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When Is Metafrontier Analysis Appropriate? An Example of Varietal Differences in Pistachio Production in Iran

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ABSTRACT

Estimates of technical inefficiency in agricultural production are suspect so long as variations exist in production technology among the sampled farmers. Traditional methods of dealing with these technological differences risk attributing "technology gaps" to technical inefficiency between farms, pointing to the need to undertake a metafrontier analysis that allows technology gaps to be distinguished from technical inefficiency. Using farm-level data on the production of three different varieties of pistachio trees in Iran, we outline two criteria to justify its use: an inability in farmers to switch between production technologies except in the long term, and satisfaction of statistical tests on metafrontier coefficients. The application of metafrontier analysis enabled technical efficiency scores to be corrected for differences in production capacity imposed by tree variety. Results reveal that there is very little difference in technical efficiency between farms growing the different tree varieties. But they show that ignoring the production constraints imposed by variety choice could overstate the scope for farmers to improve their technical performance by adopting better farming practices. The results also indicate that it is misleading to compare the performance of different tree varieties on the basis of yield per hectare alone.

Keywords: Iranian agriculture, Metafrontier, Pistachio, Stochastic production function, Technical efficiency.

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INTRODUCTION

Estimates of technical inefficiency in agricultural production are now commonplace; yet they are suspect so long as variations exist in production technology among sampled farmers. Such variations are the norm rather than the exception, from subtle changes in ways of doing things, such as slight differences in input attributes, to major differences such as use of significantly different production technologies and differences in environmental conditions and plant varieties. The usual methods of dealing with these technology differences risk attributing "technology gaps" between farms to technical inefficiency. A recent methodological advance in estimating technical inefficiency that minimizes this risk by specifying a metafrontier for production (Battese and Rao, 2002; Battese *et al.*, 2004) allows technology gaps to be distinguished from technical inefficiency. A key question is: when should a metafrontier analysis be used for this purpose?

The specification of a metafrontier depends on its capacity to add knowledge and the validity of its use. Its capacity to add knowledge depends on the nature of the research problem; in particular, whether the researcher wants to study and compare the productivity and efficiency of farms that employ different technologies. In order to

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make this decision, it is worth reviewing the meaning of technology and technique in the context of efficiency analysis. The concept of technology originally applied to so-called "industrial arts". Whitehall (1953) defined a technology as "that branch of knowledge which deals with the various industrial arts; the science or systematic knowledge of the industrial arts such as spinning, weaving, dyeing, metallurgy, brewing and the like". The concept has since been expanded to cover all forms of production that entail the use of inputs produced by industry, including commercial agriculture. Keywords here are "systematic knowledge": producers do not necessarily use all available techniques but they know of their existence. The concept of technique, on the other hand, refers to the "mechanical performance or practice of any art ..." (Whitehall, 1953) and requires the act of usage. In virtually all efficiency and productivity analyses, "systematic knowledge" has been implicit in an assumption of common production technology across all producers in the sample.

This means that, in the context of agricultural production, two criteria need to be satisfied. First, it is not necessary to resort to the use of a metafrontier if all farmers have access to the same set of production technologies, even if some choose not to use the most productive technique available. Second, if not all farmers have access to the same set of production technologies, forcing them to choose different ones, statistical tests can be used to gauge whether the use of a metafrontier adds to knowledge of the productivity and efficiency of the farmers in production.

The question of validity of use of a metafrontier is sometimes difficult to discern. Farmers may have access to a set of production technologies –that is, they know about and understand the available set of production techniques and their potential for turning inputs into outputs– but for one reason or other are unable to use them, or at least are unable to use them except in the long run. The less problematic situation is where the physical conditions prevent farmers from making full use of available production techniques, even though they know about them. That is, they cannot use certain techniques, even in the long run, because of environmental constraints. Such a situation prevails for wheat producers in different regions of Iran whose productivity and efficiency were studied by Mehrabi Boshrabadi *et al.* (2007a) using metafrontier analysis. Climate is the most obvious constraint in this circumstance.

The more problematic situation rests on practical considerations. It prevails when farmers do know about all available techniques and are not constrained by their physical environment in making full use of them, but they are not in a position to do so in their current situation. The most obvious example is where farmers have made a major investment that constrains their ability to substitute profitably between capital items in the short- to medium-term. Battese *et al.* (2004) implicitly recognized this situation confronting Indonesian textile manufacturers when applying a metafrontier because the choice of manufacturing plant prevented these manufacturers from taking advantage of more productive techniques associated with different plant configurations. It would not have been profitable –nor perhaps even feasible in some cases – for manufacturers to scrap their current plants and construct new ones allowing more productive techniques to be used. In agriculture, an analogous situation can arise with perennial crops where production cycles span many decades. Often it is not profitable (sometimes not even feasible) for farmers to replant their trees in the short- or medium-term even though more productive varieties have become available since the initial planting. In these circumstances, farmers face a different production environment in a way not dissimilar to the markedly different physical environments faced by farmers undertaking the same farm activity in different regions.

We report on an analysis of technical efficiencies and technology gaps in pistachio production in the province of Kerman in Iran. This is the first study of which we are aware in which an estimate is made of differences in production frontiers by crop variety using the metafrontier approach. The estimation of measures of technical efficiency enables policy makers and managers of extension programs to determine the scope for improving farm performance through better farming practices, subject to existing technological constraints. By studying the existing practices of farmers with low levels of technical efficiency and its causes, plans can be drawn up to improve these practices and thereby raise not only individual farm performance but performance of the whole agricultural sector.

A measure of technical efficiency indicates the extent to which a farm could produce additional output without changing the levels of inputs used if it were to operate on the production frontier, which is determined by the best-practice farms. For example, a technical efficiency index for a farm of 64 percent means that, for given levels of input use, it is operating at 64 percent of its potential output. That is, the farm could produce an additional 36 percent of output without changing the levels of inputs used if it were to improve its efficiency and operate on the production frontier. Our aim is to assess whether it is necessary to distinguish technical efficiency caused by the production practices of farmers from differences in production capacity imposed by the tree variety grown. The estimation of technology gaps provides an improved means of assessing performance between different plant varieties by comparing technical efficiencies or total factor productivities rather than the partial productivity measures of yield or output per labour unit that have been used by researchers to date.

In describing pistachio production in Iran, Talaie and Panahi (2001) reported that the water required for pistachio orchards is mostly provided by underground sources in Kerman. They observed that irrigation is especially important in the first three years of orchard establishment. All trees included in the data used in this study have passed beyond this stage. In general, pistachios are harvested manually from late August to late October, depending on the varieties and climate, and the fruits are dehulled, either sun-dried or dried using a drier, sorted and graded.

Evidence obtained from earlier studies of technical efficiency in pistachio production in Iran shows a wide range of technical efficiency scores that range from 40 percent to 81 percent (Najafi and Abdullahi, 1997; Torkamani, 1997; Karbsi *et al.,* 2004; Mehrabi Boshrabadi *et al.,* 2007b). These scores suggest that technical inefficiency exists among pistachio producers. Our concern is whether such variations in technical efficiency scores are due solely to technical limitations or whether differences in performance among the varieties grown by farmers contribute to some of this alleged inefficiency.

MATERIALS AND METHODS

Pistachio production in Iran provides a good basis for testing the two criteria to justify the use of metafrontier analysis. It meets the first criterion of environmental constraints on farming because it entails the use of different tree varieties that are not yet at the stage when uprooting existing trees to replant is a profitable option. The three pistachio tree varieties that are the focus of analysis differ significantly in their characteristics and production potential. In particular, the *Kalleh-Ghuchi* variety is sensitive to frost damage and water salinity. Yields of the *Fandoghi* variety fluctuate widely from year to year because of its strongly alternate-year-bearing nature. Finally, the *Akbari* variety is sensitive to heat stroke in summer and to water stress. Statistics reported by Mehrabi Boshrabadi *et*

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al. (2007b) suggest that yield, input use and area planted differ between varieties.

There are several approaches used for frontier estimation. Efficiency estimation in stochastic frontier models typically assumes that the underlying production technology is the same for all farms. Unobserved differences in technologies might be inappropriately labelled as inefficiency if variations in technology are not taken into account. A number of methods could be used to address this issue. They include the stochastic metafrontier framework (Battese and Rao, 2002; Battese *et al.,* 2004), latent class models (Greene, 2004), random parameter model (Greene, 2004) and switching regression model (Sriboonchitta and Wiboonpongse, 2004). O'Donnell and Griffiths (2006) used a state-contingent frontier where states of nature for the different environment are treated as a latent variable and estimated using finite mixture model. The use of the above models revealed that failure to account for environmental variables can lead to biased estimators of the parameters of the frontier and technical efficiency inefficiencies. Among these approaches, we choose the metafrontier framework because of its ability to estimate the technology-gap ratios, in addition to estimated parameters of frontiers and technical inefficiencies.

The stochastic metafrontier framework proposed by Battese and Rao (2002) and Battese *et al.* (2004) is followed in this analysis. It allows the estimation of technical inefficiencies to accommodate differences in technologies across pistachio farms and provides a measure of the technology gap between farms facing different production possibilities. The technology gap ratio (TGR) measures the ratio of the output for the frontier production function for the *k*-th group relative to the potential output that is defined by the metafrontier function, given the observed inputs (Battese and Rao, 2002; Battese *et al.,* 2004); it has values between zero and one. Values closer to one imply that the farms are producing nearer to the maximum potential output given the technology available for the industry as a whole. For example, a value of 0.92 implies that the farm produces, on average, 92 percent of the potential output. Battese *et al.* (2004) did not report standard errors for the metafrontier coefficients, but they are considered to provide important information and therefore are reported in this study.

Suppose we have *k* groups in the industry. We can estimate the stochastic group-*k* frontier using the standard stochastic frontier model defined as:

$$Y_{it(k)} \equiv f(X_{it(k)}, \beta_{(k)}) e^{V_{it(k)} - U_{it(k)}}$$

$$i = 1, 2, \ldots, N_k \qquad (1)$$

where $Y_{it(k)}$ denotes the output of the *i*-th farm in the *t*-th period for the *k*-th group; $X_{it(k)}$ denotes a vector of functions of the inputs used by the *i*-th farm in the *k*-th group; $\beta_{(k)}$ is the vector of unknown parameters to be estimated associated with the *k*-th group; $V_{it(k)}$ represents statistical noise assumed to be independently and identically distributed as $N(0, \sigma_{Vk}^2)$ random variables; and $U_{it(k)}$ are non-negative random variables assumed to account for technical inefficiency in production and assumed to be independently distributed as truncations at zero of the $N(\mu_{it(k)}, \sigma_{U(k)}^2)$ distribution.

The technical efficiency of the *i*-th farm with respect to the group-*k* frontier can be obtained using the result:

$$TE_{it}^{k} = \frac{Y_{it}}{e^{X_i \beta^k + V_{it}}} = e^{-U_{it(k)}} \qquad (2)$$

Equation (2) allows us to examine the performance of the *i*-th farm relative to the individual group frontier. In order to examine the performance of the *i*-th farm relative to the meta-frontier, the stochastic meta-frontier production function approach is used. The meta-frontier is a function that envelops the stochastic frontiers of the different groups such that it is defined by all observations in the different groups in a way that is consistent with the specifications of a stochastic frontier model (Battese and Rao, 2002).

Following Battese and Rao (2002) and Battese *et al.* (2004), a stochastic metafrontier production function model in the industry is defined as:

$$Y_{it} = f(X_{it}, \beta^{*}) \equiv e^{X_{it}\beta^{*}} \qquad (3)$$

where $i = 1, 2, \ldots, N_k$, $t = 1, 2, \ldots T$; Y_{it}^{*} is the meta-frontier output that dominates all group frontiers, and β^{*} denotes the vector of meta-frontier parameters satisfying the constraints:

$$X_{it}\beta^{*} \geq X_{it}\beta^{k} \text{ for all } k = 1,2,\ldots K \qquad (4)$$

The observed output defined by the stochastic frontier for the k-th group in Equation (1) can be alternatively expressed in terms of the meta-frontier function in Equation (3), such that

$$Y_{it} = e^{-U_{it(k)}} \times \frac{e^{X_{it}\beta^{(k)}}}{e^{X_{it}\beta^{*}}} \times e^{X_{it}\beta^{*} + V_{it(k)}}. \qquad (5)$$

The first term on the right-hand side of Equation (5) is the same as that in Equation (2), which denotes the technical efficiency of the i-th farm in the t-th period relative to the group-k frontier. The second term is what Battese and Rao (2002) term the technology gap ratio (TGR), which is expressed as

$$TGR_{it} = \frac{e^{X_{it}\beta_{(k)}}}{e^{X_{it}\beta^{*}}}. \qquad (6)$$

The TGR measures the ratio of the output for the frontier production function for the k-th group relative to the potential output that is defined by the meta-frontier function, given the observed inputs (Battese and Rao, 2002; Battese *et al.,* 2004). The TGR has values between zero and one.

The technical efficiency of the i-th farm, given the t-th observation, relative to the meta-frontier, is denoted by TE_{it}^{*} and is defined in a similar way to Equation (2). It is the ratio of the observed output relative to the last term on the right-hand side of Equation (5), which is the meta-frontier output, adjusted for the corresponding random error, such that

$$TE_{it}^{*} = \frac{Y_{it}}{e^{X_{it}\beta^{*} + V_{it(k)}}}. \qquad (7)$$

Accordingly, following Equations (2), (5) and (6), TE_{it}^{*} can be expressed as

$$TE_{it}^{*} = TE_{it}^{k} \times TGR_{it}.$$

We estimated the following model using a translog functional form. The choice of translog is based on the results of statistical tests performed in the estimation of a pooled frontier. The value of the likelihood-ratio (LR) test statistic was 36.14. The null hypothesis, that the Cobb-Douglas functional form is an adequate representation of the data was rejected at a 5 percent level of significance. A translog model has the advantages that it is flexible and allows us to examine interactions between inputs in the different stages of production. This model has been used in numerous empirical papers, including those in agricultural production. It is specified by:

$$\begin{aligned} LnY_{it(k)} &= \beta_{0(k)} + \sum_{j=1}^{6}\beta_{j(k)}LnX_{itj(k)} + \\ &\frac{1}{2}\sum_{j=1}^{6}\sum_{s=1}^{6}\beta_{js(k)}LnX_{itj(k)}LnX_{its(k)} + \sum_{p=1}^{3}\eta_{p}D_{itp(k)} + \\ &V_{it}^{k} - U_{it}^{k} \end{aligned} \qquad (8)$$

where j represents the j-th input (j= 1, 2, …6) of the i-th farm (1, 2, … , N_k) in the t-th time period (t= 1, 2) in the k-th group (k= 1, 2, 3); $\beta_{ij(k)} = \beta_{ji(k)}$ for all j and k; Y_i represents the physical output of dry pistachio (in kilograms); X_{it1} is the total area planted to pistachio (in hectares); $X_{it2(k)}$ represents total use of water (in m^3); $X_{it3(k)}$ represents the total use of labour, predominantly family labour (in man-days); $X_{it4(k)}$ represents total other costs (in local currency). $X_{it5(k)}$ represents tree age (in years); $X_{it6(k)}$ represents density (trees per hectare); $D_{it1(k)}$ is a dummy variable for the year 2004; and $D_{it2(k)}$ and $D_{it3(k)}$ are dummy variables for the North region and the Central and West regions, respectively, with the Northwestern region as the base. The year and regional dummy variables are important to include when estimating the group frontiers because varieties perform differently in alternate years and different regions. While it would have been desirable to include specific climate variables for each year of the study period, the complicated nature of the various climatic effects on pistachio trees and lack of specific climatic information by farm precluded this option. The presence of alternate bearing by pistachio trees warranted use of a two-year panel data set, which was the maximum period for which data are available. Outputs and inputs were mean-corrected to zero in the translog functional form, which implies that the first-order coefficient estimates of the model represent the corresponding elasticities.

The second criterion is tested in two ways. First, is important to examine if all the groups share the same technology. If all the farm-level data were generated from a single production frontier and the same underlying technology, there would be no good reason for estimating the efficiency levels of farms relative to a metafrontier production function. A likelihood-ratio (LR) test of the null hypothesis that the group frontier models are the same for all farms is conducted. Second, comparisons of technology gap ratios are conducted using ANOVA and Tukey-Kramer multiple comparisons tests.

The data set for the two years of the study period (2003 and 2004) that is used in the current analysis is the same as that used by Mehrabi Boshrabadi *et al.* (2007b). The analytical framework for estimating standard stochastic frontier production models also follows Mehrabi Boshrabadi *et al.* (2007b). The number of samples of *Kalleh-Ghuchi*, *Akbari* and *Fandoghi* varieties were 80, 100 and 71, respectively, in 2003 and 80, 100 and 34, respectively, in 2004. They were obtained from the same farms in each year except that the observations on the *Fandoghi* variety were taken from fewer farms in 2004. The main purpose of obtaining two years of data was to take into account the alternate-bearing nature of pistachio trees. Observations are based on plantations featuring only a single tree variety.

RESULTS AND DISCUSSION

Stochastic frontiers were estimated for the individual tree varieties using FRONTIER 4.1c (Coelli, 1996) while the metafrontier was estimated using SHAZAM following O'Donnell *et al.* (2005). A likelihood-ratio test using a mixed chi-squared distribution confirms that the technical inefficiency term is a significant addition to the individual variety and pooled models. The results are summarized in Table 1.

The variables used in the model have been scaled to have unit means so the first-order coefficients of the translog function can be interpreted as elasticities of output with respect to inputs evaluated at the input means (Coelli *et al.,* 2005). The estimates of the group frontiers indicate that the elasticity of output is highest with respect to area planted to each variety. The elasticity with respect to area is highest for *Kalleh-Ghuchi.* Except for *Kalleh-Ghuchi,* the elasticities of output with respect to water use were significant and positive. The estimated labour output elasticities are positive and significant for all group frontiers. Tree age was found to have a significant effect for *Kalleh-Ghuchi*, while the estimates for tree density are small and not significant.

Estimation of the metafrontier production model is justified on the basis of the likelihood-ratio (LR) test. The value of the test statistic is 147.62 and it is significant at the 5 percent level, with 56 degrees of freedom. Accordingly, the parameter estimates are presented in the last column of Table 1. The standard errors of these metafrontier coefficients are estimated using bootstrapping methods. Except for tree age, all of the estimated elasticities are positive and conform to our expectations. The output elasticities with respect to area and labour are the highest and are highly significant. Furthermore, the results of ANOVA and Tukey-Kramer comparisons tests indicate that significant differences exist between the estimated mean TGRs of the three varietal groups. Mean TGRs were found to be

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Table 1: Parameter estimates for the translog stochastic frontier models and metafrontier for pistachio production, Kerman Province, 2003 and 2004.

Variable	Parameter	Group frontiers						Metafrontier	
		Kalleh-Ghuchi		*Fandoghi*		*Akbari*			
		Coeff.	SD	Coeff.	SD	Coeff.	SD	Coeff.	SD
Constant	β_0	0.78[a]	0.20	0.96[a]	0.20	0.61[a]	0.07	1.05[a]	0.11
Area	β_1	0.77[a]	0.18	0.45[a]	0.11	0.42[a]	0.15	0.49[a]	0.10
Water	β_2	-0.09	0.14	0.19[b]	0.12	0.29[a]	0.11	0.05	0.12
Labour	β_3	0.14[c]	0.10	0.23[a]	0.10	0.11[b]	0.06	0.39[a]	0.07
Other Costs	β_4	0.02	0.08	0.06	0.07	-0.07	0.06	0.02	0.04
Age	β_5	0.35[b]	0.16	-0.12	0.16	-0.18	0.23	-0.11	0.12
Density	β_6	0.02	0.25	0.05	0.25	0.19	0.24	0.08	0.17
(Area)^2	β_{11}	-0.86[c]	0.56	-0.29	0.30	-0.48[c]	0.31	-0.06	0.25
Area×Water	β_{12}	0.08	0.45	0.20	0.29	1.04[a]	0.25	-0.06	0.25
Area×Labour	β_{13}	0.40	0.25	-0.31[c]	0.23	-0.57[a]	0.25	-0.37	0.16
Area×Other costs	β_{14}	0.24[c]	0.19	0.14	0.14	0.21	0.21	0.26[a]	0.09
Area×Age	β_{15}	-0.99[a]	0.41	0.55[b]	0.25	0.45	0.66	0.0005	0.26
Area×Density	β_{16}	0.44	0.39	-0.20	0.54	-0.10	0.48	-0.38[c]	0.29
(Water)^2	β_{22}	0.35	0.39	0.10	0.30	-1.73[a]	0.55	0.37[c]	0.25
Water×Labour	β_{23}	-0.19	0.19	0.32[c]	0.22	1.07[a]	0.23	0.22	0.15
Water×Other costs	β_{24}	-0.25[b]	0.14	-0.25	0.14	0.12	0.24	-0.24	0.10
Water×Age	β_{25}	0.62[b]	0.37	-0.13	0.27	0.09	0.49	-0.03	0.30
Water×Density	β_{26}	0.24	0.47	0.15	0.49	1.86[a]	0.56	0.13	0.29
(Labour)^2	β_{33}	-0.41[b]	0.22	0.02	0.20	-0.27	0.38	0.64[a]	0.17
Labour×Other costs	β_{34}	0.20	0.11	0.18[c]	0.12	-0.58[a]	0.15	-0.07	0.07
Labour×Age	β_{35}	0.53[a]	0.24	-0.40	0.28	-1.75[a]	0.34	-0.81[a]	0.21
Labour×Density	β_{36}	-0.50[b]	0.31	-0.26	0.22	-1.60[a]	0.32	-0.46[a]	0.19
(Other costs)^2	β_{44}	0.004	0.11	-0.02	0.02	-0.05	0.17	0.02[c]	0.01
Other costs×Age	β_{45}	0.29[c]	0.20	0.06	0.20	1.09[a]	0.17	0.66[a]	0.18
Other costs×Density	β_{46}	-0.07	0.23	0.07	0.20	-0.20	0.39	0.38	0.15
(Age)^2	β_{55}	-0.03	0.98	-1.65[b]	1.02	0.66	0.79	1.07[c]	0.68
Age×Density	β_{56}	0.65	0.71	-0.60[c]	0.45	1.24[c]	0.65	0.29	0.40
(Density)^2	β_{66}	0.83	0.85	-0.38	0.77	-0.20	0.46	-0.14	0.37
Dummy for 2004	η	-0.28[a]	0.10	-0.22[a]	0.10	-0.17	0.12	-0.21[a]	0.07
Sigma-squared	σ^2	0.76[a]	0.18	1.42[a]	0.26	0.75[a]	0.09		
Gamma	γ	0.76[a]	0.14	0.94[a]	0.05	1.00	0.00		
Log-likelihood	Log-L	-149.8		-215.5		-68.54			
Test for one-sided error	LR-test statistic	5.02[d]		38.89[d]		43.41[d]			

[a, b, c] Denote significant using a one-tailed test at 1, 5 and 10 percent levels, respectively; [d] Denotes significant at 5 percent level of significance using mixed chi-square distribution with 1 degree of freedom and a critical value of 2.706.

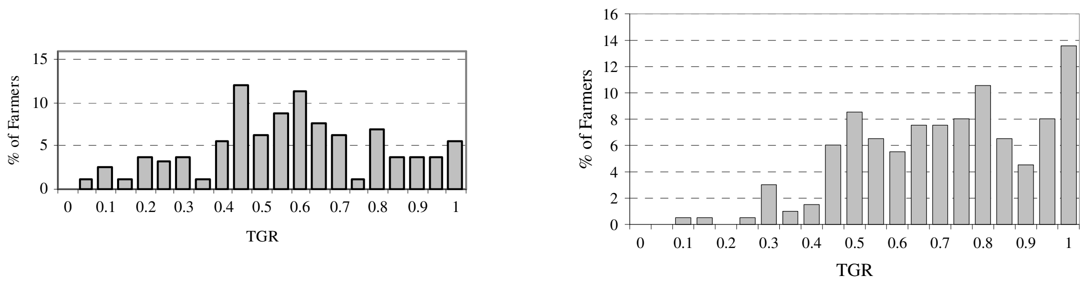
significantly different between *Fandoghi* and *Kalleh-Ghuchi* and *Fandoghi* and between *Akbari*, but not significantly different among *Kalleh-Ghuchi* and *Akbari*.

Estimates of technical efficiencies and TGRs are presented in Table 2, together with their standard deviations, and the distributions of TGRs by variety are presented in Figure 1. The standard deviation for a mean technical efficiency estimate for a variety is a measure of the dispersion of individual farm technical efficiencies in growing this variety around the mean technical efficiency. Mean technical efficiencies differ between varieties in the group frontier models. Farms growing the *Akbari* variety again achieved the highest mean technical efficiency (0.64), and farms growing the *Fandoghi* variety had the lowest mean technical efficiency (0.47). But these results can be misleading if insufficient allowance is made for differences in production technology arising from the use by farmers of different tree varieties. There is also a shortcoming in the estimation of individual group frontiers in that their efficiency levels cannot be compared; nor can TGRs be estimated. Both of these problems are overcome by estimating the metafrontier model where, as expected, technical efficiency estimates are lower but much less dispersed, suggesting that the individual group estimates exaggerate differences in technical efficiency between farms growing different varieties. The reason for this result is that the TGR estimates vary more widely than the mean technical efficiency estimates in the metafrontier model, from 0.54 for the *Akbari* variety to 0.69 for the *Fandoghi* variety.

Choice of variety plays a major role in preventing individual farmers from operating on or near the metafrontier. That is not to say that a producer cannot be located on the metafrontier because of the tree variety that has been planted: the maximum estimated TGR is unity for all varieties, which means that the three group frontiers are tangental to the metafrontier. But it is clear from Figure 1 that a higher proportion of producers who planted the *Fandoghi* variety are located on or close to

(a) Kalleh-Ghuchi

(b) Fandoghi



(c) Akbari

(d) All varieties

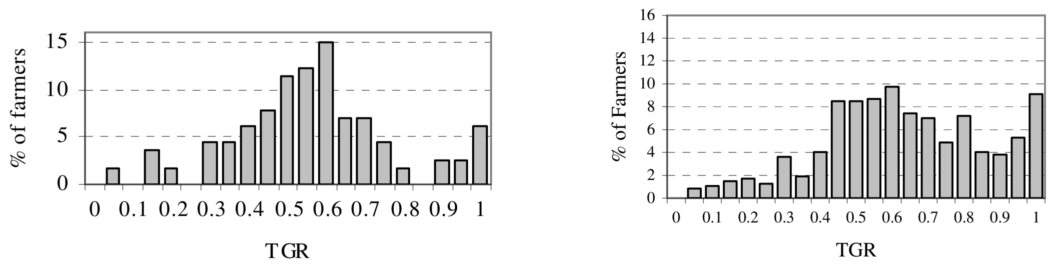


Figure 1. Distribution of TGRs of pistachio farms in Kerman Province, Iran, 2003 and 2004.

Table 2: Estimates of technical efficiencies and technology gap ratios for pistachio production, Kerman Province, 2003 and 2004.

Variety		Year	Pooled efficiency	Group efficiency	TGR	Metafrontier efficiency
Kalleh-Ghuchi	Mean	2003	0.53 (0.17)	0.59 (0.16)	0.58 (0.25)	0.34 (0.17)
		2004	0.50 (0.21)	0.58 (0.19)	0.52 (0.22)	0.31 (0.18)
		Total	0.51 (0.19)	0.58 (0.17)	0.55 (0.24)	0.32 (0.17)
Fandoghi	Mean	2003	0.55 (0.19)	0.47 (0.27)	0.71 (0.21)	0.32 (0.20)
		2004	0.54 (0.21)	0.47 (0.28)	0.68 (0.21)	0.31 (0.21)
		Total	0.54 (0.20)	0.47 (0.28)	0.69 (0.21)	0.32 (0.20)
Akbari	Mean	2003	0.57 (0.15)	0.66 (0.26)	0.53 (0.20)	0.34 (0.19)
		2004	0.57 (0.18)	0.60 (0.30)	0.55 (0.25)	0.32 (0.21)
		Total	0.57 (0.16)	0.64 (0.27)	0.54 (0.21)	0.34 (0.20)
Total	Mean	2003	0.55 (0.17)	0.57 (0.25)	0.61 (0.23)	0.33 (0.19)
		2004	0.53 (0.20)	0.53 (0.26)	0.60 (0.23)	0.31 (0.20)
		Total	0.54 (0.19)	0.55 (0.25)	0.61 (0.23)	0.32 (0.19)

Figures in parenthesis are standard deviations.

the metafrontier than producers who planted the other two varieties. This variety has a more compact distribution of TGRs and a larger proportion of observations towards the higher end of the range. Only about one-fifth of farms growing this variety recorded a TGR below 0.5 and around one-half had a TGR greater than 0.7. Production of the *Fandoghi* variety tends to be less sensitive to frost damage, water salinity and heat stroke in summer, suggesting that it is less constrained by climatic conditions.

An interesting point of comparison is that farms growing the *Akbari* variety achieved a TGR considerably below that achieved by farms growing the *Fandoghi* variety, despite the fact that they averaged the highest yield per hectare. Mehrabi Boshrabadi *et al.* (2007b) presented evidence that the *Fandoghi* variety used fewer non-land inputs, making such a result possible. This result points up the danger of relying solely on yields when comparing the performance of different varieties: all inputs used in production should be taken into account when making such a comparison.

CONCLUSIONS

Our analysis of technical efficiency and the technology gap in pistachio farming in Kerman Province in Iran is, to our knowledge, the first study to estimate a metafrontier in agricultural production based on crop variety. The recently developed metafrontier method has enabled us to test whether a metafrontier analysis is needed to take specific account of the production technologies of three varieties of pistachio trees in estimating farm-level technical efficiencies.

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Use of the metafrontier method proved to be valid and enabled technical efficiency scores to be corrected by the coefficient of the TGR. Results show that, on average, very little difference exists in technical efficiency between farms growing the different tree varieties. But they indicate that farms growing the three varieties differ in the use they make of inputs as measured by the TGR. Ignoring the limits placed on increasing technical efficiency because of constraints imposed by variety choice could lead to incorrect conclusions about the scope for farmers to improve their technical performance by adopting better farming practices. Finally, results indicate that it would be misleading to compare the performance of different tree varieties on the basis of yield per hectare alone.

A caveat is needed about drawing specific recommendations from these results in that the higher TGR for the *Fandoghi* variety is based on a province-wide assessment; data limitations prevented construction of separate group models by region as well as by variety. Because the *Kalleh-Ghuchi* and *Akbari* varieties tend to be more susceptible to extreme weather conditions, their suitability can be expected to fluctuate by region, and so the best choice of variety might alter according to which region is being examined. A further caveat is needed about the use of only two years of data. When more data become available, region-specific models need to be developed for the varieties in order for specific regional recommendations to be made.

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چه زمانی استفاده از تحلیل فرامرزی مناسب است؟ یک مثال از تفاوت ارقام پسته در ایران

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چکیده

با توجه به اینکه تکنولوژی‌های به کار رفته برای همه مزارع مورد مطالعه در تولید کشاورزی یکسان نیست، لذا برآوردهایی که از ناکارایی فنی در تولید کشاورزی انجام می‌گیرد، گسترده می‌باشند. روشهای سنتی برخورد با نااطمینانی ناشی از تفاوتهای تکتولوژیکی به "شکافهای تکنولوژی" نسبت داده شده است تا ناکارایی فنی بین مزارع به سمت پذیرش یک تحلیل فرامرزی حرکت کند. این امر امکان می‌دهد که شکافهای تکنولوژی متمایز از ناکارایی فنی باشد. در این تحقیق با استفاده از داده‌های نمونه‌ای مربوط به تولید سه رقم پسته مختلف در ایران، دو معیار برای توجیه استفاده مناسب از این روش طراحی شده است. یک، ناتوانی کشاورزان در تغییر نوع تکنولوژی مورد استفاده به جز در بلند مدت، و دوم اینکه، آزمونهای آماری مربوط به ضرایب تابع فرامرزی تا چه حد رضایت بخش است. کاربرد تحلیل فرامرزی روشی را فراهم می‌کند تا بر اساس آن کارآیی فنی محاسبه شده که به دلیل ظرفیت‌های تولیدی متفاوت ناشی از واریته‌های مختلف درختان بوده است، اصلاح گردد. نتایج نشان می‌دهد که تفاوت بسیار اندکی در کارآیی فنی بین مزارعی که واریته های مختلف کشت می‌کنند وجود دارد، اما چشم‌پوشی از محدودیت‌های اعمال شده بر تولید که ناشی از انتخاب واریته‌های گوناگون است، می‌تواند منجر به افزایش دامنه فعالیت کشاورزان برای بهبود :کارآمدی تکنیکی‌شان از طریق اعمال فعالیت‌های بهتر کشاورزی گردد. همچنین نتایج بیانگر آن هستند که استفاده از عملکرد در واحد سطح، به تنهائی برای مقایسه کارآمدی ارقام سه گانه، گمراه کننده است.

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