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Evaluation of the efficiency of sugar beet production in Qazvin plain, Iran

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ABSTRACT

Sugar beet as an industrial crop plays a main role in satisfying domestic demand of sugar. Study on the production efficiency of sugar beet is important because this is a factor that influences production without additional cost. In this study, Data Envelopment Analysis approach (DEA), was implemented to calculate technical, administrative and scale efficiency of sugar beet production. Also optimum level of inputs was determined. Data was collected from 60 questionnaires filled by sugar beet producers in 2009-2010. Results indicated that average of technical, administrative and scale efficiency is equal to 89.6%, 70.5% and 79%, respectively. Also, fertilizer, labor and seed were used more than optimum level whereas herbicide and water were implemented less than optimum level.

Keywords: data envelopment analysis, sugar beet, technical efficiency, Qazvin, administrative efficiency, scale

INTRODUCTION

Sugar beet is an industrial crop that plays an important role in supplying the sugar demand in Iran. Its molasses is used in feeding livestock, too. Therefore, it has a special position in household food basket as well as in processing and animal husbandry industries in Iran. The policies of Iranian government on sugar beet cultivation and production are based on extensive intervention to preserve low sugar price and to meet consumers' demand through importing (Najafi 2001). Since the sugar beets produced in Iran are mainly used in sugar industries, most active factories have themselves founded their own sugar beet agro-industries. The efficiency and productivity of sugar beet production have been interested by the administrators of sugar industries owing to their impact on lowering the costs of raw materials. It should be remembered that the efficiency in all economic sectors is of crucial importance in preventing the waste of resources (Pakravan et al. 2009). Generally speaking, efficiency promotion can be regarded as a complement for the policies on domestic production and optimum exploitation of the resources (Moradi Sharbabak and Yazdani 2005). The efficiency and productivity of the agricultural production is so important that they have been subjected to extensive studies throughout the world. Moradi Shahrbabak and Yazdani (2005) calculated the technical efficiency of potato producers in Bardseer township of Kerman province, Iran by parametric approach. They found the mean technical, allocation of resources and economic efficiency to be 89.1, 74 and 83%, respectively. In addition, they revealed that the producers' failure in allocating the resources caused their economic efficiency to be lower than their technical efficiency. Sadat Moazeni and Karbasi (2008) studied pistachio producers' efficiency in Zarand, Iran by data envelopment analysis method. They found that mean technical efficiency was about 52 and 62% for Zarand and Siriz re-

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gions, respectively. Also, mean net technical efficiency or administrative efficiency and mean scale efficiency were about 75 and 17% in Zarand plain and 87 and 70% in Siriz plain, respectively. Pakravan et al. (2009) determined canola producers' efficiency in Sari, Iran in 2008-2009 by data envelopment analysis method. They showed that canola producers' mean technical, allocation of resources, economic, and scale efficiencies were 80.7, 58, 46.5 and 13.77%, respectively. As well, the highest non-optimal exploitation of resources was related to herbicides with 49.4% inefficiency in using the inputs. The efficiency and productivity of sugar beet production factors were subjected to some studies, too. Some examples of these studies in Iran included Boostani and Mohammadi (2007) on productivity and water demand function of sugar beet production in Eqlid, Shafei et al. (2006) on determining technical, allocation of resources and economic efficiency among sugar beet growers in Bardseer, Seidan (2002) on analyzing total productivity of sugar beet production factors in small and large farms of Hamedan, and Mirzaei and Torkamani (2005) on factors affecting the productivity of men and women labor in sugar beet production in Kerman, Iran. In addition to calculate the productivity of sugar beet production factors, these studies have investigated the impact of various rates of inputs on sugar beet production productivity.

A glance at the studies conducted in other countries reveals that various approaches have been used for determining farmers' technical efficiency. Some examples are deterministic production frontiers method by the parametric approach of Shapiro and Muller (1977); Shapiro (1983); Belbase and Grabowski (1985); Ali and Chaudry (1990); and Ekanayake and Jayasurya (1987); and non-parametric approach and stochastic production frontiers method by using time juncture data of Kalirajan (1990); Huang and Bagi (1984); Kalirajan and Shand (1985); Ekanayake (1987); Taylor and Shonkwiler (1986); and Pinheiro (1992) and by using panel data of Kalirajan and Shand (1986); Battese et al. (1989); Battese and Coelli (1992); Dawson et al. (1991); Kalirajan (1990); and Battese and Tessema (1992). The present study was aimed at examining the sugar beet producers' efficiency in Qazvin plain, Iran in 2009-2010. Data show that 1087 sugar beet growers produced 137 070 t sugar beet in 2004 ha in the growing season in question. Sugar beet is the main crop in Qazvin plain followed by maize, wheat and barley.

Materials and Methods

The present study was of a survey type. A questionnaire was used to collect the data from sugar beet growers in Qazvin plain, Iran who sell their product to Qazvin Sugar Factory. The study for which simple random sampling was used was carried out in 2009-2010. The population of the sample was determined by Morgan Table. The data were analyzed by Deap 2.1 software targeted at calculating sugar beet producers' efficiency. Since data envelopment analysis was used, it is briefly described here.

Efficiency measurement approaches can be, in general, divided into two groups: stochastic frontier approach (SFA) and data envelopment analysis (DEA). SFA is based on the definition of efficiency proposed by Farrel (1957) according to which efficiency is divided into three kinds of technical efficiency, allocation of resources efficiency and economic efficiency. The relationship between these three kinds of efficiencies is shown in Eq. (1).

$$AE = {EE}/{TE} \tag{1}$$

where EE, TE and AE denote economic, technical and allocation of resources efficiency indices, respectively (Farrel 1957).

DEA uses linear programming technique and determines efficiency for firms separately by optimization process. The drawback of this method is the error in the measurement of the production and crop factors. This method was used for the present study because of its simple calculations, its clearness, and the lack of the requirement for the effect of discrete variables assumption (Emami Maybodi 2000). It should be noted that in DEA, the output function is maximized on the basis of certain inputs and/or the inputs are minimized on the basis of certain outputs.

Farrel (1957) formulated his theory by a simple example of firms that use two factors *L* and *K* for producing one unit of product *Y*. Fig. 1 shows the

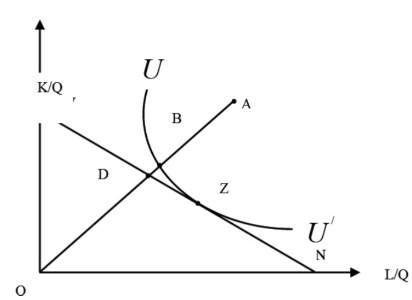

Fig. 1. Different types of efficiencies on the basis of input minimization

isoquant curve *UU'* of the production of perfectly efficient firms assuming the constant efficiency to scale. If point *A* in Fig. 1 denotes one of the firms, its efficiency will be defined as follow (Shakeri and Garshasbi 2008): technical efficiency is the capability of a firm to minimize the inputs for obtaining a certain level of output (input minimization) or obtaining the maximum product from a certain level of input (output maximization):

$$\text{Technical efficiency} = \frac{OB}{OA} \tag{2}$$

Allocation of resources efficiency is the capability of a firm to use an optimum combination of production factors with respect to their prices. The allocation of resources efficiency (price efficiency) of a firm that produces at *A* is defined as follows:

$$\text{Allocation of resources efficiency} = \frac{OD}{OB} \tag{3}$$

The present study utilized an input-based model for calculating sugar beet producers' technical efficiency in Qazvin plain.

$$\begin{aligned} & Min_{\theta,\lambda} \quad \theta, \\ & s.t. \quad -y_i + Y\lambda \geq 0, \\ & \qquad \theta x_i - X\lambda \geq 0, \\ & \qquad \lambda \geq 0 \end{aligned} \tag{4}$$

where θ is a scalar quantity, λ is the vector *N×1* of constants, x_i is the columnar vector of inputs for *i*th sugar beet grower, y_i is the columnar vector of output for *i*th sugar beet grower, *X* is the values of *K×N* inputs, *y* is the matrix M×N of outputs, *K* is the number of inputs exploited in sugar beet production, *M* is the number of products in question, and *N* is the number of sugar beet growers (Emami Maybodi 2002). θ denotes the technical efficiency of *i*th producers which is ≤1. θ = 1 shows that the firm has a perfect efficiency. DEA model assumes that the efficiency is variable ratio to the scale and provides a technical efficiency that includes net technical efficiency (efficiency caused by administration) and the efficiency caused by the economy of scale. For instance, the evaluation of the impacts of structural modification needs data about the scale efficiency. In addition, it is required to have data about the administrative efficiency in order to encourage the administrators. So, the calculation with the assumption of variable efficiency ratio to scale is carried out in Morgan problem formulation in linear programming by assuming constant efficiency ratio to scale through adding the constraint *NI'λ = 1* (convexity condition) to Eq. (4) (Sadat Moazeni and Karbasi 2008).

If the data of prices are available and the firm is aimed at cost minimization and/or income maximization, it is possible to calculate allocation of resources efficiency in addition to technical efficiency. Technical efficiency is decomposed into scale efficiency and administrative efficiency in which administrative efficiency is, in fact, net technical efficiency. In other words, net technical efficiency shows constant efficiency ratio to scale assuming no intervention on the side of scale effect and no constraints. In this case, the obtained technical efficiency is related to the management. Technical efficiency under the conditions of variable efficiency ratio to scale is the product of scale efficiency and administrative efficiency and is equal to the constant efficiency ratio to scale (Emami Maybodi 2000; Sadat Moazeni and Karbasi 2008).

The variables used in the present study included sugar beet produced in terms of t, the consumed seeds in terms of kg, the consumed chemical fertilizers in terms of kg, the consumed herbicide in terms L, the consumed labor in terms of person-day, and the consumed water in terms of 1000 m^3.

RESULTS

The examination of the status of sugar beet production by sugar beet growers revealed that the mean sugar beet production efficiency was 35t ha^{-1} in the studied region, whereas the highest sugar beet yield was 60t ha^{-1} among its growers. In the present study, the data on green area was used instead of the data on total cultivation area because the crop is harvested from the green area and the growers may allocate a part of their

Table 1. Statistical properties of inputs and sugar beet crop in Qazvin plain, Iran

Variables	Unit	Mean	Maximum	Minimum	Standard deviation
Sugar beet yield	t ha^{-1}	35.07	69	19	11.79
Seed	kg ha^{-1}	6.83	40	2	7.26
Fertilizer	kg ha^{-1}	691	1185	100	243.35
Herbicide	kg ha^{-1}	5.67	18.14	0.001	4.29
Labor consumed	person-day ha^{-1}	52.67	70	40	7.21
Water consumed	1000 m^3 ha^{-1}	9	14	6	3.36

Table 2. Statistical description of technical efficiency under the assumption of constant efficiency ratio to scale

Efficiency percentage	Number of sugar beet growers	Percentage	Mean efficiency (%)	Standard deviation
0-50	13	21.67	42.57	0.045
50-70	17	28.33	60.79	0.0439
70-90	16	26.67	79.46	0.0481
90-100	14	23.33	97.82	0.0381
0-100	60	100	70.55	0.202

announced cultivation area to other activities or may not cultivate it. The status of the consumption of seeds, too, shows that its use varies in the range of 2-40 kg ha^{-1} depending on the fact that the seed was monogerm or polygerm. One of the factors for increasing the sugar beet growers' income is higher weight and sugar content of the produced sugar beets. In other words, sugar beet growers try to use agriculture inputs to maximize the weight and sugar content of the roots. Therefore, various chemical fertilizers are used in the production of sugar beet, so that sugar beet growers consume, on average, 691 kg chemical fertilizers. The amount of fertilizers per ha consumed by sugar beet growers varied markedly. One crucial aspect of sustainable agriculture is to limit the consumption of herbicides. The study on herbicide consumption, too, indicated that sugar beet growers consumed a small amount of herbicides. As well, the status of the consumption of labor showed that, on average, 52 person-day labor per ha was used.

The relatively small variations of labor consumption per ha suggests that the technology used in sugar beet farms was almost similar in terms of the need for operator or capital. The status of the consumption of water as one of the most limited inputs revealed extensive variations among sugar beet growers. They consumed 9 000 m^3 water per ha, on average.

The examination of sugar beet growers' technical efficiency under the condition of constant efficiency ratio to scale revealed that only 50% of sugar beet growers had >70% technical efficiency. That is, over half of the growers do not use the production inputs efficiently under the condition of constant efficiency ratio to scale.

After calculating technical efficiency under the condition of constant efficiency ratio to scale, sugar beet growers' technical efficiency in Qazvin plain was calculated under the condition of variable efficiency ratio to scale.

The sugar beet growers' administrative efficiencies are shown in Table 3 according to which the administrative efficiency of almost 50% of growers was lower than 50%. In addition, mean administrative efficiency was 70.5% among sugar beet growers of Qazvin plain in 2009-2010 growing season. It implies that 70.5% of the efficiency was related to the administration of the production unit and the appropriate exploitation of inputs for maximizing the production. The relatively higher administrative efficiency suggests that technical knowledge in using the present highly-advanced technologies plays a vital role given the current resources which is stated by technical efficiency. Furthermore, it was found that about 85% of sugar beet growers had increasing efficiency ratio to scale implying that the growers can positively affect the efficiency with the increase in the exploitation of inputs if the other conditions are kept constant (Pakravan et al. 2009). In other

Table 3. Technical, administrative and scale efficiency under the assumption of variable efficiency ratio to scale

Efficiency type	Efficiency percentage	0-50	50-70	70-90	90-100	0-100
Technical efficiency	Number	0	7	20	33	60
	Percentage	0%	11.66%	33.33%	55%	100%
	Mean efficiency	0%	61.74%	82.54%	99.41%	89.6%
	Standard deviation	0	0.05	0.056	0.0199	0.134
Administrative efficiency	Number	13	17	16	14	60
	Percentage	21.6%	28.33%	26.66%	23.33%	100%
	Mean efficiency	42.57%	60.68%	79.45%	97.82%	70.54%
	Standard deviation	0.045	0.044	0.048	0.038	0.202
Scale efficiency	Number	8	12	15	25	60
	Percentage	13.33%	20%	25%	41.66%	100%
	Mean efficiency	43.5%	64.14%	79.45%	96.62%	79%
	Standard deviation	0.04	0.042	0.059	0.035	0.192

Table 4. Means comparison of actual inputs consumption and optimum level of inputs consumed in sugar beet production

Variables	Unit	Mean input consumption	Mean input deficiency	Optimum input consumption	Inefficient input consumption percentage
Seed	kg ha^{-1}	6.83	0.33	6.49	4.88
Fertilizer	kg ha^{-1}	691	686	48.6	59.3
Herbicide	kg ha^{-1}	5.67	-7.4	8.3	-136.8
Labor consumed	person-day ha^{-1}	52.67	45.9	6.66	87.3
Water consumed	1000 m^3 ha^{-1}	9	-5.13	11.57	-115.6

- Positive sign shows that the inputs are consumed over-optimally.
- Negative sign shows that the inputs are consumed under-optimally.

words, the sugar beet growers do not exploit their inputs optimally and they can improve sugar beet production by improving the exploitation of inputs.

The mean exploitation of the inputs and the optimal amount of the inputs are presented in Table 4 according to which there are differences between the present and optimal levels of the use of the inputs. Some inputs like fertilizers are used over-optimally. The field observations, also, show that farmers use fertilizer over-optimally to increase tap-root weight. However, they must be informed that the sugar content of the roots is also as important as their size. In other words, root weight and sugar content are the criteria of the sugar quantity which will be extracted from the sugar beets delivered to the factories. Some other inputs are used under-optimally. It was found that except the land which is used almost optimally, the inputs seed, fertilizer and labor are used over-optimally whereas the inputs herbicide and water are used under-optimally. Reducing fertilizer consumption by 59% and increasing the consumption of herbicides and water can improve the efficiency of inputs use.

DISCUSSION

The present study was aimed at calculating sugar beet producers' different efficiencies in Qazvin plain in 2009-2010 and the optimal level of inputs use for maximizing the efficiencies without changing the present level of production. It was found that sugar beet growers had high technical efficiency of 89.6%, on average. Therefore, it is not practically feasible to increase sugar beet production by improving technical efficiency, and the production can be increased by making use of advanced production technologies because sugar beet producers have already reached a high technical efficiency in exploiting the present technologies. The differences in sugar beet growers' efficiencies show the unbalanced distribution of technical knowledge and the training of farmers about techniques of enhancing efficiency. Hence, it is recommended to ask sugar beet growers to use the experiences and lessons of other growers. Administrative efficiency of sugar beet production was 70.5% suggesting the opportunities for improving administrative efficiency of sugar beet production in the studied region. Given the fact that the efficiency ratio to scale of 85% of sugar beet growers was of ascending type, it can be concluded that the ratio of production level to land size is not optimal and the low scale efficiency can be related to the sugar beet producers' conservative actions in using production inputs. Therefore, government can mitigate the sugar beet production risks by providing greater support for this crop. The study of optimum level of using inputs, too, revealed that the inputs fertilizer, seed and labor are used over-optimally and inputs herbicide and water are used under-optimally. Using less fertilizers and conserving the balance between herbicide and water use can contribute to higher efficiency and optimal exploitation of inputs. Although sugar beet growers' efficiency in Qazvin plain has not been studied yet, Moradi Shahrbabak and Yazdani (2005) found potato growers' technical, like fertilizers and economic efficiency in Bardseer township of Kerman, Iran to be 89.1, 74 and 83%, respectively. Additionally, like the present study, the failure of producers in allocating the resources resulted in lower economic efficiency than the technical efficiency. Sadat Moazeni and Karbasi (2008), too, calculated pistachio growers' efficiency in Zarand township of Kerman and revealed that mean technical efficiency was nearly 52 and 62% in Zarand and Siriz, respectively. Additionally, mean net technical efficiency or administrative efficiency and mean scale efficiency was 75 and 71% in Zarand and 87 and 70% in Siriz, respectively. Using data envelopment analysis for determining canola producers' efficiency in Sari, Iran in 2008-2009, Pakravan et al. (2009) found that mean technical, allocation of resources, economical, and scale efficiencies were 80.7, 58, 46.5 and 13.77% among canola producers, respectively.

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