obtain the subjectively adjusted values of crop yields and prices for each size group were the averages of the means and standard deviations of the subjective distributions of all farmers in that group.

6.2. Technical efficiency measurement

Following estimation of the level of allocative efficiency (AE), the level of technical efficiency (TE) was estimated by the following additional steps:

(c) The farms with the most efficient input–output coefficients for each crop across all groups were identified, based on the collected cross-section observations. These farms were selected by calculating the index of expected net revenue per ha of each crop for all farms in that group relative to the expected net revenue per ha of that crop for the group's representative farm. These indexes were ranked in ascending order and then values at the 95 percentile for each crop were selected. The 95 percentile procedure was used to reduce the risk of error due to recording errors and random biases. This procedure identified the most efficient level of expected net revenue per hectare for each crop for each group of farms. The maximum indexes so derived were then used to scale the data on the net revenue per hectare for each crop across alternative states. Then E[TNR] values were estimated through the DSP method for each representative farm with the same resource endowments as for the other models discussed above but using the technically efficient activity returns.

The difference in expected returns between the

Table 1
Allocatively efficient solutions for relevant range of risk aversion (small farm) [a]

Risk aversion	Activity levels							E[TNR] [b]
	Barley (ha)	Maize (ha)	Paddy (ha)	Sesame (ha)	Sugar beet (ha)	Sunflower (ha)	Wheat (ha)	(1000 Rials)
0.0001	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2442.70
0.00009	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2442.70
0.00008	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2442.70
0.00007	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2442.70
0.00006	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2442.70
0.00005	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2442.70
0.00004	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2442.70
0.00003	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2442.70
0.00002	0.00	0.00	0.40	0.00	0.75	0.00	2.75	2490.30
0.00001	0.00	0.00	0.40	0.00	1.44	0.00	2.06	2586.50
0.000001	0.00	0.09	0.40	0.00	1.18	1.30	0.92	2651.20

[a] The small representative farm has 3.9 ha of operated land.

[b] E[TNR] stands for expected value of total net revenue.

Table 2
Allocatively efficient solutions for relevant range of risk aversion (medium farm) [a]

Risk aversion	Activity levels							E[TNR] [b]
	Barley (ha)	Maize (ha)	Paddy (ha)	Sesame (ha)	Sugar beet (ha)	Sunflower (ha)	Wheat (ha)	(1000 Rials)
0.0001	0.49	0.00	0.40	0.01	1.56	0.00	5.81	5238.50
0.00009	0.49	0.00	0.40	0.05	1.64	0.00	5.80	5250.90
0.00008	0.48	0.00	0.40	0.05	1.67	0.00	5.81	5267.10
0.00007	0.46	0.00	0.40	0.05	1.67	0.00	5.82	5271.40
0.00006	0.42	0.00	0.40	0.07	1.67	0.00	5.80	5275.00
0.00005	0.37	0.00	0.40	0.11	1.67	0.00	5.80	5281.40
0.00004	0.30	0.00	0.40	0.15	1.67	0.00	5.80	5290.35
0.00003	0.19	0.00	0.40	0.21	1.67	0.00	5.82	5303.60
0.00002	0.02	0.00	0.40	0.32	1.67	0.00	5.70	5325.90
0.00001	0.00	0.00	0.40	0.00	1.99	0.41	5.60	5515.80
0.000001	0.00	0.60	0.40	0.00	2.00	2.00	3.40	5718.60

[a] The medium representative farm has 8.4 ha of operated land.
[b] E[TNR] stands for expected value of total net revenue.

above model at step (c) and E[TNR] for actual representative farm situation found at step (a) is due to differences in the level of technology and also to optimal allocation of resources. It can be attributed to economic inefficiency. Consequently, comparing expected returns between models at step (c) and step (b) shows the amount of technical inefficiency.

To summarise, the level of technical efficiency for each representative farm can be defined as follows:

$$TE_i = E[\mathrm{TNR}_{\mathrm{p}i}]/E[\mathrm{TNR}_{\mathrm{t}i}]$$

where TE_i is the level of TE of representative farm i; $E[\mathrm{TNR}_{\mathrm{p}i}]$ is the expected value of potential (denoted by p subscript) level of total net revenue of representative farm i; $E[\mathrm{TNR}_{\mathrm{t}i}]$ is the expected technically (denoted by t subscript) efficient level of total net revenue of representative farm i.

Following estimation of AE_i and TE_i, the overall efficiency index for representative farm i (EE_i) can be easily calculated from their product (Farrell, 1957). This is also equivalent to: $EE_i = E[\mathrm{TNR}_{\mathrm{e}i}]/E[\mathrm{TNR}_{\mathrm{t}i}]$.

Further, the levels of economic inefficiency (EI) and also the relative contributions of allocative and

Table 3
Allocatively efficient solutions for relevant range of risk aversion (large farm) [a]

Risk aversion	Activity levels							E[TNR] [b]
	Barley (ha)	Maize (ha)	Paddy (ha)	Sesame (ha)	Sugar beet (ha)	Sunflower (ha)	Wheat (ha)	(1000 Rials)
0.0001	0.00	0.00	0.40	3.41	1.30	0.00	7.29	6588.35
0.00009	0.00	0.00	0.40	3.41	1.30	0.00	7.29	6588.35
0.00008	0.00	0.00	0.40	3.33	1.30	0.07	7.29	6614.90
0.00007	0.00	0.00	0.40	3.33	1.30	0.07	7.29	6614.90
0.00006	0.00	0.00	0.40	3.33	1.30	0.07	7.29	6614.90
0.00005	0.00	0.00	0.40	3.33	1.30	0.07	7.29	6614.90
0.00004	0.00	0.00	0.40	3.33	1.30	0.07	7.29	6614.90
0.00003	0.00	0.00	0.40	3.33	1.30	0.07	7.29	6614.90
0.00002	0.00	0.00	0.40	3.33	1.30	0.07	7.29	6614.90
0.00001	0.00	0.00	0.40	3.07	1.30	0.34	7.29	6795.20
0.000001	0.00	0.00	0.40	0.00	1.94	4.10	5.96	6961.40

[a] The large representative farm has 12.4 ha of operated land.
[b] E[TNR] stands for expected value of total net revenue.

Table 4
Economically efficient solutions for relevant range of risk aversion (small farm) [a]

Risk aversion	Activity levels							E[TNR] [b]
	Barley (ha)	Maize (ha)	Paddy (ha)	Sesame (ha)	Sugar beet (ha)	Sunflower (ha)	Wheat (ha)	(1000 Rials)
0.0001	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00009	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00008	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00007	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00006	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00005	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00004	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00003	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00002	0.00	0.00	0.40	0.00	0.66	0.00	2.84	2961.70
0.00001	0.00	0.00	0.40	0.00	1.44	0.00	2.06	3133.45
0.000001	0.00	0.36	0.40	0.00	1.09	1.26	0.79	3261.80

[a] The small representative farm has 3.9 ha of operated land.
[b] E[TNR] stands for expected value of total net revenue.

technical inefficiencies (AI and TI, respectively) of representative farm i are defined as

$$EI_i = \{1 - E[\mathrm{TNR}_{ei}]/E[\mathrm{TNR}_{ti}]\} \times 100$$

$$AI_i = \{(E[\mathrm{TNR}_{pi}] - E[\mathrm{TNR}_{ei}])/E[\mathrm{TNR}_{ti}]\} \times 100$$

and

$$TI_i = \{1 - E[\mathrm{TNR}_{pi}]/E[\mathrm{TNR}_{ti}]\} \times 100$$

where $E[\mathrm{TNR}_{ei}]$, $E[\mathrm{TNR}_{pi}]$ and $E[\mathrm{TNR}_{ti}]$ are as defined above.

7. Empirical results

Tables 1–3 provide the set of allocatively efficient solutions for each representative farm. Clearly, a less risk-averse farmer selects farm plans that

Table 5
Economically efficient solutions for relevant range of risk aversion (medium farm) [a]

Risk aversion	Activity levels							E[TNR] [b]
	Barley (ha)	Maize (ha)	Paddy (ha)	Sesame (ha)	Sugar beet (ha)	Sunflower (ha)	Wheat (ha)	(1000 Rials)
0.0001	0.57	0.00	0.40	0.00	1.60	0.00	5.80	6307.85
0.00009	0.50	0.00	0.40	0.00	1.66	0.00	5.80	6357.90
0.00008	0.54	0.00	0.40	0.00	1.67	0.00	5.80	6366.90
0.00007	0.50	0.00	0.40	0.03	1.67	0.00	5.80	6373.20
0.00006	0.45	0.00	0.40	0.06	1.67	0.00	5.80	6381.90
0.00005	0.37	0.00	0.40	0.10	1.67	0.00	5.85	6393.60
0.00004	0.26	0.00	0.40	0.17	1.67	0.00	5.90	6411.50
0.00003	0.09	0.00	0.40	0.27	1.67	0.00	5.90	6420.50
0.00002	0.00	0.00	0.40	0.33	1.67	0.00	6.00	6444.30
0.00001	0.00	0.00	0.40	0.00	1.99	0.00	6.00	6668.90
0.000001	0.00	0.70	0.40	0.00	2.00	2.00	3.30	6913.80

[a] The medium representative farm has 8.4 ha of operated land.
[b] E[TNR] stands for expected value of total net revenue.

Table 6
Economically efficient solutions for relevant range of risk aversion (large farm) [a]

Risk aversion	Activity levels							E[TNR] [b]
	Barley (ha)	Maize (ha)	Paddy (ha)	Sesame (ha)	Sugar beet (ha)	Sunflower (ha)	Wheat (ha)	(1000 Rials)
0.0001	0.00	0.00	0.40	3.41	1.30	0.00	7.29	8550.00
0.00009	0.00	0.00	0.40	3.41	1.30	0.00	7.29	8550.00
0.00008	0.00	0.00	0.40	3.33	1.30	0.07	7.29	8652.50
0.00007	0.00	0.00	0.40	3.33	1.30	0.07	7.29	8652.50
0.00006	0.00	0.00	0.40	3.33	1.30	0.07	7.29	8652.50
0.00005	0.00	0.00	0.40	3.33	1.30	0.07	7.29	8652.50
0.00004	0.00	0.00	0.40	3.33	1.30	0.07	7.29	8652.50
0.00003	0.00	0.00	0.40	3.33	1.30	0.07	7.29	8652.50
0.00002	0.00	0.00	0.40	3.33	1.30	0.07	7.29	8652.50
0.00001	0.00	0.00	0.40	3.33	1.30	0.07	7.29	8652.50
0.000001	0.00	0.00	0.40	0.00	2.00	4.00	6.00	9045.90

[a] The large representative farm has 12.4 ha of operated land.
[b] E[TNR] stands for expected value of total net revenue.

contain more high net return cash crops. Decreasing aversion to risk results in allocating more operated land to more risky activities—sugar beet, sunflower and maize—with concomitant reductions in wheat, barley and sesame. The inclusion of 0.4 ha of paddy in all plans reflects its high returns per hectare as well as the need to satisfy the minimum food requirement of the household. However, sowing of paddy was strictly restricted by law to a maximum of 0.4 ha. This regulation is imposed to prevent rising water tables that can result in severe land salinisation.

Tables 4–6 present the optimal set (i.e. economically efficient set) of solutions for the relevant range of r_A, while Tables 7–9 show the results of efficiency analysis for each representative farm. The modelling results indicate that there exists a considerable level of economic inefficiency irrespective of the farm size.

The scope identified for increasing the existing level of E[TNR] is, on average, around 26% varying from 23.15% for medium farms to 27.79% for large farms. Small farms, on average, have the chance of increasing their E[TNR] by 8.55% due to adopting

Table 7
Measures of economic inefficiencies for relevant range of risk aversion (small farm) [a]

Risk aversion	Existing value of E[TNR]/ha [b] (10 Rials)	Potential value of E[TNR]/ha [b] (10 Rials)	Optimal value of E[TNR]/ha [b] (10 Rials)	Allocative inefficiency (%)	Technical inefficiency (%)	Economic inefficiency (%)
0.0001	56923	62633	75942	7.51	17.53	25.04
0.00009	56923	62633	75942	7.51	17.53	25.04
0.00008	56923	62633	75942	7.51	17.53	25.04
0.00007	56923	62633	75942	7.51	17.53	25.04
0.00006	56923	62633	75942	7.51	17.53	25.04
0.00005	56923	62633	75942	7.51	17.53	25.04
0.00004	56923	62633	75942	7.51	17.53	25.04
0.00003	56923	62633	75942	7.51	17.53	25.04
0.00002	56923	63854	75942	9.12	15.92	25.04
0.00001	56923	66319	80345	11.69	17.46	29.15
0.000001	56923	67978	83635	13.22	18.72	31.94

[a] The small representative farm has 3.9 ha of operated land.
[b] E[TNR]/ha stands for expected total net revenue per hectare.

Table 8
Measures of economic inefficiencies for relevant range of risk aversion (medium farm) [a]

Risk aversion	Existing value of E[TNR]/ha [b] (10 Rials)	Potential value of E[TNR]/ha [b] (10 Rials)	Optimal value of E[TNR]/ha [b] (10 Rials)	Allocative inefficiency (%)	Technical inefficiency (%)	Economic inefficiency (%)
0.0001	58834	62362	75093	4.69	16.95	21.64
0.00009	58834	62510	75689	4.86	17.41	22.27
0.00008	58834	62703	75796	5.10	17.27	22.37
0.00007	58834	62754	75871	5.17	17.29	22.46
0.00006	58834	62798	75974	5.22	17.34	22.56
0.00005	58834	62873	76114	5.31	17.40	22.71
0.00004	58834	62980	76327	5.43	17.49	22.92
0.00003	58834	63137	76434	5.63	17.40	23.03
0.00002	58834	63403	76718	5.96	17.36	23.32
0.00001	58834	65663	79391	8.60	17.29	25.89
0.000001	58834	68078	82307	11.23	17.29	28.52

[a] The medium representative farm has 8.4 ha of operated land.
[b] E[TNR]/ha stands for expected total net revenue per hectare.

allocatively efficient farm plans. This value is on average around 6 and 4% for medium and large farms, respectively. These modelling results suggest a greater allocative efficiency for large farms compared with other groups. However, small and medium size farms with technical inefficiency around 17% are better positioned than large farms. The amount of technical inefficiency is on average about 23% for large farms which offsets their higher allocative efficiency. The large farms have the highest overall economic inefficiency compared to the other size groups.

8. Discussion and conclusions

In any farm modelling study it is important that the model used should adequately characterise the circumstances of the farm, including the technology options, market conditions and risk. The conclusions

Table 9
Measures of economic inefficiencies for relevant range of risk aversion (large farm) [a]

Risk aversion	Existing value of E[TNR]/ha [b] (10 Rials)	Potential value of E[TNR]/ha [b] (10 Rials)	Optimal value of E[TNR]/ha [b] (10 Rials)	Allocative inefficiency (%)	Technical inefficiency (%)	Economic inefficiency (%)
0.0001	50471	53131	68951	3.80	22.94	26.74
0.00009	50471	53131	68951	3.80	22.94	26.74
0.00008	50471	53131	69777	3.80	23.86	27.66
0.00007	50471	53131	69777	3.80	23.86	27.66
0.00006	50471	53131	69777	3.80	23.86	27.66
0.00005	50471	53131	69777	3.80	23.86	27.66
0.00004	50471	53131	69777	3.80	23.86	27.66
0.00003	50471	53131	69777	3.80	23.86	27.66
0.00002	50471	53131	69777	3.80	23.86	27.66
0.00001	50471	54800	69777	6.20	21.46	27.67
0.000001	50471	56140	72950	7.77	23.04	30.81

[a] The large representative farm has 12.4 ha of operated land.
[b] E[TNR]/ha stands for expected total net revenue per hectare.

of this study are based on the proposition that the model used meets these requirements, so that differences between model results and reality can be attributed to inefficiencies on the farm and not to imperfections of the model. But this proposition is basically not testable in work of this kind. All that can be done is to take all proper care in model formulation, verification and validation, as was done in this case. Nevertheless, the conclusions below must be qualified by uncertainty about the validity of the DSP model used.

In the light of our empirical results suggesting the existence of considerable economic inefficiency in terms of technical and allocative inefficiencies among sample farmers regardless of their farm size, a programme for productivity raising and stability (Anderson and Dillon, 1992) might be recommended. Changes in agricultural research and extension would be crucial parts of this program. It has been argued by Karami and Torkamani (1992) that successful long-term agricultural development in Iran may be dependent upon improving the effectiveness of the present organisation of research and extension.

It has been suggested that there is a lack of interaction between farm, extension and research systems in Iran (Karami and Torkamani, 1992). Our results suggest that many farmers are not adopting the best available technologies. This may be because the technologies being extended to farmers are not well-matched to their needs and circumstances, or it may be that improvements are needed in the way extension is conducted. The farming systems research and extension approach may offer a means of improving the collaboration between users, producers and disseminators of improved technologies.

As the results of our analysis demonstrate, there are farmers who have a higher level of economic efficiency compared to other producers in the farming community. These findings are similar to earlier studies of dairy farming in Fars Province (Torkamani and Najafi, 1989). Investigation of the characteristics of sample farmers revealed that education and more contact with extension officers is generally associated with a greater level of economic efficiency. While the direction of causality in this association is not clear, it seems likely that well-informed farmers already know the answers to some existing problems. Their solutions may be checked and conveyed to others when found to be useful. There is a danger of trying to 'rediscover the wheel' if existing knowledge is not properly utilised (Norman, 1980).

Finally, our findings confirm that risk aversion may play an important role in farmers' behaviour. Farmers were predicted to sow higher risk cash crops with higher payoffs only when their coefficient of absolute risk aversion was low. As Anderson and Dillon (1992) argued, this behaviour may be rational for the individual farmer but results in output levels and product combinations that, from society's point of view, are inefficient. However, farmers' risk-taking behaviour may be influenced by improved education and promoting risk-mitigating strategies such as more reliable technologies or crop insurance. These strategies might lead farmers to increase agricultural production with consequent benefits to social welfare (Anderson and Dillon, 1992).

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