Study of the Technical Efficiency of Rice Farmers in Iran: a Case of Kohgiluyeh and Boyer-Ahmad Province

Mansour Zarra-Nezhad (Ph.D.), Belghais Bavarsad (Ph.D.) and Somayeh Noroozi Mehrian (M.Sc.) [*]

Abstract:

This paper aims at the study of the impact of socio-economic factors on the performance of rice farmers in Kohgiluyeh and Boyer-Ahmad of Iran. The required statistics and data were collected as cross-sectional data in the 2008-09 farming year through questionnaire-interview study with the province's rice farmers and analyzed by frontier production function. The research results showed that return to scale in rice farms is increasing returns to scale (IRS) and with a degree of 1.2; i.e. if all and if factors of production (capital, seeds, machinery, labor, cultivated area and water) increases with a scale of ^{t}, rate of production will rise with a scale of ^{t} 1.2. The mean technical efficiency of the rice farmers is 67.01 percent which has been fluctuated between a minimum of 33.3 to a maximum of 100 percent. Thus, increased Champa rice-growing capacity is about 66.7 percent. Therefore, through an improved technical efficiency of rice farmers it will be possible to reduce this deep gap between the rice farm and other farms in the province.

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* Professor of economics, assistant professor of management and gradute student of agriculture economics at Shahid Chamran University of Ahvaz, respectively, ahvaz, Iran. Email: (zarram@gmail.com)

1. Introduction

In order to play a far better role in the country's development and to meet the increasing food needs, the agricultural sector is required to increase the crops production. This will place the quantitative analysis of production, for the purpose of the increased crops production, on the top of the agricultural sector policies. Rice is the most important staple crop in the Asia consumed by one-half of the world's population and around 4 billion Asian people. Rice has the highest area under cultivation and among all staple crops and is by far the most common consumed grain in the world, preceded by wheat. In recent years, a production of less than global consumption has made the United Nations to take unexpected actions against the decreasing global rice yields and to declare the year 2004 as the International Year of Rice. In Iran, rice is the second-most consumed cereal grain which, in spite of a cultivated area of 628 thousand hectares and a production over 2700 thousand tons per annum, it cannot meet the domestic demands and rice is being imported into this country every year, so that as per a report from the UN's Food and Agriculture Organization (FAO), Iran is the world's 12th rice importing country.

According to statistics available, in 2007-08 there were 8096 hectares of land under rice in the husk cultivation in Kohgiluyeh and Boyer-Ahmad Province of which an area of 4754 hectares (58.72 percent) was used for growing local rice varieties such as Champa and Gerdeh. The rate of rice in the husk production in this province has been estimated about 45875 tons of which 17775 tons (38.7 percent) are local varieties.

Though more than half of the provincial land area under cultivation is local varieties, they have a relatively low production. Thus, in the present research it is attempted to estimate Champa rice production functions using data obtained from the farmers and to analyze thereof and, also, to calculate the effect of production inputs on the rate of production, production elasticities and the technical efficiency of rice farmers.

This paper contains six sections. The second section describes the research background. The third section entails the study of data and procedure, the fourth section is dealt with the study of research theoretical fundamentals and the fifth section with the study of research experimental results and the estimation of rice farmers' technical efficiency. Summary and conclusion are given in the sixth section.

2. Survey on Studies Conducted

This section briefly describes researches made about the producers' technical efficiency.

Kalirajan and Flinn (1983) estimated the production function and the technical efficiency of rice farms in the Philippines. For this purpose, a translog stochastic frontier production function the parameters of which were estimated using maximum likelihood method was applied. The research results showed that the mean technical efficiency was 75%.

Dawson and Lingard (1989) estimated the rice farm specific technical efficiency and production function in Central Luzon, Philippines. Using data for 1970, 1974, 1979 and 1982 of the International Rice Research Institute (IRRI), they estimated the stochastic frontier production functions. The results showed that the mean technical efficiency for the four years is 64.2%, 62.6%, 60.4% and 80.8%, respectively.

Wilson P., Hadley D., Ramsden S. and Kaltsas I. (1998) estimated the farm-level technical efficiency of potato growers in different regions of Britain based on translog form of a stochastic frontier production function using cross-sectional data of a stochastic sample containing 140 potato growers. The study results showed that the potato growers' technical efficiency is 89.5 percent. In addition, the socioeconomic characteristics which influence the technical efficiency were also studied.

Mohades Hosseini and Yazdani (1996) have studied the economic efficiency of farmers growing different rice varieties in Mazandaran Province. In this study, the production function has been estimated based on Cobb-Douglas form with using Ordinary

Least Squares (OLS). Then, linear programming technique was used for frontier production function. The study results showed that the highest technical efficiency of rice farmers is related with the high quality long-grain rice and the lowest technical efficiency of rice farmers is related with the high quality medium-grain rice, respectively. The mean economic efficiency showed that the rice farmers of high yield long-grain rice have the lowest economic efficiency as compared to other rice varieties.

Najafi and Abdollahi Ezzatabadi (1997) studied the technical efficiency of pistachio producers in Rafsanjan City, Iran. In this survey, firstly, the technical efficiency of pistachio producers in Rafsanjan City was calculated by stochastic frontier production function method and the impact of the agricultural researches on the technical efficiency was studied with using t-test. The research results showed that the mean technical efficiency in plains of Rafsanjan City, i.e. Nugh, Anar and Koshkuyeh are 40, 50 and 52 percent, respectively. The results of t-test showed that agricultural researches have resulted in increased technical efficiency of the region's farmers.

In their survey, Koupahi and Kazemnejad (1997) paid to factors effective on tea production in Gilan and the calculation of the tea farmers' technical efficiency. Through production function estimation, they estimated the technical efficiency of tea growers to be 0.38. In this study, the age, the educational level and the farm's size have been presented as factors which affect the producers' efficiency.

Hassanpour and Torkamani (2000) estimated the technical efficiency of fig producers in Fars Province with using transcendental stochastic frontier production functions estimation through maximum likelihood method. The results showed that the mean technical efficiency of fig producers in Estahban, Kazeroon and Neyriz cities are 65.7, 80.2 and 63.7 percent, respectively. The study of the effect of different socioeconomic factors on the technical efficiency also showed that the number of

caprification, farm's size and the educational level of producers are directly related to the technical efficiency of fig producers.

3. Data and Procedure
3.1. Research Methodology and Data Collection

The data and information required for this survey research were collected and questionnaire was completed by personal interview. For this purpose, after preparing the primary questionnaire and interviewing with 30 rice farmers in the province, the defects in the questionnaire data were corrected and the final questionnaire was set forth. Also, with these 30 primary samples, the variance of the sample was calculated and used for determining the sample size required. The sample size was 150. The sample size is obtained by the following formula:

$$n = \frac{z^2 \delta^2}{d^2} \tag{1}$$

where n is the sample size, z is the value of normal variable of unit corresponding to confidence level $1-\alpha$, δ^2 is the variance of the study variable and d is the difference between parameter and estimation.

$$n = \frac{(1.96)2 - 0.19}{(0.07)^2} = 148.96$$

Stratified sampling method was used for appropriate sample selection. The selection of strata from the statistical population is based on the area under rice cultivation in different regions of the province. Also, the required number of samples in each city is determined on the basis of each city's share in the total rice production in the province. The share of each city from 150 samples determined is as follows:

Table 1: The share of each city out of 150 research samples

Cities	Boyer-Ahmad	Dena	Kohgiluyeh	Gachsaran	Bahmaei
Number of Samples	44	66	15	24	1

Source: Research findings

The rainfall, temperature and relative humidity data were collected from the Provincial Department of Meteorology and some other data like the records of studies conducted and the study of theoretical fundamentals were collected as library and with using evidence and statistics available at the relevant organizations such as Agricultural Jihad Organization, Management and Planning Organization as well as Agricultural Research Center.

The data collection tools included primary data, written questionnaire and personal interview. The questionnaire was prepared as a set of open-ended questions. The reliability of the questionnaire by the content validity method was confirmed by professionals in the case study and its consistency was measured by Cronbach's Alpha with using SPSS. Cronbach's Alpha coefficient of 64% was obtained showing the consistency of the questionnaire.

3.2. Data Analysis Method

EViews software is applied for data analysis and estimation of the models used. Data collection was cross-sectional and for year 2006. Durbin-Watson test and Lagrange Multiplier Test were used for the autocorrelation test, Arch and White tests for variance heteroscedasticity variance testing, the normality histogram test for testing the normality of the error terms and Ramsey's reset test for the functional misspecification testing and, also, *Fronteir* 4.1 software was used to calculate the technical efficiency of rice farmers.

4. Theoretical Study of Some Production Functions
4.1. Cobb-Douglas Production Function
Cobb-Douglas production function has been widely used in most agricultural researches because of its simplicity. It was first used in 1928 in an empirical study to calculate the productivity of capital and labor in the United States. This function which was presented by Douglas had been already used by Wixel. The primary form of this function was as follows:

$$y = AL^{\alpha}K^{\beta} \tag{2}$$

where y is yield, L is labor and K is capital inputs. A, α and β are determined positive parameters which can be defined by information under any condition. The higher the value of A, the more advanced the technology. α parameter measures the increase percentage in y as a result of a 1% increase in L, if we keep K constant. Similarly, β measures the increase percentage in y as a result of 1% increase in K, supposing that L is constant. Thus, α and β are the elasticity of L and K, respectively. If $\alpha + \beta = 1$, there will be a constant return to scale and if $\alpha + \beta > 1$ an increasing return to scale and if $\alpha + \beta < 1$ a decreasing return to scale, respectively (Salvatore, 1988).

By developing the function in terms of the number of inputs, the function will be transformed to:

$$y = Ax_1^{\beta_1} x_2^{\beta_2} x_3^{\beta_3} ... x_4^{\beta_4} \qquad i = 1,2...4 \tag{3}$$

This type of function with any number of inputs may be changed to a logarithmic equation. The general form of this function may be depicted as follows:

$$y = A\prod_{i=1}^{n} x_1^{\beta_1} x_2^{\beta_2} x_3^{\beta_3} ... x_n^{\beta_n} \tag{4}$$

In function above, y is the yield, x_i the production inputs of $(i = 1, 2,...,n)$ with positive values, A is the intercept and β_i is the inputs elasticities. The abovementioned function has nonlinear form and its logarithmic form as shown below was used to make it linear.

$$Lny = LnA + \sum_{i=1}^{n} \beta_i Lnx_i \qquad (5)$$

$$Lny = LnA + \beta_1 Lnx_1 + \beta_2 Lnx_2 + ... + \beta_n Lnx_n \qquad (6)$$

MP_k and AP_k for the Cobb-Douglas function with two variable inputs are as follows:

$$MP_k = \frac{dy}{dk} = \alpha AK^{\alpha-1}L^{\beta} \qquad (7)$$

$$AP_k = \frac{y}{k} = AK^{\alpha-1}L^{\beta} \qquad (8)$$

The production elasticity in Cobb-Douglas function can be given as follows:

$$E_K^{\phi} = \frac{MPK}{APK} = \frac{\alpha AK^{\alpha-1}L^{\beta}}{AK^{\alpha-1}L^{\beta}} = \alpha \qquad (9)$$

The Marginal Rate of Technical Substitution for Cobb-Douglas function is as follows:

$$MRTS = \frac{MPK}{MAPL} = \frac{\alpha L}{\beta K} \qquad (10)$$

The Marginal Rate of Technical Substitution of capital for labor is a function of labor / capital (L to K) ratio. With considering this feature, when the both inputs increase at a defined rate, even where the production level changes, the slope of the curves does not change.

4. 2. Transcendental Production Function

The transcendental production function is a logarithmic function firstly proposed by Halter, Carter and Hocking (1957). They made modifications in Cobb-Douglas function. In such modifications, the base of the natural log, e, was added and raised to a power that was a function of the amount of input that was used. Based on this modification, the generalized production function has three production regions with variable production elasticities which are so useful to describe the input-output relationships for crop production and is widely used in the agricultural economics researches. This function is referred to as

Higher Transcendental Function. Its' mathematical form for n inputs is as follows:

$$y = A\prod_{i=1}^{n} X_i^{\alpha i} - e\sum \beta_i X_i \tag{11}$$

where y is the yield, x_i is the production inputs $(i = 1, 2, ..., n)$ with positive value; A is the intercept and α_i and β_i are the parameters of $\beta_i \leq 0$ and $\alpha_i \geq 0$ to be estimated (Mousanejad and Hassani Moghadam, 1997).

This function is non-linear. In order to make it linear, take the logarithm of both sides of equation (9):

$$Lny = LnA + \sum_{i=1}^{n} \alpha_i Lnx_i + \sum_{i=1}^{n} \beta_i x_i \tag{12}$$

The final production for each input x_i is:

$$MP = \frac{dy}{dx_i} = \left(\frac{\alpha_i}{x_i} + \beta_i\right) y \tag{13}$$

where α_i is the coefficient of log input x_i, β_i is the linear coefficient of x_i and y is the total yield. With considering the values of α_1, α_2, β_1 and β_2, the final productions of inputs is positive, negative or null. Therefore, there are three stages of production be determined in this function. The production elasticity of this function can be obtained by the following equation:

$$EP_{xi} = \frac{MP_{xi}}{AP_{xi}} = \frac{dy}{dx_i} \cdot \frac{x_i}{y} = \alpha_i + \beta_i x_i \tag{14}$$

in this function the return to scale which is equal to the total inputs production elasticities is not constant; but its value depends on the rate of inputs consumption.

The rate of technical substitution for transcendental function is as follows:

$$MRTS = \frac{MP_L}{MP_K} = \frac{a_1\left(\dfrac{y}{K}\right) + \beta_1 y}{a_2\left(\dfrac{y}{L}\right) + \beta_2 y} \tag{15}$$

$$MRTS = \frac{L(a_1 + b_1 K)}{K(a_2 + b_2 L)} \tag{16}$$

As noted, $MRTS$ depends on the values of K and L.

4.3. Technical Efficiency

Theoretical fundamentals of efficiency were first developed by Farrell (1957). He decomposed economic efficiency into two components of technical and allocative efficiency and he used the concept of the production frontier to measure them. According to Farrell, technical efficiency is defined as the ability of a firm to maximize output from a given set of inputs. Allocative efficiency is the ability of a firm to use inputs in optimal proportions resulting into maximum profit at minimum cost by current methods. The economic efficiency, also referred to as overall efficiency, is the product of technical and allocative efficiency.

Since the frontier functions estimation is important in the measuring of efficiency, the economists proposed different methods for frontier functions estimation. These fall into the methods of Linear Programming (LP), Corrected Ordinary Least Squares (COLS) and Maximum Likelihood estimation. The results of investigations made by Bravo-Ureta and Rieger (1990), Zibaei and Soltani (1995) show that firstly, with using the same data, the above methods used in determining the technical efficiency will result in different results; and, secondly, the two methods of linear programming and the corrected ordinary least squares are very sensitive to the outliers, so that the omission of some observations will cause significant difference in the mean technical efficiency calculated by the two abovementioned methods, before and after omission of outliers. However, in recent years the most economists have come around this view that the stochastic frontier functions estimation techniques by the

maximum likelihood have led to better results than other methods (Battese and Corra, 1977).

4.3.1. Maximum Likelihood Estimation

A unified method of statistical estimation used for the technical efficiency calculation is the Maximum Likelihood Estimation (MLE). The MLE logic is that the estimators of the selected sample should be so estimated as to consider the maximum probability for the population. Using the estimator of the maximum likelihood it should be considered a defined statistical distribution such as exponential, half-normal or gamma for the error term of the function. When a gamma distribution is assumed for the error term, the logarithmic form of the likelihood function will be as follows:

$$LnL = KPl(\mu) - KLn[G(P)] + (P-1)\sum_{j=1}^{K} Ln(\varepsilon_j) - \mu \sum_{j=1}^{K} \varepsilon_j \qquad (17)$$

$$\varepsilon_j = Lny_j - Lna_0 - \sum_{j=1}^{m} \beta_i Lnx_{ij} \qquad (18)$$

where K is the number of observations, P and μ are the parameters for the form and scale of gamma distribution, respectively, and $G(P)$ is the gamma distribution function.

Greene (1980) showed that with supposing gamma for the error term, when limitation is considered for the P and U parameters, so that $P > 2$ and $U > 0$, then the function No. 21 can well be estimated by MLE.

4.3.2. Stochastic Production Frontiers

As stated previously, using the Production Frontier (PF), Farrell (1957) was the pioneer to propose the concept of the frontier function to primarily measure efficiency. Followed him, other economists have generally used the two methods of Deterministic Production Frontier (DPF) and Stochastic Production Frontier (SPF) for the estimation of production frontier. DPF method is estimated by Linear Programming (LP) and the Corrected Ordinary Least Squares ($COLS$) techniques.

The advantage of *COLS* over *LP* is that the standard error and the value of t may be obtained for each parameter and the disadvantage of the both of these methods is that they attribute all the deviations of production frontier or the value of the error term to the economic units' technical inefficiency which is due to managerial factors.

To introduce *SPF* proposed by Aigner, Lovell and Schmidt (1977) and Meeusen, W. and J. van den Broeck (1977), we consider the stochastic production frontier function as follows:

$$y_i = F(X_{ki}, \beta) \exp(\varepsilon_i) \tag{19}$$

where Y_i is the yield, X_{ki} is the vector of inputs, β is the vector of parameters, ε_i is the error term, K is the number of independent variables and i is the number of observations. In contrast to *DPF* models, the error term in *SPF* models is separated into two independent components and, thus, these models are known as Composed Error Models shown as follows:

$$E_i = V_i - U_i \tag{20}$$

In above equation, V_i is a symmetric component to account for stochastic changes in production due to the effects of factors beyond of the producer's (farmer's) control such as climatic factors, herbicides and diseases. This component has normal distribution with an average of zero and a variance of δ_v^2. U_i is associated with measuring economic units' technical efficiency. This component has normal distribution with one-sided domain, i.e. it has half-normal distribution $\left[U_i \approx \left| n(0, \delta_u^2) \right| \right]$.

For units the production rate of which accurately lies on the frontier curve, $U_i = 0$. But, for units the production rate of which lies below the frontier curve $U_i > 0$. Therefore, U_i is the difference between the maximum (frontier) production and the realized output at a defined level of input consumption. The variance of the error term of frontier production function with considering Equation (24) is as follows:

$$\delta_s^2 = \delta_v^2 + \delta_u^2 \tag{21}$$

For determining the technical efficiency, Battese and Corra (1977) defined γ parameter as follows:

$$y = \frac{\delta_u^2}{\delta_s^2} = \frac{\delta_u^2}{\delta_v^2 + \delta_u^2} \qquad\qquad 0 \leq y \leq 1 \qquad\qquad (22)$$

Where $\gamma = 0$, then there will be no U_i in the model. Hence, all changes in production and the differences between the economic units are associated with factors beyond the control of the farmer. Therefore, under such conditions the technical efficiency is not observed and Ordinary Least Squares (OLS) is preferable to Maximum Likelihood Estimation (MLE). Otherwise, i.e. under conditions when a part of the error term is associated with factors under the farmer's control, the Maximum Likelihood Estimation is applied.

John Derow et al. (1982) showed that with considering hypotheses made in relation with U_i and V_i statistical distributions, the criteria for the technical efficiency of each unit can be obtained through the mathematical expectation of U_i conditioned by E_i.

$$E(u_i | E_i) = \frac{\delta_u - \delta_r}{\delta_s} \left[\frac{f^{\cdot}(E_i \lambda / \delta)}{1 - F^*(E_i y / \delta)} = \frac{E_i \lambda}{\delta} \right] \qquad\qquad (23)$$

In equation above, f^* and F^* denote the standard normal density function and the standard normal distribution function and $\lambda = \frac{\delta_u}{\delta_r}$. Finally, the criteria for the economic units' technical efficiency can be obtained through:

$$TE = \exp\left[-E(u_i | E_i) \right] \qquad\qquad (24)$$

Battese and Coelli proposed a stochastic frontier production function capable of applying panel data. The firm's inefficiency effects are expressed as a variable with truncated normal distribution and it is observed that it can vary systematically over time. This, as the first model proposed by Battese and Coelli, known as "Composed Error Model", is defined as follows:

$$Y_{it} = X_{it}\beta + (V_{it} - U_{it}) \qquad i = 1,...,N \qquad t = 1,...,T \qquad (25)$$

$$U_{it} = \{U_i \exp(-\eta(t-T))\} \qquad U_{it} \sim N(\mu, \delta_v^2) \qquad (26)$$

where Y_{it} is the production of the i th firm in time period t, X_{it} is a (k+1) vector of inputs used in the production, V_{it} are random variables of error terms with a distribution of $V_{it} \sim N(0, \delta_v^2)$ and U_{it} are the non-negative random variables independent of V_{it} indicating the technical inefficiency in production function and has truncated normal distribution at zero. Coefficients η and β are parameters to be estimated. A feature of this model is that it may be estimated with unbalanced panel data.

Since this model considers the inefficiency effects with time-varying, only panel or time series data are used in this method. That is, at least one observation should be available at each time period and in each cross section. Applying some limitations on this model, it will be possible to obtain certain models having been so far proposed in this respect. If limitation of $\eta = 0$ is assumed, the above model will be transformed to a model proposed by Battese, Coelli and Colby (1989). In this model, the technical inefficiency has been assumed constant during time. When the limitation $\mu = 0$ is added, it is transformed to Pitt and Lee Model (1981). Also, if another limitation as $T = 1$ is added, the above model will be returned to the main model proposed by Aigner, Lovell and Schmidt (1977). Similarly, when all these limitations excluding the limitation of $\mu = 0$ are entered into the model, the Stinson model (1980) is obtained.

All models described above can be estimated using *Frontier* 4.1 software package developed by Coli (1994). Generalized Likelihood Ratio Test ($GLRT$) can be used to identify an appropriate model in a certain study:

$$\lambda = -2\{LogLikelihood(H_0) - LogLikelihood(H_1)\} \qquad (27)$$

where static λ is the ratio of the maximum likelihood (LR), H_0 is the null hypothesis and H_1 is the alternative hypothesis. Statistic λ under the null hypothesis is asymptotically co-distributed with statistic χ^2.

Before discussion about the hypotheses of each model above, we introduce parameters on which these hypotheses are applied. μ is the average of the error term U. The positivity of this parameter shows the two-sided normal distribution for U and its equality to zero shows one-sided normal distribution for U. η shows the technological changes over time. This parameter can be positive, negative or zero which indicates that the technical efficiency over time is increasing, decreasing or constant, respectively. As the research data are cross-sectional, $\eta = 0$. This model status will be used as a base for maximum likelihood ratio test. γ denotes the status of variance of the error term. The hypotheses which can be studied are as follows:

1. Suppose η, γ and μ take given values, in such status the model will be of no limitation.

2. Suppose $\mu = 0$; this indicates the one-sided normal distribution for the error term U.

3. $\mu = \gamma = 0$ is assumed; here the variance of the error term will be zero and all differences between units are due to factors beyond the control of the farmer. As a result, technical efficiency is not observed and Ordinary Least Squares (OLS) is preferable to Maximum Likelihood Estimation (MLE). The Analysis of Variance (ANOVA) test is used to study the socioeconomic characteristics and its effect on farmers' technical efficiency. Depending on whether the said characteristics are categorized into two or more groups, F- and t-tests are used. But, Battese, Coelli and Colby presented another model referred to as "A Model for Technical Inefficiency Effects" (1995). They presented the following model both to estimate the technical efficiency and to determine the factors which affect the inefficiency.

$$y_{it} = \exp\left(X_{it}\beta + V_{it} - U_{it}\right) \tag{28}$$

where y is the yield, X is a vector $(1 \times k)$ of the values of inputs and explanatory variables, β is a vector $(k \times 1)$ of parameters, V_{it} is stochastic error with a distribution of

$N\left(0\,,\delta_v^2\right)$ having been distributed independent of U_{it}. U_{it} is a non-negative random variable and independent of V_{it} which inefficiency and has truncated normal distribution at 0 and a mean of m_{it} .is associated with farming technical

$$U_{it} \sim N\left(m_{it},\delta^2\right) \qquad (29)$$

In the following equation, Z_{it} is a vector of explanatory variables associated with the technical inefficiency of the production of units over time and δ is a vector of unknown coefficients. The effect of factors on the technical efficiency of production $\left(U_{it}\right)$ in stochastic frontier model can be written as follows:

$$U_{it} = Z_{it}\delta + W_{it} \qquad (30)$$

where W_{it} is a random variable with a mean of 0 and a variance of δ^2.

$$W_{it} \geq -Z_{it}\delta \qquad (31)$$

Parameters associated with model are γ and δ_s^2 which are defined as follows:

$$\gamma = \frac{\delta^2}{\delta_s^2} \qquad (32)$$

$$\delta_s^2 = \delta_V^2 + \delta^2 \qquad (33)$$

Considering the above, technical efficiency can be defined as:

$$TE_{it} = \exp\left(-U_{it}\right) = \exp\left(-Z_{it}\delta - W_{it}\right) \qquad (34)$$

The two models presented by Battese and Coelli have no common thing and it was not so that imposing conditions on one of them will give the other's pattern. That is, these two patterns do not belong to one group. Battese and Coelli propose that it is required to simultaneously estimate the first equation, i.e. stochastic frontier production function and the second equation, i.e. the effect of factors on the technical inefficiency. *Frontier* 4.1 software package proposed by Battese and Coelli was used for the simultaneous estimation of two functions. This software has been prepared by Coelli's team at the University of New England

for the simultaneous estimation of the parameters of the stochastic production function by the method of maximum likelihood. This predicts the technical efficiency of any entity having been estimated with using the frontier production function. Also, the method of maximum likelihood allows the entities to play further role in determining the production frontier in order to reduce the structural default of the ordinary least squares method which gives the same weight to remote observations. This program is not able to estimate the system of equations.

5. Study of the Results of the Experimental Research
5.1. Introduction to Model Variables
In the production function model, LNY denotes the logarithm of Champa rice production rate in tones as dependent variable. Many variables were considered as dependent variables, but they were omitted from the model because they were collinear or insignificant. Finally, the dependent variables used in the model are as follows: C as intercept, X_1 capital in tomans, X_2 seed consumption in Kg, X_3 number of hours machinery work, X_4 labor in man days, X_5 land area under cultivation in hectares and X_6 water consumption in cubic meters.

5.2. Estimation of Various Production Function and Appropriate Model Selection
Many models were used to estimate the production function of Champa rice in Kohgiluyeh and Boyer-Ahmad Province, but among the estimated models the two models of Cobb-Douglas and Transcendental were recognized as more appropriate because they had definitive answer in Ramsey's reset test. The Cobb-Douglas and transcendental production functions logarithmic form, respectively, used in this paper are written as follows:

$$LnY = C + \alpha_1 LnX_1 + \alpha_2 LnX_2 + \alpha_3 LnX_3 + \alpha_4 LnX_4$$
$$+ \alpha_5 LnX_5 + \alpha_6 LnX_6 + u_i \tag{35}$$

$$LnY = C + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3$$
$$+ \beta_4 LnX_4 + \beta_5 LnX_5 + \beta_6 LnX_6 + \beta_7 X_7 \qquad (36)$$
$$+ \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + u_i$$

The summary of the results of these two functions estimation are as shown in Table below:

Table 2: The Cobb-Douglas and Transcendental Functions Estimation results

Variable Coefficient	Cobb-Douglas Function		Transcendental Function	
	Value	t	Value	t
C	-3.358	-3.643	-5.626	-2.698
β_1	0.102	3.739	0.090	2.22
β_2	0.147	2.859	0.256	2.59
β_3	0.039	5.695	0.041	2.05
β_4	0.181	2.100	1.109	3.28
β_5	0.552	5.673	0.482	2.46
β_6	0.183	2.100	0.086	0.49
β_7	-	-	3.636	0.27
β_8	-	-	-0.001	-1.65
β_9	-	-	-0.010	-0.141
β_{10}	-	-	-0.016	-2.73
β_{11}	-	-	0.940	0.59
β_{12}	-	-	9.548	0.68
	$R^2 = 0.87, \ \overline{R}^2 = 0.87$ $F = 167.7 \ (0.00)$ $DW = 1.98, \ n = 150$		$R^2 = 0.88,$ $\overline{R}^2 = 0.87$ $F = 87$ (0.000) $DW = 2.13,$ $n = 15$	

Source: Research findings

Definite regression test was made for non colinearity, Durbin-Watson test (DW) and Lagrange Multiplier Test (LM) for serial correlation, Ramesy reset test to ensure that the functional form is correct, Normality test for testing normality of error terms and the ARCH test and White tests for heteroscedasticity test of the variance of the error terms. On the basis of the results of the classical hypotheses testing on the error terms, the Cobb-Douglas and transcendental production functions have all classic conditions in terms of serial correlation, normality and heteroscedasticity and the functional form used is appropriate.

F-test of Pooled Least Squares was used to compare rice production functions (Cobb-Douglas and Transcendental) and the appropriate model selection.

$$F = \frac{\dfrac{\left(R_{uR}^2 - R_R^2\right)}{m}}{\dfrac{\left(1 - R_{uR}^2\right)}{N - K}} = \frac{\dfrac{\left(0.884 - 0.875\right)}{6}}{\dfrac{\left(1 - 0.884\right)}{150 - 13}} = 1.78 \tag{36}$$

The value of computational F ($F = 1.78$) is less than the value of table F at the 0.01 probability level, i.e. $F_{1\%} = (6, 137) = 2.96$. Thus, Cobb-Douglas production function is preferable to the transcendental production function. This result is confirmed by Akaike Info Criterion ($AKIC$) which for the Cobb-Douglas function (0.447) is less than the corresponding statistic in the transcendental function (0.450). Schwarz Banzin statistic (SB) of Cobb-Douglas function (0.588) is less than the corresponding statistic in the transcendental function (0.711) and indicates that the Cobb-Douglas model is preferred. Standard Error of the Estimate (SEE) in the Cobb-Douglas function (0.2900) is also less than its corresponding in transcendental function (0.2907) indicating that the production function is preferable to Cobb-Douglas form. In this function, about 87 percent of the changes of dependent variables (rate of Champa rice production) in rice farms of Kohgiluyeh and Boyer-Ahmad Province is explained by independent variables (capital, seed consumption, machinery, labor, area under cultivation and water consumption). All

independent variables are significant and positive at the 0.05 probability level.

5.3. Production Coefficients and Elasticities

After selecting Cobb-Douglas model as appropriate rice production function in Kohgiluyeh and Boyer-Ahmad Province, we are to calculate the coefficients of elasticity and to analyze it. The production elasticity of the ith input is defined as follows:

$$EP_{xi} = \frac{\frac{dy}{y}}{\frac{dx_i}{x}} = \frac{MP_{xi}}{AP_{xi}} \qquad (37)$$

$$EP_{xi} = \frac{\frac{dy}{y}}{\frac{dx_i}{x}} = \frac{MP_{xi}}{AP_{xi}} \qquad (38)$$

Since the function used is of Cobb-Douglas function nature where the variables have been defined in logarithmic form, the elasticity formula above shows that the coefficient of each variable, in fact, is the product elasticity for the corresponding input. As previously stated, the result of the function estimation is as follows:

$LnY = -20358145 + 0.102479LnX_1 + 0.147846\ LnX_2 + 0.039978\ LnX_3 +$

$\qquad +0.181172\ LnX_4 + 0.55164\ LnX_4 + 0.183349\ LnX_6 \qquad (39)$

With considering the above-mentioned model, the production elasticities is as shown in Table 3.

Table 3: Champa rice production inputs elasticity

Input	Capital	Consumed seed	Machinery	Labor	Area under cultivation	Water
Elasticity coefficient	0.102	0.147	0.039	0.181	0.552	0.183

Source: Rresearch findings

It is noted that all coefficients range between zero and one; i.e. the rice farmers stand in the second production region in terms of their using the given production factors. The highest production elasticity is related with the input of the area under cultivation. The positive coefficient of the land area under cultivation (0.552) indicates its direct and strong effect on the production, so that a one percent increase in the land area under cultivation will lead to the yield increase by 0.552. Thus, the area under cultivation of the labor and the water consumption inputs with a production elasticity of 0.183 and 0.181 has the highest effect on the production so that a one percent increase in each of these inputs will increase the yield by 0.183% and 0.181%, respectfully. Regarding the consumed seed input, a one percent increase in this input will increase the yield by 0.4%. One percent increase in the capital input will increase the yield by 0.1%. The lowest elasticity is related with the machinery input on the basis of which the one percent increase in the number of hours the machinery used will increase the yield by 0.03.

5.4. Return to Scale

In Cobb-Douglas function elasticities, the return to scale for production units is as follows:

$E = 0.1 + 0.14 + 0.03 + 0.18 + 0.55 + 0.18 = 1.2$

Therefore, the return to scale in rice farms in Kohgiluyeh and Boyer-Ahmad Province is 1.2. Wald test was used to obtain this result. Based on this test, with considering the F statistic, $F = (7.36)$ the hypothesis H_0 of $H_0 : \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 = 1$ is rejected at the 0.05 significance level and the hypothesis H_1 of $H_1 : \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 \neq 1$ is accepted at the 0.05 significance level. As this value is >1, there is an increasing return to scale (IRS); i.e. with all production inputs increase by 1 % simultaneously, the output increases 1.2%.

5.5. Technical Efficiency

The Champa rice stochastic frontier Cobb-Douglas function is specified for the estimation of the technical efficiency of rice

farmers in Kohgiluyeh and Boyer-Ahmad Province and estimated by the Maximum Likelihood Estimation (MLE) and the Ordinary Least Squares (OLS) methods using $Frontier$ 4.1 software.

For estimating the parameters of the stochastic frontier production function, firstly we estimate the triple hypotheses without limitation, with the limitation of $\mu = 0$, and the limitation of $\mu = \gamma = 0$ regarding the stochastic variables of U_i and V_i separately within the framework of the triple models through the maximum likelihood (ML). Then, we select the best model from among the triple models with using the generalized maximum likelihood ratio test given in Equation (44). The results of the maximum likelihood estimation of Champa rice stochastic frontier production function within the triple models with using $Frontier$ 4.1 software are summarized in Table 4.

Table 4: Maximum likelihood estimation of stochastic frontier Cobb-Douglas models

Model	Model I (no limitation)		Model II $(\mu = 0)$		Model III $(\mu = \gamma = 0)$	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
β_0	-2.24	0.754	-2.23	0.767	-0.35	0.921
β_1	0.087	0.025	0.088	0.025	0.102	0.027
β_2	0.124	0.045	0.123	0.044	0.147	0.051
β_3	0.033	0.006	3.033	0.006	0.0389	0.007
β_4	0.144	0.083	0.148	0.080	0.181	0.086
β_5	0.640	0.075	0.640	0.076	0.552	0.097
β_6	0.136	0.059	0.136	0.061	0.183	0.087
σ^2	0.221	0.156	0.195	0.036	0.087	-
γ	0.897	0.064	0.891	0.062	-	-
μ	-0.111	0.651	-	-	-	-
$Log - LikeLihood$	-21.70	-	-21.72	-	-26.56	-

Source: research findings

In Table 4, β_1 to β_6 parameters are the coefficients of explanatory variables and β_0 is the intercept in the rice farmers'

stochastic frontier production function. If we plug the value of the $Log - LikeLihood$ of the estimated stochastic frontier in Equation (44), it may be possible to compare the estimated stochastic frontier function under the two hypotheses of $H_0 : \mu = 0$ and $H_0 : \mu = \gamma = 0$ and also, to select the most appropriate model. When the computational λ value of each hypothesis above is higher than the λ value in the Table at the 0.05 probability level, the said hypothesis will be rejected.

$$\lambda = -2\{\log LikeLihood(Ho) - \log LikeLihood(H_1)\} \tag{39}$$

In the equations below, the first equation is the hypothesis testing of $H_0 : \mu = \gamma = 0$ and the second equation is the hypothesis testing of $H_0 : \mu = 0$ which is calculated as follows:

$\lambda = -2[-26.56-(-21.70)] = 9.72$
$\lambda = 2[-21.72-(-21.70)] = 0.04$

We consider the value of the calculated statistic λ as equal to the chi square computational value (χ^2) and compare it with the chi square table with r degree of freedom and 0.05 probability level.

Table 5: Generalized maximum likelihood ratio test for appropriate model selection

Hypothesis H_0	Computational χ^2	Degree of freedom	Table's χ^2	Decision
$(\mu = \gamma = 0)$	9.72	2	5.99	Not accepted
$(\mu = 0)$	0.04	1	3.84	Accepted

Source: research findings

The maximum likelihood ratio test generalized for appropriate model selection concerning the provincial rice farmers shows that hypothesis H_0 based on $\mu = \gamma = 0$ is rejected with two degrees of freedom; because the computational χ^2 value of $H_0 : \mu = \gamma = 0$ is more than the value of χ^2 table at 0.05 probability level. Therefore, it can be concluded that the maximum likelihood

(ML) method via Ordinary Least Squares (OLS) is preferred to estimate the stochastic frontier production function for Champa rice farms. That is, some difference in Champa rice production in the rice farms of the province is due to the impact of managerial characteristics.

With considering Table 5, the acceptance of $H_0 : \mu = 0$ with single degree of freedom indicates that the rice framers' technical efficiency has a half-normal distribution.

We add the socioeconomic variables to the model in order to study the factors effective on the technical inefficiency and, also, the required tests are made to obtain an appropriate model. In Table 6, parameters β_1 to β_6 are the coefficients of explanatory variables and δ_1 to δ_3, respectively, are the coefficients of socioeconomic variables e.g. experience, age and education level; β_0 and δ_0, respectively, are also the intercept in the stochastic frontier production function and the intercept in the function of factors effective on the technical inefficiency.

Table 6: Estimated coefficients of frontier production function

Coefficients	MLE	$\delta_0 = 0$	$\delta_3 = 0$	$\delta_2 = \delta_3 = 0$	$\delta_1 = \delta_2 = \delta_3 = 0$
β_0	-1.145	-1.92	-0.886	-0.340	-2.243
β_1	0.063	0.094	0.054	0.066	0.087
β_2	0.113	0.134	0.075	0.088	0.124
β_3	0.021	0.031	0.019	0.02	0.033
β_4	0.062	0.018	0.02	-0.047	0.144
β_5	0.413	0.591	0.318	0.326	0.640
β_6	0.137	0.116	0.112	0.120	0.136
δ_0	11.180	-	12.3	5.61	-0.111
δ_1	-4.551	-0.652	4.78	-1.239	-
δ_2	1.858	0.691	1.783	-	-
δ_3	-0.0003	-0.012	-	-	-
γ	0.350	0.862	0.506	0.008	0.897
σ^2	0.037	0.130	0.305	0.047	0.221
$Log-LikeLihood$	37.71	14.75	24.08	16.39	21.70

Source: research findings

Table 7: Maximum likelihood ratio test

Test No.	Hypothesis	Calculated χ^2	d.f,	Table's χ^2	result
1	$\delta_0 = 0$	45.91	1	3.84	Not accepted
2	$\delta_3 = 0$	27.26	2	5.99	Not accepted
3	$\delta_2 = \delta_3 = 0$	42.64	3	7.81	Not accepted
4	$\delta_1 = \delta_2 = \delta_3 = 0$	32.02	4	9.49	Not accepted

Source: Research findings

With considering the results of Table 7, the first hypothesis indicating that the constant of the equation on the factors which have impact on technical efficiency is rejected because 45.91>3.84; i.e. the technical inefficiency function has an intercept. The second and the third hypotheses are also rejected because in the second hypothesis 27.26>5.99 and in the third

hypothesis 42.64>7.81; rejection of the second and the third hypotheses shows that the socio-economic characteristics (age and education level) have non-zero coefficients and these characteristics have effect on the rice farmers' efficiency. The fourth hypothesis indicated that the effect of the technical inefficiency is a function of the mentioned effective factors (work experience, age and education level). Since this hypothesis is rejected, all three given variables have effect on the rice farmers' technical inefficiency function.

Table 8: Final frontier production function model

Coefficients	Final Model	*SE*
β_0	-1.145	0.708
β_1	0.063	0.023
β_2	0.113	0.036
β_3	0.021	0.006
β_4	0.062	0.049
β_5	0.413	0.077
β_6	0.137	0.061
δ_0	11.180	0.850
δ_1	-4.551	0.421
δ_2	1.858	0.231
δ_3	-0.0003	0.004
γ	0.350	0.206
σ^2	0.037	0.006
$Log-LikeLihood$	37.71	-

Source: research findings

As depicted in Table 8, there is a negative relationship between the farmers' experience in rice farming and their technical inefficiency. This relationship indicated that as the experience in rice farming increased the efficiency rises. The more experience a farmer has, the higher the technical efficiency. The relationship between the farmers' age and the inefficiency levels is positive; i.e. there is negative relationship between the

rice farmers' experience and their technical efficiency and increase in farmers' age in years increases the levels of their technical efficiency. The relationship between farmers' education and technical inefficiency is negative; i.e. the higher the number of years of school the farmer has had in formal education, the higher the technical efficiency.

According to hypothesis testing and final model selection, the frequency distribution of farmers by technical efficiency level is as shown in Table 9.

Table 9: Technical Efficiency of Rice

Technical Efficiency (%)	Frequency	Relative Frequency (%)	Relative Aggregated Frequency (%)
≤ 40	16	10.7	10.7
> 40 and ≤ 50	28	18.6	29.3
> 50 and ≤ 60	18	12	41.3
> 60 and ≤ 70	28	18.6	59.9
> 70 and ≤ 80	16	10.7	70.68
> 80 and ≤ 90	11	7.4	78
> 90 and ≤ 100	33	22	100
Mean: 67.01	Range: 66.7	Minimum: 33.3	Maximum: 100

Source: Research findings

The results obtained from the technical efficiency estimation according to the final model shows that the technical efficiency of rice farmers ranges between the minimum of 33.3% and the maximum of 100%. Such a great difference between the minimum and maximum technical efficiency indicates that it is still possible to significantly increase the production level. This requires the improvement of methods for inputs application and efficient management at the farm level. From the viewpoint of production technology and management, the gap between the best rice farming and the weakest rice farming in terms of production level in Kohgiluyeh and Boyer-Ahmad Province is 66.7% and this reveals the very high potential of Champa rice production in Kohgiluyeh and Boyer-Ahmad Province.

Therefore, at the same technology level, this deep gap between the production levels of rice farms in the province may be reduced through improved technical efficiency.

6. Summary and Conclusion

The main objective of this paper is to estimate the Champa rice production function and to calculate the rice farmers' average and final productivities in Kohgiluyeh and Boyer-Ahmad Province. For this purpose, a questionnaire was prepared to collect required data. Data were collected by personal interview and visiting rice farms. 150 samples were studied using stratified sampling method. Information was collected as cross-sectional data in 2006. With considering each city's share in the total production, 44 out of these 150 samples were selected from Boyerahmad City, 66 of Dena, 15 of Kohgiluyeh, 24 of Gachsaran and 1 of Bahmaei, respectively.

After the study of different forms, the Champa rice production function was estimated separately by the two models of Cobb-Douglas and transcendental for the province. In these production functions, the dependent variable was the Champa rice production rate and the independent variables were the capital, consumed seed, machinery, labor, area under cultivation and water consumption. Using pooled least squares F-test and comparing the calculated statistics it was determined that the Cobb-Douglas model can better show the effects of the Champa rice production rate posed by determinants in the province. In this function, about 87% of Champa rice production in the rice farms of Kohgiluyeh and Boyer-Ahmad Province is explained by independent variables (capital, consumed seed, machinery, labor, area under cultivation and water consumption). All independent variables were significant and positive at the 0.05 probability level. The research results also showed that the production elasticity of the capital is 0.102, of the consumed seed is 0.147, of the machinery is 0.039, of the labor is 0.181, of the area under cultivation is 0.552 and of the water consumption is 0.183, respectively. Therefore, a one percent increase in the capital will

lead to the yield increase by 0.102. One percent increase in the consumed seed will lead to the yield increase by 0.147. One percent increase in the machinery will lead to the yield increase by 0.039. One percent increase in the labor will lead to the yield increase by 0.181. One percent increase in the water consumption will lead to the yield increase by 0.183. As seen, the production sensitivity to the input of the area under cultivation is higher than other inputs. Since there is a positive coefficient between zero and one, the consumption of these inputs is in the second production region (economic area) in the rice farms of the province.

Thus, one can say the rice farmers have been reasonable in using each of inputs above. The return to scale in rice farms in Kohgiluyeh and Boyer-Ahmad Province is of increasing returns to scale (IRS) with a degree of 1/2; i.e. if the factors of production (capital, seeds, machinery, labor, area under cultivation and consumed water) simultaneously increases by one percent, the rate of production will rise by 1.2. With considering that the area under cultivation is the most effective factor in Champa rice production in the province it is suggested to apply required land consolidation policies, because the land consolidation will result in increased production and increased product operation.

Using *Frontier* 4.1 the Champa rice stochastic frontier Cobb-Douglas functions were estimated by the two methods of Maximum Likelihood Estimation and the Ordinary Least Squares. The hypotheses on the error term of the stochastic frontier production function were tested using the generalized maximum likelihood test. Then, the more appropriate model to determine the technical efficiency of rice farmers in Kohgiluyeh and Boyer-Ahmad Province was selected and hypothesis H_0 based on $\mu = \gamma = 0$ is rejected with two degrees of freedom. Therefore, it may conclude that the Maximum Likelihood Estimation (*MLE*) is preferable to Ordinary Least Squares (*OLS*). The results also showed that the technical efficiency for each rice farmer in the province can be measured. That is, the

technical efficiency has stochastic distribution and the difference in the rice farmers' operation in rice farms is due to managerial characteristics and is not related with factors beyond the control of the farmers. And, each rice farm has a different technical efficiency in the province.

The mean technical efficiency of the rice farmers in the province is 67.01 percent which has been fluctuated between a minimum of 33.3 to a maximum of 100 percent. Such a great difference between the minimum and maximum technical efficiency indicates that it is still possible to significantly increase the production level. This requires the efficient management at the farm level. From the viewpoint of production technology and management, the gap between the best rice farming and the weakest rice farming in terms of production level in the Province is 66.7% and this reveals the very high potential of Champa rice production in Kohgiluyeh and Boyer-Ahmad Province. Therefore, at the same technology level, this deep gap between the production levels of rice farms in the province may be reduced through improved technical efficiency and to increase the rice production in the province. Thus, the competent authorities of the agricultural sector (Agricultural Jihad Organization) are recommended to increase the level of farmers' knowledge through promotional services center and to transfer the findings of research centers as well as the experiences of rice farmers operating at a high level of efficiency to other rice farmers. This will lead to improved production in agricultural sector.

In order to study the effect of the socioeconomic characteristics including rice farming experience, age and educational level on the technical inefficiency in Kohgiluyeh and Boyer-Ahmad Province, the said characteristics were entered into the stochastic frontier Cobb-Douglas function as effective variables and their effect was tested. According to results obtained, negative relationship exists between rice farmers' experience and inefficiency; as the experience in rice farming increases the efficiency rises. The relationship between rice

farmers' level of education and their technical inefficiency is negative; i.e. the higher the number of years of school the farmer has had in formal education, the higher the technical efficiency. Therefore, the rice farmers' experience and level of education is directly related with their technical efficiency. But, regarding the socioeconomic variable of rice farmers by age, the results showed that the final function indicates that there is a positive relationship between age and inefficiency; i.e. the relationship between age and technical efficiency is negative and older farmers are technically less efficient than younger farmers. Thus, the province rice farmers' age is directly related with their technical inefficiency.

Reference:

Aigner, D.J., C.A.K. Lovell & P. Schmidt. (1977). Formulation and Estimation of Stochastic Frontier Production Function Model. Journal of Econometrics, 6: 21-37.

Battese, G.E. & G.S. Corra. (1977). Estimation of a Production Frontier Model : with Application to the Pastoral Zone of Eastern Australia. Journal of Agricultural Economics, 21: 169- 179.

Battese, G.E. & T.J. Coelli. (1992). Frontier Production Functions, Technical Efficency and Panel Data:with Application to Paddy Farmers in India. Journal of Productive Analysis, 3: 153- 469.

Bravo – ureta, B.E. & L. Rieger. (1990). Alternative Production Frontier Methodologies and Dairy Farm Efficiencies. Journal of Agricultural,36:150-139.

Dawson, P.J. & J. Linqard. (1989). Measuring Farm Efficiency Over Time on Philippine Rice Farms. Journal of Agricultural Economics, 40:168-177.

Greene, W.H. (1980). Maximum Likelihood Estimation of Econometric Functions, Journal of Econometrics. 13: 27-56.

Handerson, J. M. & Quant, R. (2007). Microeconomic Theory (mathematical approximation). Translated by Jamshid Pajooyan and Morteza Gharebaghian, Rasa, Tehran.

Hassanpour, B. & J. Torkamani. (2000). Determining the technical efficiency of fig producers in Fars Province, Application of transcendental stochastic frontier production functions. Quarterly Journal of Agricultural Economics and Development, 30: 171-198.(in Persian).

Jondrow, J., C.A.K. Lovell, I.S. Materov & P. Schmidt. (1982). On the Estimation of the Technical Inefficiency in the Stochastic Frontier Production Function. Journal of Econometrics, 19: 233-238.

Kalirajan, K.P. & J.C. Flinn. (1983). The Measurement of Farm Specific Technical Efficienc, Pakistan. Journal of Applied Economics, 2:167-180.

Karipour, H. (1996). Estimation of the Rice Production Function and the Study of Factors which Affect it (case study in Babolsar City). Master thesis, Mazandaran University.

Koupahi, M. & M. Kazemnejad. (1997). Study and Economical Analysis of Tea Farmers' Technical Efficiency in Gilan with Emphasis on the Effect of Age, Educational Level and Land Size. Quarterly Journal of Agricultural Economics and Development, 89-99: 9.

Meeusen, W. & J. Vonden Broeck. (1997). Efficiency Estimation From Cobb – Douglas Production Function with Composed Error. International Economic Review, 18: 435- 444.

Mohades Hosseini, S. M. & S. Yazdani. (1996). Study of the Economic Efficiency of Farmers Growing Different Rice Varieties in Mazandaran

Province. Articles Collection of the First Conference on Iran Agricultural Economics, Faculty of Agriculture, Zabol.

Mousanejad, M. & R. Najarzadeh. (1997). Agricultural production economics. Economic Researchers Institute's Press, Tarbit Modarres University, Tehran.

Salvatore, D. (1988). Microeconomic Theory. Translated by Hassan Sobhani, Ney Press, Tehran.

Zibaei, M. & Gh. Soltani. (1995). Different Methods of the Estimation of the Frontier Production Function and Technical Efficiency of Milk Producing Units. Plan and Development Magazine, 18-26: 11.