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Relationship between Meta-Technology Ratios and Varietal Differences in Date Production (Case Study of Sistan and Baluchestan, Iran)

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Abstract

This paper uses the concept of Meta-frontier to investigate the relationship between Meta Technology Ratios (MTR) and different varieties in datepalms including; Mazafati, Rabi and Zardan that are produced widely in Sistan and Baluchestan province of Iran. We used a stratified sampling of 300 date farmers of this province in 2010, 2011 and 2012 and estimated a stochastic production frontier using pooled data. Then, stochastic production frontiers were estimated for each variety, separately. At the end, the meta-frontier parameters were obtained to estimate the Meta technology ratio. Results showed that the estimated mean values of technical efficiency for the pooled frontier, variety group frontiers and Meta frontier across all data were 0.558, 0.543 and 0.0014, respectively. The value of Meta technology ratio was 0.407 for Mazafati variety, 0.432 and 0.507 for Rabi and Zardan varieties respectively. Mazafati had the lowest MTR while, Zardan and Rabi varieties are more closed together. Surprisingly, Mazafati had the lowest technical efficiency with respect to group frontier and Meta-frontier. The estimated average technical efficiencies with respect to group frontiers for Mazafati, Zardan and Rabi are: 0.518, 0.520 and 0.592, respectively; while Mazafati is kind of date which is the most exported variety.

Keywords:
Meta -frontier, Meta technology ratio, Datepalms, Sistan & Baluchestan

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INTRODUCTION

Good performance is an important factor for improving productivity in agricultural economics of developing countries. These countries can use the results of studies involved with this context broadly for their benefits because of resource and opportunity shortages they are faced for accepting and developing new technologies. Results of these studies show that it is still possible to improve the productivity with efficiency increment without using more basic resources or expanding new technologies. In addition; these research outcomes will be helpful in level of policy making, for choosing between two options; accepting new technologies or increasing the efficiency of existent technology (Sabouni, 1997).

A few farmers produce solely one variety of date, but many of them turn out two or more kinds of dates. Animals are sometimes fed by Zard variety. Mazafati and Rabi varieties are just for selling in the country or exporting abroad. One of important issues related to date production that should be noticed by farmers is technical efficiency. Although much has been written to measure technical efficiency of crops in Iran (see Najafi and Zibaee, 1994; Najafi and Abdollahi, 1997; Bakhsude *et al.,* 2001; Karbasi *et al*., 2004, and Karim koshte *et al.*, 2004 for surveys), relatively little attention has been paid to the varietal or regional differences in agricultural field. O'Donnell *et al.,* (2008), put it well, "Firms in different industries, regions and/or countries face different production opportunities. Technically, they make choices from different sets of feasible input-output combinations and these so-called technology sets differ because of differences in available stocks of physical, human and financial capital (e.g., type of machinery, size and quality of the labor force, access to foreign exchange), economic infrastructure (e.g., number of ports, access to markets), resource endowments (e.g., quality of soils, climate, energy resources) and any other characteristics of the physical, social and economic environment in which production takes place. Such differences have led efficiency researchers to estimate separate production frontiers for different groups of firms", (O'Donnell, *et al.*, 2008).

Battese and Rao (2002), Battese *et al*. (2004), and then O'Donnell *et al.* (2008) introduced Meta frontier (MF) approach to address this issue. Battese and Rao (2002) and also Rao *et al.* (2003) showed that, we should put aside the similar production technology assumption for all groups of an industry. In agricultural sector Mehrabi *et al.* (2006) estimated the technical efficiency of wheat farmers of Kerman province with translog production function. They obtained the technology gap, between five main regions which were producing wheat. Results showed a higher technology gap ratio respected to meta-frontier in drought regions than others. Mehrabi *et al.* (2007) and Villano *et al.* (2010) appear to be the only authors that have published using the Battese *et al*. (2004) procedure for varietal differences in agricultural crops. Mehrabi *et al*. (2007) reported a significant technology gap between three varieties of pistachio with using a selected sample random of 475 pistachio farmes of Kerman in 2003 and 2004 which was included three main varieties of pistachio. Results emphasized the importance of taking into account the differences in frontiers imposed by different tree varieties. Villano *et al.* (2010) discussed about factors which contribute to not using the meta-frontier production technology by most farmers except in the long run. Physical conditions, environmental constraints, capital scarce, production cycle span, specialy for perennial crops and unprofitability of changing the current varieties are the most important reasons expressed by them that should be taken into account, if farmers would like to reach the meta-frontier. So far, to the best of our knowledge, no study had tried to measure productive efficiency of the datepalm farms while taking into consideration the varietal differences and their relationship with technology gap. In this paper we are going to examine the unsimilarity of technologies in three main datepalm varieties by stochastic production analysis. The rest of this paper organizes as follows: section 2 describes the econometric modeling from basic stochastic frontier analysis to meta-frontier parameters linear programming. Section 3, elaborates the data and empirical models. Section 4 presents the empirical results and discussion and section 5, includes summary and conclusion.

Analytical frame work

Stochastic frontier analysis:

Stochastic frontier analysis was developed by Hayami (1969), Hayami and Ruttan (1970) to introduce the meta-production function idea as a function which envelops the neoclassical production functions. Thus, it is a common underlying production function that is used to represent the input-output relationship of a given industry (Lau and Yotopoulos, (1989)). The basic Meta production concept discusses the hypothesis that all the groups in an industry have potential access to the same technology. However, each producer may choose to operate on a different part of it depending on circumstances such as the natural endowments, relative prices of inputs, and the economic environment (Lau and Yotopoulos, 1989). Battese and Rao (2002) extended the Meta production approach which is reviewed here. Suppose a number of groups like different varieties of datepalms are defined. If for the j-th group there is data for Nj firms then the stochastic frontier model is written as (Battese *et al.* (2004); O'Donell *et al*. (2008):

$$y_{it}^{j} = f\,(x_{1it}, x_{2it}, \ldots, x_{lit}; \beta^{j})\, e^{v_{it}^{j} - u_{it}^{j}} \qquad (1)$$

Where y^{i}_{jt} implies the output of the i-th firm in the j-th group for the t-th period; x^{i}_{Nit} denotes the N-th input of the i-th firm in the j-th group for time period t; β^j is the vector of unknown parameters to be estimated, v^{i}_{jt} represents statistical noise (random variables) and is assumed to be distributed as N (0, σ^2_{vj}) that is independent on u^{i}_{jt} which is distributed as N ($z^{j}_{it}\,\theta + \omega^{j}_{it}, \sigma^2_{uj}$) and indicates inefficiency where the effects of different factors on technical efficiency (U_{iyj}) can be showed like this:

$$u_{it}^{j} = \delta_{it}^{j}\theta + \omega_{it}^{j} \qquad \text{s.t.} \qquad \omega_{it}^{j} \geq -\delta_{it}^{j}\theta \qquad (2)$$

Where ω^{j}_{it} is a stochastic variable with normal distribution of zero mean and σ [2] variance. Having Assumed that the exponent of the frontier production function is linear in the parameter vector, β^j, then the Eq. 3 is equivalent to:

$$e^{x'_{it}\beta^{j} + v_{it}^{j} - u_{it}^{j}} \qquad (3)$$

Where x_{it} is the transformed vector of inputs for the *i*-th firm in the *j-th* group for the time period t. Given data on inputs and output for group j, Maximum likelihood (ML) estimates of β^j vector for this frontier are attained. Using the above notations, we can calculate TE for the *i-th* firm in the *t-th* period with respect to group *j* frontier as:

$$TE_{it}^{j} = \frac{y_{it}}{e^{x'_{it}\beta^{j} + v_{it}^{j}}} = \exp(-u_{it}^{j}) = \exp(-\delta_{it}^{j}\theta - \omega_{it}^{j}) \qquad (4)$$

Frontier software is programmed to estimate the predictor of the TE proposed by Battese and Coelli (1988). After estimating the group frontier parameters separately, it is time to examine whether the different groups have an identical frontier or not. Likelihood ratio test can verify this issue, where L (H_0) is the value of log likelihood function associated with pooled data of all groups and L (H_1) will be the sum of the values of log likelihood functions exploited from the individual group frontiers. The degrees of freedom (df) for the test of significance of LR would be the difference between the number of parameters being estimated under the alternative hypothesis (eg., three times the total number of parameters being estimated for each model, if there are three groups, and number of parameters being estimated under the null hypothesis (the number of parameters in any model)). For example the df will be thus twice the number of the parameters in each model (for the pooled data, say) if we have three groups[1]. If the null hypothesis was rejected, it means that the groups have different frontiers and the Meta-frontier should be estimated; otherwise, the pooled frontier is enough and it makes sense not to estimate Meta-frontier parameters. (Battese *et al.*,

[1] The LR statistic is calculated by: λ= -2 [L (H_0) – L (H_1)]. L (H_0), is the log likelihood function of null hypothesis and L (H_1) is the log likelihood function under alternative hypothesis. λ, has a chi-square distribution.

2004). Therefore, if the null hypothesis was rejected, then the Meta-frontier which is a deterministic parametric frontier and will have a larger predicted value from all group frontiers and also envelops all those grouped frontiers smoothly (Battese *et al.,* 2004). Meta frontier is defined as below:

$$y^*_{it} = f(x_{1it}, x_{2it}, ..., x_{lit}; \beta) \equiv e^{x'_{it}\beta} \quad (5)$$

Where y^*_{it} is the Meta frontier output and β is an unknown column vector of Meta frontier parameters satisfying the inequality. 5: (O'Donnell *et al*. (2008)):

$$x'_{it}\beta^f \geq x'_{it}\beta^j \quad \text{For all} \quad j = 1, 2, ..., J \quad (6)$$

A Meta frontier has to envelop all the group frontiers, but the above constraints may do not do this. For obtaining the Meta frontier parameters which envelops all the group frontiers, this optimization is to be solved:

$$\min_{\beta^f} \sum_{i=1}^{m}\sum_{t=1}^{T}[\ln f(x_{1it}, x_{2it}, ..., x_{Lit}; \beta^f) - \ln f(x_{1it}, x_{2it}, ..., x_{Lit}; \hat{\beta}^j)]$$

$$\text{s.t. } \ln f(x_{1it}, x_{2it}, ..., x_{Lit}; \beta^f) \geq \ln f(x_{1it}, x_{2it}, ..., x_{Lit}; \hat{\beta}^j) \quad (7)$$

Where $\hat{\beta}^j$ is the column vector of coefficients associated with the group $-j$ stochastic frontier model. Moreover, if the Ln $f(x_{1it}, x_{2it}, ..., x_{Lit}; \beta^f)$ is log linear in parameters then, an equivalent form of the linear problem can be shown as:

$$\min_{\beta^f} \bar{x}'_{it}\beta^f$$

$$\text{s.t.} \quad x'_{it}\beta^f \geq x'_{it}\beta^j \qquad \text{For all } i \text{ and } t, \quad (8)$$

Where $\bar{x}$ is the arithmetic average of the x_{it} -vectors for all firms in all periods (O'-Donnell *et al.* (2008)). After solving the LP problem, in order to estimate the Meta technology ratios, we use equation (9) that includes three parts. The first term is the technical efficiency which estimated by eq. (3). The second term is the Meta technology ratio (technology gap) for the *i-th* firm in the *t-th* period (in the *j-th* group):

$$y_{it} = e^{-u^j_{it}} \times \frac{e^{x'_{it}\beta^j}}{e^{x'_{it}\beta^f}} \times e^{x'_{it}\beta^f + v^j_{it}} \quad (9)$$

Relationship between Meta technology ratio and Technical efficiency of different groups is verified as:

$$\hat{TE}^f_{it} = \hat{TE}^j_{it} \times M\hat{T}R^j_{it} \quad (10)$$

Where, $\hat{TE}^j_{it}$ is the technical efficiency of *i-th* firm relative to a specific group in the *t-th* period, and $\hat{TE}^f_{it}$ is the technical efficiency of the firm in period with respect to Meta frontier. $M\hat{T}R^j_{it}$ is the Meta technology ratio which according to O'Donnell *et al.* (2008) indicates that a higher value in this measure, showes a lower technology gap between a specific group frontier and Meta frontier. Meta technology ratio for the *i-th* firm in *t-th* period of the group *j-th* is measured simply by substituting the β^j and β^f in Eq. 11. (O'Donnell *et al.* (2008)).

$$M\hat{T}R^j_{it} = \frac{e^{x'_{it}\beta^j}}{e^{x'_{it}\beta^f}} \quad (11)$$

Data and Empirical models

The five largest producers of date in the world, are Egypt, Iran, Saudi Arabia, Iraq and United Arab Emirates, but Egypt, China, Bahrain, Gaza strip and Qatar have the largest yield by hectare respectively, (FAO, 1992-2010). Date is kind of fruit and food that is eaten around Sistan and Baluchestan by people and also animals. Datepalms have been cultivated because they have provided almost all rural people's necessities. Now this province is the second largest producer of date in Iran because of it's weather condition; 76 kinds of dates are produced and sold from 30 regions of the province, 46000 hectares of Sistan and Baluchestan agricultural lands are under datepalms with 200000 tones dates produced in 2012 (Ministry of Jihad-e- Agriculture, 2012). As shown in the figure 1, Production of date reduced in 2006 and 2008 0.7 and 4 percent relative to the past year, respectively, in Iran, this reduction took place because of

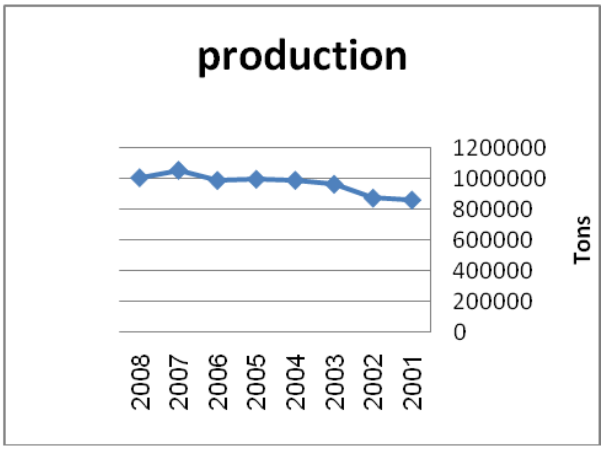

Figure 1: Historical trends in Iran dates production
Sources: Ministry of Jihad-e-Agriculture, 2012

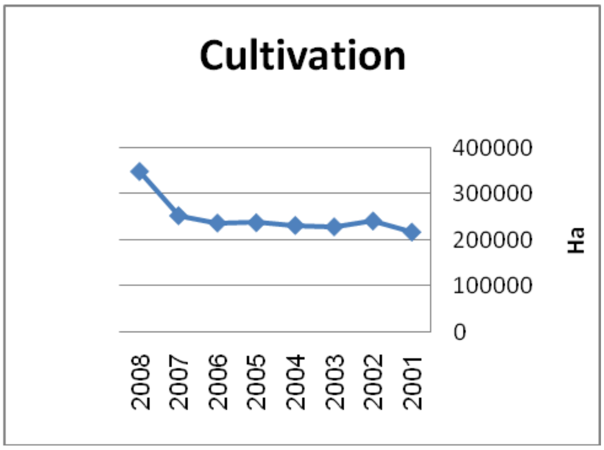

Figure 2: Historical trends in Iran palms cultivation

sequent droughts, salinity of irrigation water, storms in eastern and southern regions and palming phenomenon.

In this research, t he sample included 341 palm farmers which involved 126 Mazafati farmers, 113 Zard farmers and 102 Zard farmers. With using stratified random sampling approach, finally 300 respondents (100 Mazafati farmers, 100 Zard farmers and 100 Rabi farmers) were specified. Data was collected by questionnaires in the region of Saravan, Sistan and Baluchestan, over 3 agricultural years: 2009/2010, 2010/2011 and 2011/2012.The sample statistics for the input and output variables are reported in Table 1 briefly. Seven inputs were considered in this research, i.e., labor use (man-days), sown area (hectare), fertilizer (kg), tree age (years), density (trees per hectare), water (m^3), toxin (liter), and one output that is the physical product of dates in each period of harvesting. Hayami and Ruttan. (1970) measured fertilizer by thousands of tonnes of nitrogen, phosphate and potassium. In our sample, farmers use the animall dungs as fertilizer not chemical fertilizer, so we only measured the fertilizer by Kilogramms of animal dungs used in farms. Also there are two dummy variables; D_1 and D_2 for fertilizer and toxin, because fertilizer and toxin variables had zero values for some of farmers. For considering the zero observations of toxin and fertilizer, following Battese (1997), for each dummy variable, we used this modification:

$D_i = 1$, if $x_i = 1$ and $D_i = 0$, if $x_i > 0$; and $x^*_i = \max(x_i, D_i)$ and we use x^*_i instead of x_i in our production function. This implies that when the x_i variable has a positive value, then $x^*_i = x_i$; but if x_i has value zero then $x^*_i = 1$ (Battese,1997). Our production function involving seven inputs and one output is defined by:

$$y_{it} = \beta_0^j + \sum_{l=1}^{3} \beta_l^j x_{it} + 0.5\sum_{l=1}^{3}\sum_{k=1}^{3} \beta_{lk}^j x_{lit} x_{kit} + \sum_{d=1}^{2} \lambda_d^j D_d + \alpha_t^j T_{it} + v_{it}^j - u_{it}^j \quad (12)$$

Where subscript j represents the j-th group and T_{it} denotes the time trend which captures the technological change effects during time for each i-th firm in period t-th. The Eq. 12 expresses the translog functional form of stochastic production function, but it should be noted that the approperiate functional form has to be specified by LR test based on the values of log likelihood function. After opting out the best functional form (Cob-Douglas or Translog) for SFA model, three hypothesis tests were examined regardin U_{it} and V_{it} distributions (Coelli, 1995; Battese, 1993). At first, the existence of inefficiency effects was examined by this null hypothesis: H_0: $\gamma = \delta_i = 0$. Rejecting this hypothesis, confirms the existence of inefficiency effects. An additional test is done regarding the H_0: $\gamma = 0$, if this Hypothesis is accepted, this would indicate that the U_{it} term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least squares (Coelli, 1996) otherwise the maximum likelihood estimates are prefered. Moreover, rejecting the hypothsis: H_0: $\delta_i = 0$ insinuates that the social variables like education or having second job, are influencing technical efficiencies. By omitting the second-order interaction terms from translog model, the Cob-Douglas model can be written as:

$$y_{it} = \beta_0^j + \beta_{x_1}^j x_1 + \beta_{x_2}^j x_2 + \beta_{x_3}^j x_3 + \beta_{x_4}^j x_4 + \beta_{x_5}^j x_5 + \beta_{x_6}^j x_6 + \beta_{x_7}^j x_7 + \lambda_1^j D_1 + \lambda_2^j D_2 + \alpha_t^j T + v_{it}^j - u_{it}^j \quad (13)$$

Dependent and explanatory variables' quantities were stated in natural logarithms.

RESULTS

Table1 represents that the mean production of Mazafati and Rabi is 900 kg higher than Zard, but Mazafati has the highest standard deviation. Results also denote that the value of labor used in Mazafati is the highest, because Mazafati variety needs more tendency either in harvesting period or before. Furthermore, the average water used in Mazafati is 73.96 M3 higher than Zard variety and 74.32 M3 compared to Rabi variety.In addition, sown area for Mazafati variety is comparatively higher than sown area usage for Zard and Rabi variety as, 0.11 and 0.13 hectare. There is no significant difference between varieties in density. Fertilizer is more utilized in Zard variety than Mazafati and Rabi, as 13.79 and 21.84 kg, respectively. Farmers applied more toxins for Rabi variety than other varieties. Trees in Rabi variety are notably older than other two varieties. As we see in table 1, most of inputs are used in Mazafati are higher than other varieties, and this vindicates the higher production of this variety. Mazafati variety has a higher price in markets, so this induces farmers to use more inputs for getting more output from Mazafati variety. It can be seen in table 1 that, on average, farmers have 14 years experience in agriculture as a profession and almost 43 percent of them have a second job. This is because of inadequate income they have. Unfortunately, the average year of education is almost 8 years. (Table 1). This might be an important reason for inefficiency of most farmers. More than half of farmers in all three groups are member of agricultural cooperative according to table1 and 35 percent of them have participated in extension classes. This section proceeds by at first, fitting stochastic production frontier for pooled data including all dates' varieties and individual dates, separately. Then, the specification tests are discussed and finally we analyze technical efficiencies with respect to group frontiers and with respect to Meta-frontier. It is necessary

Table 1: Input and output variables summary

Variable	Symbol	Unit	All dates	Mazafati	Zard	Rabi
Production	y	10^3 kg	1.96(1.8)	1.99(1.9)	1.9(1.7)	1.99(1.8)
Sown area	x_1	Hectare	1.73(1.39)	1.81(1.43)	1.70(1.39)	1.68(1.39)
Water	x_2	M^3	123.74(77.4)	173.17(91.55)	99.21(84.55)	98.85(84.18)
Labor	x_3	Man-days	1.52(1.11)	1.57(1.05)	1.53(1.2)	1.46(1.07)
Toxin	x_4	Liter	15.43(24.52)	15.64(32.10)	14.40(14.17)	16.25(24)
Fertilizer	x_5	Kg	138.74(299)	136.81(302.5)	150.66(392)	128.76(155.77)
Tree age	x_6	Year	24.34(13.3)	23.4(13.23)	25.04(13.5)	60.09(24.06)
Density	x_7	Tree per ha	60.83(24.5)	62.24(25.45)	60.17(24.2)	60.09(24.06)
Experience	δ_1	Year	14.69	14.62	14.73	14.73
Education	δ_2	Year	8.41	8.14	8.35	8.74
Having 2nd job	δ_3	Percentage	43	40	38	50
Co-member	δ_4	Percentage	65	61	67	68
PIEXC	δ_5	Percentage	35	37	38	31

Notes: Number of observations, is 100 for Mazafati variety, 100 for Zard variety and 100 for Rabi variety; Values in brackets are standard errors of variables. Co-member is the brevity of being the the agricultural cooperative member and PIEXC implies participating in Extension classes. Agricultural Cooperatives and Extension programms are planned by Ministry of Jihad-e-agriculture to improve farmers knowledge about results of new agricultural researches in country. Density of datepalms was measured by tree per hectare which is shown by "Tree per ha".

Table 2: LR test results for choosing better functional form

Groups	LLF of CD	LLF of TR	LR	χ2 statistic(df)	Decision
Pooled	-873.828	-812.031	123.594	49.578**(29)	Translog
Mazafati	-304.862	-282.11	45.504	49.578**(29)	Cobb-Douglas
Zard	-278.059	-235.025	86.068	49.578**(29)	Translog
Rabi	-275.357	-224.772	101.17	49.578**(29)	Translog

**P < 0.01

to specify the appropriate functional forms for SPF model, before measuring technical efficiencies. The translog (TR) and Cobb-Douglas (CD) forms were estimated for pooled data and each group, separately. By LR test results which are reported in table 2, just for Mazafati variety, Cobb-Douglas functional form is opted out, but it is obvious that translog form is prefered. So we applied translog form for all varities.

We also have to test the hypothesis whether or not the pooled frontier model is prefered to separate group frontiers (all varieties adapt the same stochastic production frontier or no) with the separate estimation of the three varieties as the alternative model. The likelihood ratio statistic is distributed as chi-square with a degree of freedom as 94[2]. The alternative hypothesis is accepted by 1% of significance. So the data for different varieties cannot be pooled and we have to estimate meta-frontier to measure the technical efficiencies of three groups with respect to it. The estimates of stochastic frontier coefficients which can be interpreted as production elasticities, because of using corrected to geometric mean data are reported in table 3. As shown in table 3, most of first-order coefficients for Mazafati variety are highly significant except Toxin, fertilizer and density. But, fertilizer has a more considerable effect on production of Mazafati variety than other varieties separately. Interestingly, Tree age had a positive value for Mazafati, demonstrating that older Mazafati datepalms will increase the production. Mazafati production is remarkably affected by toxin as 0.4081. This is justified by high sensitivity of Mazafati variety to pests. The coefficient of t (time) for Mazafati, shows that this variety was faced a higher negative technical change during time than other varieties. Tree age has the largest positive coefficient among other inputs, which portends that a percent change in tree age will mutate the production of Mazafati variety more strongly than other inputs. Intercept which is an index for the level of technology, is highly significant as 1.02** for Mazafati variety. And Mazafati variety has a higher technology level compared to other datepalm's varieties has a higher technology level compared to other datepalms. The results show that the coefficients for water, fertilizer, toxin, density and the interactions of these inputs are negative in the instance of Mazafati. This is because, Mazafati farmers use overplus inputs.

Zardan variety is somehow different from Mazafati. It is kind of dry date whose coefficients of fertilizer and density are negative and almost all its first-order coefficients are highly significant with except to toxin. The function coefficient of Zardan variety is less than one. In fact, it implies that if farmers increase the size of farm, the production of Zardan variety will decrease (decreasing returns to scale). As we aforementioned for Mazafati, t (time) coefficient for Zardan variety is negative too and negative technical change is incurred with Zardan variety. The level of technology for Zardan variety is dramatically lower than Mazafati and Rabi because the price of Zardan date is not as high as Mazafati and Rabi, so, farmers do not use high technologies for Zardan variety. Rabi variety is sort of moist date which has a less sweet taste in comparison to Mazafati. According to table 2, sown area and density coefficients for Rabi are negative. The intercept (technology level) of Rabi is higher than Zardan variety's intercept but lower than Mazafati's intercept. Density has

[2] *The degree of freedom is calculated by twice the number of the parameters in each group model. In this case it is as 2 47=94.*

Table 3: Estimates of stochastic frontier parameters

Variable	Pooled	Mazafati	Zard	Rabi	MF
Intercept	0.5570	1.02**	0.405**	0.7302***	1.0054
X_1	0.3024***	0.301***	0.3368***	-0.3702*	0.3387
X_2	-0.0083**	-0.2339**	0.2198*	0.2471*	0
X_3	- 0.0841**	-0.0798**	-0.2316**	0.1811	0
X_4	-0.0622***	-0.2592*	-0.0579**	0.0805**	0
X_5	0.04671	0.4081	-0.0181	-0.0013	0.3544
X_6	-0.4833	0.5408**	-0.4334***	- 0.6882***	0.1469
X_7	0.9306***	-0.9860	0.9076**	1.1408***	0
X_1^2	0.2578	0.3501	0.1871*	0.4778***	0.1141
X_2^2	0.01116***	0.00617*	-0.0516***	-0.0894	0
X_3^2	0.6458**	0.6692*	0.6185	0.4533*	0
X_4^2	0.06995**	0.1043	0.08794	0.1012**	0.0036
X_5^2	-0.00427	-0.0138**	0.0118	-0.0315*	0
X_6^2	1.1162	1.5630	1.5908*	1.4343***	1.2378
X_7^2	0.3102***	-0.1608	0.2702	1.3095***	1.0647
X_1X_2	-0.0199**	-0.1827	-0.4853	0.0685	0
X_1X_3	-0.9163*	-0.4514*	0.0175**	-0.6015*	0
X_1X_4	0.1003	0.1581	0.3725	-0.0172	0
X_1X_5	-0.0499	-0.0022	0.0088	0.2346***	0
X_1X_6	-0.2687	-0.4826	-1.1363*	0.4163	0
X_1X_7	-0.9487	-1.6052**	-0.7389*	-0.2421	0
X_2X_3	-0.1072**	-0.0721	0.1352	0.5788**	0
X_2X_4	-0.9590	-0.1062	-0.1303	-0.3641***	0
X_2X_5	0.0066	0.1017	-0.07964*	0.0511	0
X_2X_6	0.3847	0.1801	0.5013	0.6993**	0
X_2X_7	0.4313	1.1037*	0.8028	-1.5122*	0
X_3X_4	0.0158	0.1954	-0.1772	-0.2553*	0.2486
X_3X_5	-0.0413	-0.0027	0.1191*	0.1694**	0
X_3X_6	-0.2908	-0.3886*	-0.3206	-0.4388	0.1017
X_3X_7	-0.2381	-0.0249	-0.2076	-0.6153	0
X_4X_5	-0.02892*	-0.0257	-0.3873	-0.0522**	0
X_4X_6	0.1484*	0.3271	0.0200	0.0707	0
X_4X_7	-0.4221	-0.3797*	-0.5298	-0.8793***	0
X_5X_6	-0.009186	-0.1047	0.0660	0.0085	0.0279
X_5X_7	0.1440**	0.2322	0.1363	0.5374***	0
X_6X_7	-0.2124*	-1.2611	-1.652	-1.3711***	0
D_1	-2.1248	-0.1376	0.0635**	0.0201	0
D_2	0.0241	-0.1110	0.0063	-0.05103	0
T	-0.0116***	-0.2626*	-0.117*	-0.1724***	0
ω	0.0420**	0.0113***	-0.1271***	0.2651**	0.06921**
δ_1	-0.0260**	-0.0026**	0.0045***	-0.0557**	0.00530**
δ_2	-0.1711**	-0.121*	-0.0280*	-0.0123	0.01160*
δ_3	-0.0302*	0.1330**	-0.1205	0.0589**	-0.00580
δ_4	0.1666	0.0499	0.2340	-0.0158*	-0.01453*
δ_5	0.0028***	0.0015**	0.0101**	-0.0082	-0.00093*
σ^2	0.2883***	0.3114***	0.2422**	0.1788***	-[a]
γ	0.9406***	0.9587***	0.9022***	0.9999***	-[a]
FC	0.0642	-0.309	0.7232	0.5898	0.84
LLf	-812.031	-282.110	-235.025	-224.772	-[a]

Note: LLF represents log likelihood function, ***P<0.001, **P<0.05, *P<0.1. FC denotes on function coefficient. –a, implies that those parameters are not measured, because the meta frontier parameters were estimated by mathematical programming, not by stochastic frontier function.

the largest coefficient between inputs in the case of Rabi. It shows that the Rabi farms are so diffused and it is still possible to plant more datepalms per hectare. Lots of interaction coefficients are significant in Rabi farms compared to other varieties. Rabi variety has dropped off, technically with a lower t coefficient than other varieties. Function coefficient of Mazafati is -

Table 4: Hypothesis test

Groups	Null hypothesis	LR	$\chi 2$ (df)0.01	Decision
Pooled	H_0: $\gamma = \delta_i = 0$	461.726	17.755(7)*	reject
	H_0: $\gamma = 0$	346.439	18.475(7)	reject
	H_0: $\delta_i = 0$	461.720	16.811(6)	reject
Mazafati	H_0: $\gamma = \delta_i = 0$	180.188	17.755(7)*	reject
	H_0: $\gamma = 0$	146.665	18.475(7)	reject
	H_0: $\delta_i = 0$	180.197	16.811(6)	reject
Zard	H_0: $\gamma = \delta_i = 0$	155.152	17.755(7)*	reject
	H_0: $\gamma = 0$	122.142	18.475(7)	reject
	H_0: $\delta_i = 0$	155.153	16.811(6)	reject
Rabi	H_0: $\gamma = \delta_i = 0$	194.857	17.755(7)*	reject
	H_0: $\gamma = 0$	139.518	18.475(7)	reject
	H_0: $\delta_i = 0$	194.858	16.811(6)	reject

Note: Asterisk *, indicates that the values have a mixed chi-square distribution extracted from Table 1 of Kodde, D.A., and F.C. Palm (1986).

0.309, the lowest among three species of dates, again indicating decreasing returns to scale. Table 2 also portrays the results of regression model for pooled data and meta-frontier parameter estimates attained by linear programming of Eq. 8. First-order coefficients are significant with except to toxin and tree age and production is affected by density more than other inputs for pooled data. The level of technology ascents over Zard but it is lower than Mazafati and Rabi. Beside, the technical change is falling over three agricultural years by -0.0116 as coefficient of t, for pooled data. Finally, Table 2 includes the Meta-frontier parameters which all of them are positive and a function coefficient of 0.84. Toxin has the largest coefficient and the level of technology is 0.4484 higher than the level of technology of pooled data.

Moreover, the technical change coefficient is zero denoting that the technology is constant in meta-frontier. After choosing the best functional form, for estimating the production function, some hypothesis tests have to be done. The results of likelihood ratio tests are portrayed in Table 3. Rejecting the hypothesis H_0: $\gamma = \delta_i = 0$ confirms the existence of inefficiency effects. This hypothesis is examined by comparing the LR test of the one-sided error reported in Frontier Software output. Amazingly, LR one-sided error values for all three varieties are highly significant and reject the lack of inefficiency effects. The highest value of this index belongs to Rabi as 194.857 and the lowest is for Mazafati as 146.665. Accepting the null hypothesis H_0: $\gamma = 0$ vouches that the conventional production function is enough, so Ordinary least square is prefered to

Table 5: Technical efficiencies and Meta technology ratios

	Groups	Average	SD	Minimum	Maximum
Meta technology ratio	Mazafati	0.407	0.1725	0.02796	1
	Zard	0.507	0.1703	0.00404	0.8592
	Rabi	0.432	0.1927	0.00339	1
Technical efficiency with respect to group frontiers	Mazafati	0.518	0.270	0.460	0.999
	Zard	0.520	0.254	0.010	0.941
	Rabi	0.592	0.229	0.046	0.932
	All dates	0.558	0.239	0.012	0.939
Technical efficiency with respect to meta frontier	Mazafati	0.210	0.09	0.125	0.360
	Zard	0.263	0.011	0.011	0.480
	Rabi	0.255	0.011	0.031	0.395
	All dates	0.200	0.011	0.010	0.250

Source: Research findings

Table 6: Spearman correlation coefficients for TE measures of translog stochastic frontier and meta-frontiers

Variety / Model	TL-frontier	MF- frontier
Mazafati		
TL-frontier	1	
MF-frontier	0.28	1
	Translog	**Meta-frontier**
Zard		
TL-frontier	1	
MF-frontier	0.11	1
	Translog	**Meta-frontier**
Rabi		
TL-frontier	1	
MF-frontier	0.05	1

TL-frontier: TE measured with respect to translog production frontier, MF-frontier: TE measured with respect to meta-frontier.

Maximum likelihood estimation and closer γ to 1 means that there are more significant inefficiency effects (Battese and Coelli, 1992). According to Table 3 the parameter γ revolves from 0.009 for Rabi variety to 0.006 for Mazafati variety. Statistical tests exhibit that all varieties have stochastic frontiers at the 1% level of significance (Table 3). Rejecting the hypothesis H_0: $\delta_i = 0$ explains that the socio-economic characteristics like education, having second job or participating in extension classes which are considered in empirical model are influencing the efficiency scores of farmers. This null hypothesis was strongly rejected too for all varieties.

Meta technology ratios and technical efficiencies

Meta technology ratios (MTR) and technical efficiencies (TE) with respect to group frontiers and Meta-frontier are summarized in table 5. MTR is the ratio of a specific farmer's output from a particular group to the meta-frontier output with the same inputs. Therefore, the higher MTR, the less technology gap between individual frontier and Meta frontier and if the MTR is unity, then the individual frontier is palced on Meta frontier, so the MTR cannot be greater than one. The mean estimated MTR for the Mazafati instance is 43.2% varying from a minimum of 2.7 % to a maximum of 100.0%. The average estimated MTR for Zard variety is 40.7% and goes from a low of 0.4% to 85.9%; and the average MTR for Rabi variety is 50.7%, ranges from 0.3% to 100.0%. The highest average MTR belongs to Rabi variety which means that Rabi farmers are closer to the expected output of Meta frontier. The lowest MTR is related to Zard farmers which have the lowest gross incomes compared with other farmers because of low prices of Zardan date. This analysis emphasizes that Rabi farmers use higher technologies than Zardan and Mazafati farmers. The average technical efficiencies with respect to Meta-frontier and group frontiers are 7.5% and 51.8% for Mazafati, 7.1% and 59.2% for Zard, and 5.9% and 52% for Rabi (Table 5). There is not a significant difference between TE measures of Zardan (26.3%) and Rabi (25.5%) with respect to Meta-frontier, although they are remarkably higher than for Rabi (5.9%). A comparison of the average TE among the three varieties, estimated from the pooled stochastic frontier, portends that there is no main difference (Mazafati = 56.1%, Zard = 54.8% and Rabi = 56.5%). This issue again corroborates usage of Meta-frontier for these three varieties, i.e., a reasonable frontier which envelops all the three different frontiers to compare their performance. Victor, *et al*. (2010) found similar TE measures in their research on three South American regions.

It is useful to compare the TE measures obtained from translog model with those of meta-frontier model for each group. So the Spearman correlation coefficients of TE measures of translog stochastic production and meta-frontiers are reported in table 6. As shown in table6, all pair wise comparisons show positive correlations, ranging from 0.05 between the TL-frontier and the MF-frontier for Rabi variety and 0.28 for Mazafati. These results are also similar to those of Moreira *et al.* (2010), and imply that the TEs measured by the two models are fairly consistent.

TL-frontier: TE measured with respect to translog production frontier, MF-frontier: TE measured with respect to meta-frontier.

CONCLUSION

Agriculture is the mainstay economic sector of rural areas in Iran that it has great potential for development. Datepalms are cultivated in dozens southern provinces of Iran, such as: Khuzestan, Kerman, Hormozgan, Fars and Sistan and Baluchestan. This study provides some interesting results on the datefarmers technical efficiencies in Sistan and Baluchestan province, one of the leading producers of different varieties of dates in Iran. The objective of this paper was to compare technical efficiency (TE) for different varieties of dates in Sistan and Baluchestan province using the Meta-frontier method extended by Battese and Rao (2002) and advanced by Battese *et al*. (2004) and O'Donnell *et al*. (2008). The data are completely balanced panels including 300 farms and 3 periods for the various varieties of date including 100 observations for Mazafati, 100 for Zard and 100 for Rabi variety. Stochastic Production Frontier (SPF) models were estimated separately for each variety and pooled for all three varieties. Then, a meta-frontier model was estimated using linear programming with the pooled data. Translog functional form was prefered to Cobb-Douglas by specification test and the maximum likelihood estimation was used instead of ordinary least square. Besides, the socio-economic characteristics were strongly influencing the efficiency scores of date farmers and the inefficiency effects were revealed to exist significantly. The null hypothesis that the date farms from the three varieties operate on the same pooled production frontier was strongly rejected. So we estimated a meta-frontier which envelops all the three individual variety frontiers. The difference or gap between individual variety frontiers and meta-frontier is called Meta Technology Ratio (MTR). The average MTRs for Mazafati, Zard and Rabi are 0.407, 0.507 and 0.432, respectively. Thus, the Mazafati frontier is the most distant to the meta-frontier while the Zard frontier is the closest, and the Rabi is in an intermediate position. The average TEs with respect to group frontiers are 0.518, 0.520 and 0.592, respectively, for Mazafati, Zardan and Rabi. But these TEs are not comparable because they are not from the same frontier. So the TEs which obtained with respect to the Meta-frontier can be compared. The TEs with respect to Meta-frontier are 0.00134, 0.00144 and 0.00142, respectively for Mazafati, Zardan and Rabi. The average TEs for Zardan and Rabi variety are not significantly different from each other and both are higher than the value for Mazafati. All frontier models including Mazafati, Zard, Rabi and Meta-frontier had decreasing returns to scale (RTS), with average Function Coefficient (FC) values as, 1.309, 1.723, 0.589 and 0.840 respectively. These RTS indices imply that on average date farms in Sistan and Baluchestan are not operating at a sub-optimal scale. A noteworthy result of the analysis reported in this paper is that, Mazafati farmers had the lowest efficiency score among others while Mazafati variety is the most popular and expensive variety in the region. It is, therefore, felt, that if the Mazafati farmers apply more efficient technologies, they will definitely gain more profit than now.

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