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Technical Efficiency of Apple Farming in Turkey: A Case Study Covering Isparta, Karaman and Niğde Provinces

Mevlüt Gül
Department of Agricultural Economics, Faculty of Agricultural,
Süleyman Demirel University, 32260 Isparta, Turkey

Abstract: In this research technical efficiencies of apple production in Turkey were estimated with Data Envelopment Analysis (DEA). Main material was collected through a questionnaire study from farmers in three provinces (Isparta, Karaman and Niğde) of Turkey. Personal interview did from 129 agricultural enterprises during 2001 apple production year. In this study, mean efficiencies of surveyed apple farms were estimated to be 0.60 and 0.90 for constant and variable returns to scale assumptions, respectively and greatest slacks were in fertilizer use (K, P and N, respectively). Appropriate soil tests should be made to determine fertilizer requirements of the soils. According to the results of the tobit regression analysis, the most significant factor affecting efficiency was found to be total farm size.

Key words: Efficiency, data envelopment analysis, apple farming

INTRODUCTION

Turkey ranks third in world apple production and areas allocated to apple farming. Actually, Turkey is considered as the origin of apple fruit. However, Turkey's apple exports are not at a satisfactory level, corresponding to its status in the world. This fact can be attributed to several facts, such as varieties grown, characteristics of apple farms, infra structural facilities and product quality. Efficiency is also an important aspect of apple farming in today's competitive conditions.

Average apple yield in Turkey, which was 585.3 kg decare^{-1} (da) between 1961-1965, has shown a remarkable increase and reached to 2167.12 kg da^{-1} at the end of the 2000-2004 periods (FAO, 2005).

Apple farming in Turkey has been analyzed for several aspects. Ergun *et al.* (1984), Güney (1985) and Uçar (1986) were done articles in different regions about apple production cost and input used. Cetin *et al.* (2004) compared drip irrigation investment different apple varieties. Oguz (1995) analyzed producers marketing and production problems of apple farms in Karaman provinces. Oguz (1997) analyzed economics of apple farms in Karaman provinces. Çardak (1999) analyzed economics structures of apple farms in Karaman provinces. Gül (2005) analyzed socio-economic characteristics of apple farms in Trans Taurus mountains region and reveals economic structure and problems of apple farming and also world apple production and trade were analyzed and Turkey's place was assessed. However, there are only a few studies concerning efficiency.

Apple farming is practiced in several locations in Turkey. Özbek (1978) classified apple growing areas of Turkey into four regions. This classification is based on ecological conditions and hence different growth and cultural practices required for apple farming. Study area is located in the third apple farming region of Turkey, according to his classification. This region does not have favorable conditions for apple farming under natural conditions. However, apple can grow under special climatic conditions of some river valleys and lake basins under suitable cultural practices such as soil tillage and adequate irrigation.

The purpose of this study was to investigate technical efficiencies of apple orchard in Turkey based on the primary data obtained from farmers in three important producers' provinces of Turkey. For this reason a nonparametric method (data envelopment analysis) was used.

MATERIALS AND METHODS

Main material was collected through a questionnaire study from farmers in three provinces of Turkey. These three provinces are Isparta, Niğde and Karaman produce 48% of Turkey's apple production. Data has taken from farmers for 2001 production season. A questionnaire study was conducted in 26 villages located within the boundaries of 9 districts of these three provinces. Only villages having a total apple growing area greater than 25 ha were taken into the study. Stratified sampling procedure was employed in selecting apple farms in order to decrease variance, form homogeneous stratification and represent different production units.

Data Envelopment Analysis (DEA) is a nonparametric method widely used in efficiency measurement studies. In this method, each production unit is given an efficiency score based on its distance to a production frontier constructed by means of linear programming model. No explicit functional form is assumed for the underlying production technology in DEA.

Mathematical development of DEA can be traced to Charnes and Cooper (1978) who introduced their basic CCR model (Charnes-Cooper-Rhodes model) based on the works of Farrell (1957) and others.

An input oriented BCC model (Banker-Charnes-Cooper model) is given below for N Decision Making Units (DMU), each producing M outputs by using K different inputs (Coelli *et al*., 1998):

$$\text{Min}_{\theta,\lambda} \quad \theta$$

Subject to:

$$-y_i + Y\lambda \geq 0 \quad \text{and} \quad \theta x_i - X\lambda \geq 0$$

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

Where, θ is a scalar, N1' is convexity constraint and λ is N x 1 vector of constants. Y represents output matrix and X represents input matrix. The value of θ will be the efficiency score for the I-th firm. This linear programming problem must be solved N times, once for each firm in the sample. A θ value of one indicates that the firm is technically efficient according to the Farrell (1957) definition. However, slacks are not handled in Farrell definition of efficiency. According to a more strict efficiency definition known as Koopmans (1951) criteria a firm is only technically efficient if it operates on the frontier and furthermore all associated slacks are zero.

Original DEA specification has been extended in several ways and multi stage models were developed in order to meet more strict Koopmans (1951) criteria, to identify the nearest efficient points and to make the model invariant to units of measurements. Coelli (1996, 1997) developed such a multi stage methodology and a computer program which implements a robust multi-stage model among other options.

A ratio of technical efficiency scores obtained from DEA under CRS (Constant Return to Scale) and VRS (Variable Return to Scale) assumptions measures Scale Efficiency (SE). This scale efficiency measure can be interpreted as the ratio of average product of a firm operating at a point to the average product of another firm operating at a point of technically optimal scale. A value of scale efficiency equal to one implies that the farm is scale efficient and a value less than one suggests the farm is scale inefficient. A farm operating under decreasing returns to scale conditions means that it is operating under super-optimal conditions. On the other hand a farm operating under increasing returns to scale is operating under sub-optimal conditions.

An input oriented DEA model was chosen since farmers have more control on inputs than they have on outputs.

The most widespread apple varieties grown in the survey area are: Starking Delicious, Starkrimson Delicious, Golden Delicious, Stark Spur Golden Delicious, Granny Smith and Amasya. Average size of apple farms in the region is 14.89 decare. Almost all apple growing areas are owner operated lands (93.75%). All of the farmers irrigate their apple orchards.

Eight inputs (N, P, K, trees, labor, machinery, irrigation, pesticides) and one output (apple) were used in the analyses. Fertilizing was represented with three inputs, nitrogen (kg da^{-1} N) and phosphorus (kg da^{-1} P_2O_5) and potassium applied. For this purpose, animal manure and different types and brands of commercial fertilizers were converted to pure nutritional elements. Labor input consists of both hired and unpaid family labor. The fifth input is machinery working hours. Irrigation was represented as the number of irrigations since there are no volumetric measurements available. Pesticides and other chemicals are the only input group represented by monetary units (TL da^{-1}), since their conversion to a standard physical unit is difficult.

A critical input is the number of trees in unit area. DEA analysis requires production units using similar inputs to obtain similar outputs, under similar climatic, social and economic conditions.

All apple farms are located within the third ecological apple growing region, according to Özbek (1978) classification. However it is very difficult to satisfy some of the similarity conditions in farming perennial crops. In an apple orchard, there are trees of different varieties and ages. Replacement of old trees complicates this situation. In order to account for different ages and to create a data set covering farms working under similar conditions, orchards where the share of trees between ages of 11 and 30 was greater than 80% were selected for the analysis. Hence, 129 farms satisfying this condition were taken into analysis. On the other hand, in order to make a fair comparison and avoid biases, another variable is

Table 1: Summary statistics for variables used in the efficiency analysis

Input/output variables	Min.	Max.	Mean	SD
Output:				
Apple gross value product (10^6 TL da^{-1})**	145.96	1540.48	587.80	312.32
Inputs :				
Total weighted trees (trees da^{-1})	8.35	40.00	15.78	5.22
Fertilizer-N (kg N da^{-1})	0.16	73.57	25.47	18.61
Fertilizer-P (kg P_2O_5 da^{-1})	0.00	53.54	16.85	12.72
Fertilizer-K (kg K_2O da^{-1})	0.00	23.89	3.95	6.09
Labor (h da^{-1})	24.36	198.75	95.08	43.87
Machinery (h da^{-1})	0.41	21.02	6.12	4.46
Pesticide (1000 TL da^{-1})	6.97	156.30	38.38	29.34
Number of irrigations	2.00	12.00	5.10	1.49

*Standard Deviation; ** 1 da = 0.1 ha

constructed to represent number of apple trees. This variable is called Total Weighted Fruit Bearing Trees (TWFBT).

TWFBT variable is defined as:

$$TWFBT_{ij} = \lambda_{0710}T_{0170(ij)} + \lambda_{1121}T_{1121(ij)} + \lambda_{2237}T_{2237(ij)}$$

Where, TWFBT represents the total number of weighted fruit bearing trees; T_{0810} represents the number of trees in 7-10 age group; T_{1121} represents the number of trees in 11-21 age group; T_{2235} represents the number of trees in 22-37 age group and λ values are coefficients to calculate number of weighted trees. These coefficients were derived from the questionnaire data.

During the questionnaire study, apple yields were obtained for different age groups. These data were used to obtain yield-age profile indices. Yield-age profile index of mature trees was taken as unity and yield indices of trees in different age groups were calculated as a ratio.

Another problem is the differences in the quality of apples. Since prices reflect quality differences under assumed free market conditions, gross value of apple product (per unit area) was used to represent output.

As it is seen from Table 1, large variations exist in some of the inputs. The greatest variations are observed in labor, pesticide cost, K, N and K fertilizers, when coefficients of variation are taken into consideration. It is also clear from Table 1 that some farmers are not using all of these fertilizers. Great variations in input use levels may be an indicator of mismanagement problems.

In order to identify Koopmans efficient points, compare the farms with those having similar input mixes and also to make the model invariant to measurement units a multi stage DEA model is used as recommended by Coelli (1996, 1997).

Efficiency scores were regressed upon with several environmental variables in order to determine determinants of inefficiency.

RESULTS AND DISCUSSION

DEA scores were estimated using the software DEAP version 2.1 developed by Coelli (1996). Efficiency scores of the farms were calculated under CRS and VRS assumptions (Table 2).

Of the 129 apple orchards studied, 19 farms under CRS and 66 farms under VRS are fully efficient. 52 farms under CRS and only 1 farm under VRS showed a performance below 0.50. In DEA analysis, 2 farms became a peer more than 50 times and 4 farms became a peer more than 32 times for other farms. Those farms were identified as robustly efficient farms since their production practices are such that they were frequently used to construct the efficient frontier for the other farms.

Slack variables were also analyzed in order to determine excess input use. A farm can reduce its expenditure on an input by the amount of slacks without reducing its output. Mean input slacks and excess input use percentages are given in Table 3.

The greatest input excess is in potassium fertilizer. According to the results of efficiency analysis, potassium fertilizers are used excessively in approximately one third of the apple orchards (46 out of the 129 apple farms, Table 3). Average amounts of N, P and K fertilizers used

Table 2: Frequency distributions of technical efficiency scores obtained with DEA model

	DEA		
Efficiency scores	CRS	VRS	SE
1.00	19.00	66.00	19.00
0.90-1.00	6.00	11.00	8.00
0.80-0.90	7.00	21.00	9.00
0.70-0.80	9.00	20.00	15.00
0.60-0.70	14.00	7.00	20.00
0.50-0.60	22.00	3.00	23.00
0.40-0.50	21.00	1.00	22.00
<0.40	31.00	0.00	13.00
Mean	0.60	0.90	0.66
Minimum	0.12	0.48	0.12
Maximum	1.00	1.00	1.00
Standard deviation	0.25	0.13	0.22

Table 3: Input slacks and number of farms using excess inputs

Input	No. of farms	Mean slack	Mean input use	Excess input use (%)
TWFBT	22	1.06	15.78	6.69
Fertilizer-N	62	7.91	25.47	31.05
Fertilizer-P	64	8.61	16.85	51.12
Fertilizer-K	46	2.16	3.95	54.52
Labor	53	15.94	95.08	16.77
Machinery	53	1.21	6.12	19.79
Pesticide costs	56	7.66	38.38	19.95
No. of irrigations	37	0.36	5.10	7.14

TWFBT: Total Weighted Fruit Bearing Trees, Fertilizers in kg-nutrient da^{-1}. Labor and machinery in h da^{-1}, Pesticide costs in 10^6 TL da^{-1}. 1 da = 0.1 ha

Table 4: Characteristics of farms with respect to returns to scale

	No. of farms	Mean farm size	Mean output	Mean Gross return
Sub-optimal	109	14.19	2534.76	559.37
Optimal	19	18.09	3798.22	1188.4
Super-optimal	1	13.78	5805.56	1385.24

Table 5: Results of Tobit regression analysis

Variable	Coefficient	SE	z-score	Significance
C	0.782137	0.041498	18.84761	0.0000
Area	0.001709	0.000869	1.967151	0.0492
Plots	-0.028231	0.010825	-2.607807	0.0091
Yields	0.0000272	0.0000105	2.607155	0.0091
Experience	0.002994	0.000851	3.516160	0.0004
R-squared				0.147292
Adjusted R-squared				0.112629

by the efficient 66 farms under VRS assumption are 22.30, 17.51 and 2.79 kg-nutrient da^{-1}. Excesses in fertilizer use can be attributed to the habit of farmers, whose fertilizing decisions are not based on appropriate soil tests.

It is well known that some nutritional elements such as phosphorus are combined with the soil by a process known as fixation. Therefore, soil tests are important in determining actual fertilizer requirements of soils. Mixed fertilizer use may also be another cause of excess phosphorus use.

Relatively high efficiency scores and low input excesses may be attributed to apple's being a commercial crop. Commercial crops are grown by mostly specialized farmers and applications are almost standardized.

For the inefficient farms, the causes of inefficiency may be either inappropriate scale or misallocation of resources. Inappropriate scale suggests that the farm is not taking advantage of economies of scale, while misallocation of resources refers to inefficient input combinations. In this study, scale efficiencies are relatively high. Therefore, efficiencies are mainly due to improper input use.

Mean scale efficiency of the sample apple farms is 0.90. Out of the 129 apple farms, 19 show constant returns to scale, 109 show increasing returns to scale. There are one farms practicing under decreasing returns to scale conditions. Characteristics of optimal, sub-optimal and super optimal farms are given in Table 4. As it is seen from the Table 4, mean farm sizes are approximately the same for optimal and sub-optimal apple orchards. However, there are great differences between mean output and mean gross return per unit are.

In order to get information on determinants of inefficiency, efficiency scores were regressed upon some environmental variables. Technical efficiency score was used as the dependent variable. Since scores are bounded to be between zero and one using ordinary least squares regression model would not be appropriate. Hence a Tobit analysis model was employed. Table 5 shows Tobit regression results examining the relationships between technical efficiency scores and land size, number of plots, yields per da and experience of farm head. As it is seen from table, number of plots, yields per da and experience of farm head have significant effect on efficiency scores (1% level). And also apple area has a significant effect on efficiency scores (5% level).

Signs of the parameters are as expected. Sign of the area parameter is positive. This indicates that the bigger farms are more efficient. Farms with higher plot sizes (greater land fragmentation) are less efficient. As it is well known, fragmented lands increases in labor and machinery use. And also experience of farm head has positive effect on efficient.

In this study, technical efficiencies of apple orchard in Turkey investigated based on the primary data obtained from farmers in three important producers' provinces of Turkey. For this reason data envelopment analysis was used. Data was collected through a questionnaire study from farmers in three provinces (Isparta, Karaman and Niğde) of Turkey.

High efficiency scores and number of efficient farms imply that apple farming is almost standardized among farmers. This is an expected result since apple is a commercial crop and requires special techniques and qualification. Also findings that some important resources use inefficiencies in apple farming in selected regions. In surveyed enterprises technical efficiencies can be increased by 10% through better use of available resources under VRS assumption.

The greatest excesses were observed in fertilizer use. Accordingly findings, appropriate soil tests should be conducted in order to determine fertilizer requirements of the soils in the region.

Input slacks associated with other input variables are also important although their extent is not as great as that of phosphorus. All these excesses adversely affect technical efficiencies of apple farms. Inefficiencies indicate a wrong input mix between these the inputs.

Inefficiencies in irrigation may be negligible in our case for two reasons. First; its extent is not so large (37 farms and 7.14%). Second; the parameter used to measure this parameter does not reflect the actual amount of input used since volumetric measurements were not available.

Finally, it should be kept in mind that inefficiency is not just a result of the amount of inputs used. Factors such as timing of irrigation and fertilization and environmental factors have also an effect on efficiency.

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