Determination of Technical Efficiency and Optimum Size of Rice Farms in Mazandaran Province (Case study: Fereydunkenar County)

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Abstract

A reason for the success of the agricultural sector in developed countries is the regulation of farm size as it allows for the scale economy of production. Considering that the size of agricultural production units should be specifically determined based on the crop and the area where it is produced, this study aims to determine the optimum size of rice farms in Fereydunkenar County, Mazandaran Province. So, 198 farmers were randomly interviewed in 2014. The results show that the optimal economic size of the farms in the study area is 1.949 ha, 43% larger than the average cultivation area in the region. The results of the technical efficiency using the Stochastic Nonparametric Envelopment of Data model (StoNED) also show that paddy size has a direct correlation with the efficiency of these units in the studied area and production in larger farms is more economical and efficient. Therefore, it is suggested to consider plans to encourage rice farmers to establish cooperatives and change their farm management style from small farm owning to integrated management.

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INTRODUCTION

One of the effective factors of agricultural productivity is the size of the agricultural unit. The optimal size of an agricultural unit represents a combination of production factors that have the highest efficiency in producing a certain amount of product (Esfanjari Kenari, 2012). The relationship between farm size and efficiency plays an important role in economic research due to its consequences for agricultural and rural development policies (Burja & Burja, 2016).

The Common Agricultural Policy (CAP) follows objectives such as sustainable food production, sustainable management of natural resources and climate actions, and moderate development of land to achieve sustainable and comprehensive growth on the horizon of 2020. Achieving these goals requires adjusting farm size to accomplish maximum efficiency considering the need for environmental conservation and appropriate risk management. Determining the optimal size of agricultural units is one of the most important agricultural issues in developing countries. In general, the ideal farm size depends on the type of agricultural crop and the regional economic and social conditions. Integrating lands and developing efficient agricultural structures are global problems whose goal is to provide food security for the growing population. Therefore, the aggregation of agricultural production at farms with a certain size is one of the main goals of the agricultural policy in all countries, which is an attempt aimed to prevent land fragmentation and increase farm size to a level that allows effective use of production factors (Burja & Burja, 2016).

An overview of the agricultural sector in Iran's economy shows that, despite many shortcomings, agriculture is one of the most important sectors accounting for 18 percent of Iran's employment and 12.7 percent of its non-oil exports (Agricultural Jihad Office of Mazandaran, 2016). Rice and wheat are two important strategic commodities. Policymakers and planners in any country often place a special emphasis on these two basic crops in the agricultural economy and economic development. According to the Agricultural Jihad statistics, the total cultivated area and production of rice in Iran were 596,035 hectares and 2,921,046 tons in 2016, respectively. Mazandaran Province is the leading rice producer in Iran where 218,239 hectares is cultivated by rice and 1,187,481 tons of rice is produced. Given the role of this province in supplying the rice demand of the country, it is important to evaluate the efficiency and size of paddies across the province and conduct necessary studies to assist rice farmers and policymakers in this regard. Since no study has ever calculated the optimal level of rice cultivation in Fereydunkenar County, the present work addresses this issue. Below is a brief review of the literature on the estimation of the optimal size of agricultural units.

Hasanpour et al. (2012) determined the optimum size of rice farms using the cost function in Kohgiluyeh and Boyer Ahmad Province, Iran. Based on their results, the optimum size of a rice farm in the province was estimated at almost 1.7 ha.

Theodorou et al. (2010) studied the optimum size of Mediterranean mussel production units in Greece. The results showed that farms less than 2 ha were not economical and since most of the studied farms were small (1-2 ha), it was suggested that these sectors be restructured in larger projects such as co-operatives for financial sustainability. Fernandez and Nuthall (2012) analyzed farm size and its effect on the production efficiency of sugarcane farms in the Philippines. The results showed that small farms were inefficient and middle-sized and large-sized farms had similar efficiency. In general, larger farms could have a positive impact on the productivity of the sugarcane industry in the Philippines. Hassanpour (2013) estimated the economic efficiency of rice farmers in Kohgiluyeh and Boyer Ahmed Province. In this study, the Data Envelopment Analysis model was used. Based on the results, the difference between the economic efficiency of the best

farmer and the average sample was calculated to be 55 percent. The average technical, allocative, and economic efficiency of rice farmers was 1.62 percent, 3.74 percent, and 6.44 percent, respectively. Ogunbo (2015) calculated the resource efficiency and optimal size of pepper farms in Ogun State of Nigeria. In this study, the multi-stage random sampling method was used for analysis. The results revealed that 35 percent of experienced farmers had mixed cultivation and the optimal farm size for the intercropping of peppers and tomatoes and also for the intercropping of pepper, corn, and cassava were 0.25 and 0.66, respectively.

Anatolii (2015) determined the optimal size of agricultural units in Ukraine using nonlinear functions and depending on the specialty of the unit in producing a certain product. The results showed that the optimal size for the crop-producing agricultural units was 3732 h, whereas it was 5336 ha for the units that produced some livestock products (up to 40 percent) and 5392 hectares for the units that were assigned more than 40 percent of their activity to produce livestock. Burja and Burja (2016) studied the amount of production and efficiency of production factors in Romanian agriculture. This study focused on the relationship between the investment and the performance of agricultural production factors. In order to achieve this goal, the Data Envelopment Analysis method and comparative analysis were used according to the characteristics of other EU countries. The research findings showed that the productivity of the production factors in agriculture was low. Therefore, a new organization for investment in the agricultural sector was needed that could optimize the size of the agricultural units so that the difference in the performance of the units can be minimized or even removed compared to developed EU countries.

Different studies have reported contradictory results so that some indicate a positive relationship between farm size and efficiency (Bojnec & Latruffe, 2007) whilst others show an inverse relationship (Okoye et al., 2009). These inconsistent findings indicate that, in addition to farm size, other factors may also be involved in efficiency level.

METHODOLOGY

The optimal farm size was calculated using the long-run average cost and its relationship with the short-run average cost. If a farm manager decides to establish a production unit, he/she can consider a number of farms in different sizes and choose a farm with an average production cost less than that of the other sizes. Furthermore, before establishing a production unit, the farm manager is in the long-run conditions because the cost is still unpaid and all the costs are variable and he/she can use the long-run average cost curve to achieve optimal farm size (Bakhshodeh & Akbari, 2009). To estimate the long-run average cost, we need to use cross-sectional data instead of time series data or combined data because the estimation of the long-run average cost aims to find different sizes that are available over a period of time. In other words, the long-run average cost must be estimated assuming that the technology and the price of the production factors are constant. For this purpose, an explicit form of the cost function must be presented. The explicit form of the cost function was considered a third-order function according to the purpose of the paper and the economic theories as below:

$$TC = a_0 + a_1 x - a_2 x^2 + a_3 x^3 \qquad (1)$$

in which *TC* is the total cost and *x* is the cultivated area. In the first step, to calculate the optimal size of the unit, the long-run average cost function should be estimated:

$$LAC = a_1 - a_2 x + a_3 x^2 \qquad (2)$$

in which *LAC* is the long-run average cost. If there is a demand in the market, the optimum level of cultivation in the production units is a point where the long-run average

cost is the least.

$$\frac{\partial LAC}{\partial x} = \alpha_2 + 2\alpha_3 x = 0 \Rightarrow x = \frac{\alpha_2}{2\alpha_3} \quad (3)$$

The necessary and sufficient condition for minimizing Function (3) is that the cost function derived from the cultivation level is greater than zero:

$$\frac{\partial^2 LAC}{\partial x} = 2\alpha_3 \phi\, 0 \quad (4)$$

If the sufficient and necessary condition is satisfied, then x is equal to: $-a_2/2a_3$. In other words, each production unit with a capacity of x can produce goods at a minimum cost and supply them to the market.

To calculate efficiency, it is necessary to estimate the frontier function or cost function for which various techniques have been proposed. These techniques can be classified into two parametric and nonparametric methods based on their characteristics (Bakhshodeh & Akbari, 2009). In this study, we applied the stochastic non-parametric estimation method, which has been developed by Kuosmanen (2006). The StoNED model applies a two-stage method, which is applied to each group separately. At first, a piecewise linear production function is estimated. Concave nonparametric least squares (CNLS) can be written as a quadratic programming problem.

$$\min_{\alpha,\beta,\hat{\varepsilon}} \sum_{i=1}^{n} \hat{\varepsilon}_i^2$$

$$s.t.$$
$$y_i = \alpha_i + \beta_i' x_i + \hat{\varepsilon}_i \qquad \forall_i = 1,...,n$$
$$y_h \leq \alpha_i + \beta_i' x_h + \hat{\varepsilon}_h \qquad \forall_h = 1,...,n$$
$$\beta_i' \geq 0 \qquad \forall_i = 1,...,n \quad (5)$$

CNLS allows for the intercept and the slope coefficients to vary from one firm to another. Thus, there are (n) different slope vectors β_i, i=1,..,n. The CNLS regression (5) estimates n tangent hyperplanes to one unspecified production function. The slope coefficients β_i'

represent the marginal products of the inputs. The second constraint imposes concavity by applying a system of inequality constraints known as "Afriat inequalities". The third constraint imposes monotonicity. The CNLS regression provides us with composite residuals () that consist of error and inefficiency. To disentangle these two components, we can use the method of moments and calculate the second and third central moments of residual distributions (Kuosmanen, 2006):

$$m_2 = \sum_{i=1}^{n} (\hat{\varepsilon}_i - \hat{E}(\varepsilon_i))^2 \Big/ n \quad (6)$$

$$m_3 = \sum_{i=1}^{n} (\hat{\varepsilon}_i - \hat{E}(\varepsilon_i))^3 \Big/ n \quad (7)$$

These moments μ_2, μ_2 are consistent estimators of the true momentswhich depend on the variance of the inefficiency term and the error terms as follows (Kuosmanen, 2006).

$$\mu_2 = \left[\frac{\pi - 2}{\pi}\right]\sigma_u^2 + \sigma_v^2 \quad (8)$$

$$\mu_3 = \left[\sqrt{\frac{2}{\pi}}\right]\left(1 - \frac{4}{\pi}\right)\sigma_u^3 \quad (9)$$

Thus, the variances s_v^2, s_u^2 can be estimated based on the moments m2 and m3 (Greene, 2008).

Thus, given the estimated variances (which should be negative), we can estimate the parameter s_u by

$$\hat{\sigma}_u = \sqrt{\frac{\hat{m}_3}{\sqrt[3]{\left(\sqrt{\frac{2}{\pi}}\right)\left[1 - \frac{4}{\pi}\right]}}} \quad (10)$$

Subsequently, the standard deviation of the error term is s_v estimated using Eq. (11) as below

$$\hat{\sigma}_v = \sqrt{\hat{m} - \left[\frac{\pi - 2}{\pi}\right]\hat{\sigma}_u^2} \quad (11)$$

Given the variance estimates, we can use the conditional estimator for the inefficiency term. Jondrow et al., (1982) showed that the conditional distribution of inefficiency μ_i given $\hat{\varepsilon}$ is a zero truncated normal distribution with mean μ_* and σ^2_* variance presented by Eq. (12) and (13).

$$\mu_* = \frac{-\hat{\varepsilon}_i \, \sigma^2_u}{\sigma^2_u + \sigma^2_v} \qquad (12)$$

$$\sigma^2_* = \frac{\sigma^2_u \, \sigma^2_v}{\sigma^2_u + \sigma^2_v} \qquad (13)$$

As a point estimator for μ_*, we can use the conditional mean

$$\mathrm{E}\langle u_i | \hat{\varepsilon}_i \rangle = \mu_* + \sigma_* \left[\frac{\phi(-\mu_*/\sigma_*)}{1-\Phi(-\mu_*/\sigma_*)} \right] \qquad (14)$$

where Ø is the standard normal density function and ɸ is the standard normal cumulative distribution function (Kuosmanen & Kortelainen, 2012).

Given the estimated parameters $\hat{\sigma}^2_v, \hat{\sigma}^2_u$ the conditional expected value of inefficiency can be computed as

$$\hat{\mathrm{E}}\langle u_i | \hat{\varepsilon}_i \rangle = \frac{-\hat{\varepsilon}_i \, \hat{\sigma}^2_u}{\hat{\sigma}^2_u + \hat{\sigma}^2_v} + \frac{\hat{\sigma}^2_u \, \hat{\sigma}^2_v}{\hat{\sigma}^2_u + \hat{\sigma}^2_v} \left[\frac{\phi(\hat{\varepsilon}_i/\hat{\sigma}^2_v)}{1-\Phi(\hat{\varepsilon}_i/\hat{\sigma}^2_v)} \right]$$

$$(15)$$

where $\hat{\varepsilon}_i = \hat{v}_i - \hat{\sigma}_u \sqrt{2/\pi}$ is the estimator of the composite error term.

In the CNLS regression, constant constraint represents the return to scale, which is defined as follows:

1. Decreasing returns to scale

$$a_i \, \mathrm{p} \, 0 \qquad "_i = 1,...,n$$

2. Increasing returns to scale

$$a_i \, \mathrm{f} \, 0 \qquad "_i = 1,...,n$$

3. Constant returns to scale

$$a_i = 0 \qquad "_i = 1,...,n$$

y_i: The amount of paddy produced for i^{th} DMU (Kg)

x_{i1}: The amount of cultivated area (ha)

x_{i2}: Quantity of chemical fertilizer used (Kg)

x_{i3}: The amount of pesticide used (L)

x_{i4}: The amount of seed (Kg)

x_{i5}: Labor force (person-day)

x_{i6}: Cost of machinery (thousand IRR)

x_{i7}: Divisia index to account other costs (thousand IRR)

The cross-sectional data for this study were collected by interviews with 198 randomly selected farmers in 2014.

RESULTS

Information on the variables used in the study is listed in Table (1). The status of the cultivated areas in the study area shows that the largest and smallest farms are 14.3 and 0.1 ha, respectively. The average cultivated area is 1.1 ha.

To determine the optimal economic size of rice farms, the total costs were first estimated as a third-grade function using the Stata software. Then, the long-run average cost was calculated and the minimum long-run average cost curve was obtained using Eq. (3) in which if the sufficient condition (Eq. 4) is satisfied, the unit size is optimal. According to Table (2), the amount of R^2 indicates that 99 percent of the dependent variable is accounted for by the independent variables used in the study. However, due to the nature of the cross-sectional data, the problem of autocorrelation is not much discussed from the beginning, but the Dorbin-Watson statistic indicates a lack of autocorrelation between the components of the error term. The Jarque-Bera Test also indicates that the components of the error term are normal.

The comparison of the estimated t with table t showed that the coefficients of all variables were significant at the 1 percent level. According to the results in Table (2), the third-grade cost function can be shown as follows:

$$TC = -35973.45 + 5992005x - 77861.12x^2 + 19974.63x^3$$
$$t = (-3.06) \quad (240.81) \quad (-15.97) \quad (191.49)$$

Table 1

Descriptive Information on the Variables Used in the Model

	Land size (ha)	Production (Kg)	Fertilizers (IRR)	Pesticide (IRR)	Seed(IRR)	Labor force (IRR)	Machinery (IRR)
Mean	1.1	1536.3	5121826.7	2455672	4462573.2	39470856.9	12860083.1
Max	14.3	23397	71864981	3459	59234435	286570000	121984200
Min	0.1	58	345000	250000	300000	1100000	0.8
SD	0.3	1154.6	236.7	13.4	32.7	45.2	67.6

Table 2

The Results of Estimating the Third-Grade Cost Function

Variable	Coefficients	T Statistic	Significant	SD
X1	5992005	240.81	0/00	24882.84
X2	-77861.12	-15.97	0/001	4875.72
X3	19974.63	104.31	0/001	191.49
Constant	-35973.45	-3.06	0.02	11752.03
(R²) = 0.99	D-W = 1.96			
R² Adjusted = 0.99	Jarque-Bera Normality Test = 0.722			

To determine the optimal economic size of rice farms, the average cost function is calculated as follows:

$$LAC = 5992005 - 77861.12\,x + 19974.63\,x^2$$

The above equation can be used to determine the optimum economic size of farms:

$$\frac{\P LAC}{\P x} = -77861.12 + 39949.26x = 0$$

$$x = 1.949$$

Therefore, the optimal economic size of rice farms in Fereydunkenar County is 1.949 ha. So, each farm in the studied area with a cultivated area of 1.949 ha will impose the minimum average cost. However, the average cultivated area of the studied paddies is 1.1 ha in this county. Therefore, farmers in the region can improve their production profitability by increasing their farm size. In other words, the size of the farms in this county should be increased by more than 1.5 times to achieve optimal economic size. These results are in accordance with the results of the study of (Hosseinzad et al., 2009) who examined the optimal size of rice fields in Guilan Province.

The results of estimating technical efficiency using the StoNED model are presented in Table (3). In the present study, farms were classified into three groups based on their average cultivated area and the standard deviation. The first group was small-sized farms whose cultivated area was less than the average cultivated area minus their standard deviation (i.e., farms with a size of less than 0.8 ha). Based on the results, the average technical efficiency of the small-sized farms is 64 where about 60 percent of the cultivated areas are in the first group.

The second group included medium-sized farms whose cultivated area was between the average cultivated area minus the standard deviation and the average cultivated area plus the standard deviation (i.e., farms with a size between 0.8-1.4 ha). The average technical efficiency of the medium-sized farms was 76 percent. The third group was large-sized farms whose cultivated area was more than the average cultivated area plus the standard deviation (i.e., farms with a size of more than 1.4 ha). The results showed that the average technical efficiency of the large-sized farms was 88 percent. The results of returns to scale for rice farmers are presented in Table (4). According to Table (4), 58.58 percent of the farms (116 farms) have an increasing return to scale regardless of the farm size. Increasing returns to scale for these farms shows that increasing all inputs will lead to a proportionally greater increase in rice. Based on the results, only 12.63 percent of the farms (25 farms) have a constant return to scale. This means that increasing the number of inputs will proportionally increase the rice. Also, 28.79 percent of the farms (57 farms) have a decreasing return to scale. In other words, increasing inputs will lead to a proportionally smaller increase in rice. According to the concepts of technical efficiency, increasing the scale of production in these fields will increase technical efficiency. Similar results have been obtained in some other studies such as (Hosseinzad et al., 2009) and (Boussemart et al., 2006). The results of returns to scale for rice farms also confirm that the current size of rice farms is under-optimal in Fereydunkenar County.

CONCLUSION

According to the present study, there is a direct relationship between the efficiency and size of paddies in Fereydunkenar County. Based on the results, more than 80 percent of these farms produce at less than optimal levels in this county, meaning that the farmers cannot enjoy economies of scale and their profits will be reduced with increasing production costs because they use the inputs irrationally. Therefore, small-sized farms can improve their efficiency if they apply the principles of economics through an optimal

Table 3

The Results of the Estimation of the Technical Efficiency Using the StoNED Model

Land size	Average Technical Efficiency	Number of farms	Percent	Max	Min
Small	64	117	59.1	1	0.36
Medium	76	59	29.8	1	0.32
Large	88	22	11.1	1	0.43
Total	67	198	100	1	0.32

Table 4

Returns to Scale of Rice Farms

Returns to scale	The number of farms	Percent
Constant return to scale	25	12.63
Decreasing returns to scale	57	28.79
Increasing returns to scale	116	58.58
Total	198	100

and reasonable combination of production factors. Since the results indicate that large-sized farms have high efficiency in using the production factors, agricultural policies that motivate moving towards larger farm sizes can have a positive impact on the efficiency of these farms. It is, so, suggested to consider plans to encourage rice farmers to change the management of farms from small-sized farm ownership to integrated management. But, it should be considered that small farms play an important role in sustainable rural development, protecting biodiversity and rural population stability. Therefore, supportive plans from small-sized farmers should be considered for more economical use of production factors, such as establishing cooperatives. In this case, small-sized farms will have an appropriate agricultural structure that will increase the efficiency of the production factors and sustainable rural development will also be provided.

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