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Impact of Energy Subsidies Elimination on Technology Gap Ratio in Cucumber Production

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Abstract

This paper presents an analysis of technical efficiency and technology gap ratio (TGR) in greenhouse cucumber in Fars Province, Iran. Cucumber production was chosen for this study for the reason that greenhouse productions in this province mainly have focused on this product. The data used in this study was obtained from a random sample of 127 greenhouse s in Fars Province for 2010 to 2011. Metafrontier production function model for firms was used within the parametric framework of stochastic frontier analysis (SFA). The frontier models are applied in the analysis of cross-sectional data by assuming a translog functional form. Results indicate that eliminating energy input subsidies has led to significant decrease in greenhouse cucumber production efficiency so that the mean technical efficiency declined from 98% to 67 % during 2010-2011. Furthermore, subsidies elimination has also led to decrease of the mean technology gap ratio in greenhouses from 0.92 to 0.87, in other words, it has caused more distance from efficient production frontier.

Keywords:
metafrontier, stochastic frontier Analysis, translog function, Fars

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INTRODUCTION

Agricultural sector has a significant contribution for economy growth in respect to providing food for population, supplying essential materials required by industry and assisting foreign balance of payments through the exports. In this regard, food security is one of the most controversial issues in developing countries with the high rate of population growth. In order to confront with food shortages and their negative impacts on the economic development, food production capacity in agriculture must be increased. The increasing population growth, reducing water resources and arable lands due to the development of urban areas, warrant more efficient use of existing resources. In this context, greenhouse production technology can be considered as an applicable way to improve the efficiency and productivity of these resources.

Among various approaches to increase production, development of production inputs and making major changes in technologies are faced with several difficulties and limitations particularly in developing countries. Therefore, increasing technical efficiency has been considered as the most appropriate solution. Improving technical efficiency can result in more production outputs from a specified set of inputs and it also can prevent wasting resources. Up to 2010 energy consumption in Iran due to having cheap sources of energy and support from government subsidies in comparison with the international standards has been high. Determining energy prices lower than the world price by the government increases government spending and as a result increases unsustainable budget deficit. Undoubtedly, removing energy subsidies for optimal allocation of limited resources is the most important task that should be done in the Iranian economy. The aim of this study was to investigate the effects of removing energy subsidies on technical efficiency and technology gap ratio.

Monjezi and Sheikhdavoodi, (2011) investigated the energy efficiencies of cucumber producers using a non-parametric method of Data Envelopment Analysis (DEA) for 25 greenhouses in Khuzestan province of Iran. Average technical, allocative and economic efficiency indices were estimated to be 88%, 91% and 96%, respectively. (Taki et al., 2012), applied a parametric (Cobb-Douglas production function) and a non-parametric (DEA) method to analyze the efficiency for 25 cucumber greenhouses in Esfahan province (Iran). The average values of technical, allocative and economic efficiency of greenhouses were found to be 0.90, 0.95 and 0.94, respectively. (Omid et al., 2011) studied the degree of Technical Efficiency (TE) and Scale Efficiency (SE) of 18 selected cucumber greenhouses in Iran during September–December 2008 period. The TE of the inefficient units, on average, was calculated as 91.5%. This implies that, there are possibilities for either increasing total production of cucumber using the same inputs or decreasing input for the current level of cucumber production or a mixture of both by filling the gap between the best producer and other producers.

Mehrabi Boshrabadi et al., (2008) used a translog metafrontier production function to estimate TE and environmental-technological gaps (ETGR) in wheat production in Kerman Province of Iran in five major wheat production regions. Their results demonstrated that in regions with a lack of water resources, there was a wide technological gap compared with metafrontier function.

In another study by (Moreira & Bravo-Ureta, 2010), they estimated the technical inefficiency of pistachio farms in Kerman Province using a translog production function. The estimated TE of different varieties of pistachio trees reported to be from 59.4% to 78.7%, while the farmers experience was found to be the most effective factor. Some studies compared technical efficiency indices for different groups. For instance Battese et al., (1993) measured TE of wheat farmers in some distinct districts of Pakistan. But they did not test whether the frontiers of all districts are the same or not. Villano et al., (2010), discussed about when was meta frontier analysis appropriate; they 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. They mentioned farmers may have access to a 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. Physical conditions, environmental constraints, capital scarce and are the most important reasons expressed by them that should be taking into account, if farmers want to reach the metafrontier. So far, to the best of our knowledge, no study had tried to measure technical efficiency of the greenhouse cucumber while taking into consideration the varietal difference and their relationship with technology gap.

Cucumber is one of the major greenhouse vegetable products worldwide. In Iran, the planted area for cucumber was 78,000 ha with 1.72 million tones production in 2007. From 2002 to 2007, the total greenhouse area doubled in Iran from 3380 ha to 6630 ha. The shares of greenhouse crops production were as follows: vegetables 59.3%, flowers 39.81%, fruits 0.54% and mushroom 0.35 % (Omid et al., 2010). In Fars Province, the planted area of greenhouse vegetable production was 614523 m^2 (180 units) of which 48 ha was dedicated to cucumber production with 7841.8 tons of production in 2010-2011. The greenhouse cucumber production has been specified the most area and production among the other varieties of vegetables such as tomato and pepper in Fars province (Ministry of Jihad-e-Agriculture, 2010). The purpose of this study was to analyze the technical efficiency and technology gap ratio (TGR) in greenhouse cucumber production in Fars Province Iran, where the cucumber production was the major greenhouse productions. The effect of subsidies elimination was also assessed by comparison of TE and TGR calculated for the two time periods (prior to and after elimination of subsidies).

MATERIALS AND METHODS

In present study the stochastic frontier production function approach is used to estimate the TE In stochastic frontier models, efficiency estimation typically assumes that the fundamental production technology is the same for all farms. Due to differences in technology for greenhouse cucumber production under the survey period (2010 and 2011), efficiency comparison is not valid for categorized groups. The main advantage of stochastic frontier analysis is its ability to detect stochastic effects errors from the resultant errors of inefficiency effects. Given the other inputs, technology and environmental factors, technical efficiency is estimated based on the ratio of realized to expect maximum output.

(Aigner et al., 1977; Meeusen et al., 1977) developed the original model which later has been improved to handle different situations by (Pitt & Lee, 1981; Jandrow et al., 1982; Battese & Coelli, 1992, 1995; Kumbhakar, 2002). In recent studies, excluding the assumption of the uniformity in technology across the firms has been considered as a remarkable progress. In respect to this (Battesse & Rao, 2002; Battesse et al., 2004) have recommended that the stochastic metafrontier framework to compute both the technical inefficiencies of firms and the technology gap.

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 & Rao, 2002; Battese et al., 2004). According to this method, we assume there are *k* groups with different technologies in the industry. The standard stochastic frontier model for group-k defined as:

$$Y_{it(k)} = f(X_{it(k)}, \beta_{(k)})e^{V_{it(k)}-U_{it(k)}} \quad (1)$$

Where Y_{it} *(k)* implies 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 a $N(0,\sigma^2 v_{(k)})$ 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 $N(\mu_{it(k)},\sigma^2 U_{(k)})$ distribution.

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

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

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 metafrontier, the stochastic metafrontier production function approach is used. The metafrontier 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 & Rao, 2002). Following a stochastic metafrontier production function model in the industry is defined as:

$$Y_{it}^{*}=f(X_{it},\beta^{*})e^{X_{it}\beta^{*}} \quad i=1, 2, \ldots, N_k \quad t=1, 2, \ldots T \quad (3)$$

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

$$X_{it}\beta^{*} \geq X_{it}\beta_{(k)} \qquad \text{for all } k$$

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

$$Y_{it}=e^{-U_{it(k)}} \times e^{X_{ij}\beta(k)} / e^{X_{it}\beta^{*}} \times e^{X_{it}\beta^{*}+V_{it(k)}} \quad (4)$$

The first term on the right-hand side of Equation (4) 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 named the Technology Gap Ratio, which is expressed as:

$$\text{TGR}= e^{X_{it}\beta(k)} / e^{X_{it}\beta^{*}} \quad (5)$$

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 metafrontier function, given the observed inputs (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 metafrontier, 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 metafrontier output, adjusted for the corresponding random error. Following Equations (2) and (5), equation 6 can be determined such that:

$$TE_{it}^{*}=TE_{it}^{k} \times TGR_{it} \quad (6)$$

In this study, we estimated the Cobb–Douglas and translog functional forms of equations (1) and (3). In order to choose the appropriate form between two aforementioned functions, the likelihood-ratio test (equation 7) was used (12).

$$LR = -2\left[\ln\left(\frac{L(H_0)}{L(H_1)}\right) = -2[\ln(L(H_0) - \ln(L(H_1))\right] \quad (7)$$

Based upon equation (7), the specification of the translog and Cobb- Douglas functional forms is given by

$$LnY_{i(k)} = \beta_{0(k)} + \sum_{j=1}^{4}\beta_{j(k)}LnX_{ji(k)} + \frac{1}{2}\sum_{j=1}^{4}\sum_{s=1}^{4}\beta_{js(k)}LnX_{ji(k)}X_{si(k)} + V_{i(k)} - U_{i(k)} \quad (8)$$

where *j* represents the *j*-th input $(j= 1, 2, \ldots 4)$ of the *i*-th unit $(1, 2, \ldots, N_k)$ in the *t*-th time period $(t= 1, 2)$ in the *k*-th group $(k= 1, 2)$; $Y_{i(k)}$ represents the output for the *i*-th unit in the *k*-th group $(k=1,2)$ (kilograms); $X_{i1(k)}$is the pesticides (kilograms); $X_{i2(k)}$ is fuel (liter); $X_{i3(k)}$ represents amount of chemical fertilizer (Kilograms); $X_{i4(k)}$ represents the total other costs (in local currency) and Ln shows natural logarithm. $\beta_{ij}(k)= \beta_{ji}(k)$ for all *j* and *k*. Stochastic frontiers were estimated for the individual two groups using FRONTIER 4.1 (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.

First, considering equation 8, pooled stochastic frontier is estimated using cross-sectional data collected from greenhouses for 2010-2011. Then based on equation 8, estimation of individual stochastic frontier is carried out with respect to the number of groups. SFA models and technical efficiency are estimated with Maximum Likelihood Estimation (MLE).

The generalized likelihood ratio statistic was used for testing the hypothesis $\gamma=0$ as the most important assumption in this method. Having calculated LR statistics using equation 7 and its comparison with critical value chi-square, the hypothesis $\gamma=0$ was examined and is presented in Table 1.

It can be concluded that the null hypothesis (lack of inefficiency effects) is rejected at 10% level and higher in all presented models; hence MLE is preferred to ordinary least square estimation (OLS). This indicates that production difference is to some extent influenced by the management factors. An additional assumption is to choose an appropriate functional form (Cobb-Douglas vs. Translog) for desired data and selected samples. To examine this hypothesis, both Cobb-Douglas and Translog functions were estimated individually utilizing FRONTIER software. The data set of this study consisted of two years (2010 – 2011) which was obtained from 127 greenhouses in Fars province of Iran and further divided into two groups. Group 1 included greenhouses in 2010 (prior to elimination energy input subsidies) and group 2 comprised of greenhouses in 2011(after elimination energy input subsidies).

RESULTS AND DISCUSSION

Results for tests of both the best functional form and the hypothesis that the group frontiers are the same are summarized

in Table 1, it should be noted that the suitable functional form has to be specified by LR test based on the values of log likelihood function. According to the Table 1, the values of likelihood function for null hypothesis (H_0) and alternative hypothesis (H_1) which are related to values of likelihood Cobb-Douglas and Translog functions are more than critical chi-square. Subsequently, the null hypothesis is rejected in both individual and pooled models, which indicates that Translog functions have more consistency and compatibility for existing data. Therefore, all analyses have been performed using Translog function.

As can be seen from Table 2, gamma coefficient is significant at 1% level for both groups. The

Table 1
MLE Test Results

Groups		Null hypothesis	X^2	(X^2)	decision	Model
Individual stochastic for group1	Cobb-Douglas	$\gamma=0$	9.883	2.7(1)	reject	SFA
	Translog		12.796	2.7(1)	reject	SFA
	Cob-douglas or translog	$\gamma=0$	17.432	15.98(10)	accept	Translog
Individual stochastic for group2	Cobb-Douglas	$\gamma=0$	44.374	2.7(1)	reject	SFA
	Translog		60.085	2.7(1)	reject	SFA
	Cob-douglas or translog	$\gamma=0$	288.066	15.98(10)	accept	Translog
Pooled frontier model	Cobb-Douglas	$\gamma=0$	37.426	2.7(1)	reject	SFA
	Translog		56.445	2.7(1)	reject	SFA
	Cob-douglas or translog	$\gamma=0$	-35.978	15.98(10)	accept	Translog
Individual or pooled model	LR(pooled) with sum LR for two groups		73.81	21.06(14)	accept	Metafrontier

Table 2
MLE Test Results

Groups	Variable	Panel data	Group frontier			Meta frontier
			2010	2011	Total	
β_0	Constant	30.057	22.221	40.452	29.504	51.878
β_1	Pesticide(Rial)	0.135	0.706	0.474	1.302	-0.091
β_2	Fertilizer(Rial)	0.049	8.505	-1.475	-0.674	0.490
β_3	Fuel (Rial)	0.052	-1.582	0.355	1.580	-2.685
β_4	Divi (Rial)	-7.037	-11.769	-8.577	-8.253	-0.420
β_{11}	(Pesticide)^2	0.002	-0.033	-0.273	0.286	0.140
β_{22}	(Fertilizer)^2	-0.412	-0.978	-0.086	-0.024	-1.262
β_{33}	(Fuel)^2	0.014	0.212	-0.863	-0.753	0.181
β_{44}	(Divi^2	0.070	0.192	0.179	0.138	-0.088
β_{12}	Fertilizer * Pesti-	-0.174	-0.468	-0.161	-0.251	-3.089
β_{13}	cide	-0.040	-0.112	0.174	-0.339	0.194
β_{14}	Fuel * Pesticide	0.177	0.440	0.188	0.098	0.720
β_{23}	Divi * Pesticide	-0.100	-0.560	-0.089	-0.089	-6.813
β_{24}	Fertilizer * Fuel	0.672	0.618	0.477	0.386	-0.071
β_{34}	Divi * Fertilizer	0.129	0.653	0.551	0.749	-0.039
Sigma-squard	Divi * Fuel	2.413	0.678***	0.945***	0.849	
Gamma		0.873	0.669***	0.938***	0.812	
Loglikelihood		-2.902	-	-108.528	239.827	
function		-3.610**	118.687	-	-	
Eta			-			

*p<0.1, **p<0.05 and ***p<0.01

estimate of γ parameter using MLE was 0.667 and 0.938 for greenhouses in 2010 and 2011, respectively. These results are consistent with this concept that $\gamma > 0$. The calculated γ value is close to 1, which also denotes a high convergence of stochastic frontier toward metafrontier. This means that the contribution of these errors in production function and interpretation of production variations is lower in respect to included variables.

The statistical significance of η at 5% level indicates that the technical efficiency of cucumber production greenhouses for the study period (for panel data, 2010-2011) did not follow a constant trend and also the mean of the efficiencies for two years are significantly different. Table 3 shows that mean efficiency estimation using panel data has reduced from 98% (2010) to 67% (2011), suggesting that the elimination of subsidies for energy inputs led to significant reduction in greenhouse cucumber production efficiencies.

The results, as shown in Table 1, suggest that the hypothesis that the group frontiers are the same is rejected which means groups are different in applying different technologies. In these cases, stochastic metafrontier function has been considered as appropriate framework for estimating production function as well as comparison of technical efficiencies between groups (Bettesse et al., 2004). Accordingly, coefficients of stochastic metafrontier functions were obtained using the estimated coefficients from individual stochastic frontier functions and also SHAZAM software (calculating linear programming and coefficients), which are presented in the last column in Table 2.

The results of technical efficiency and Technology Gap Ratio are shown in Table 3, wherein TE indicates technical efficiency resulted from pooled stochastic frontier. TEK is technical efficiency of individual stochastic frontier for two groups which are being examined. TE* denotes the technical efficiency of units relative to the metafrontier. As can be seen, the maximum estimated mean TGR for

Table 3
Estimates of TEs and TGRs

Model	Item	Year		Total	Panel data	
		2010	2011		2010	2011
TE	Mean	0.609	0.611	0.610	-	-
	Min	0.028	0.055	0.028	-	-
	Max	0.940	0.844	0.940	-	-
	SD	0.119	0.152	0.136	-	-
TE ^{K}	Mean	0.648	0.609	0.629	0.987	0.674
	Min	0.056	0.031	0.031	0.093	0.078
	Max	0.922	0.915	0.922	0.995	0.829
	SD	0.104	0.174	0.144	0.013	0.148
TE *	Mean	0.594	0.528	0.561	-	-
	Min	0.054	0.027	0.027	-	-
	Max	0.879	0.851	0.879	-	-
	SD	0.109	0.158	0.140	-	-
TGR	Mean	0.917	0.870	0.894	-	-
	Min	0.585	0.344	0.344	-	-
	Max	1.000	1.000	1.000	-	-
	SD	0.088	0.094	0.094	-	-

both groups are equal to unity, which means that stochastic frontier functions of these groups are tangent to the metafrontier.

Our findings show that the mean TE, TE^{K} and TE^{*} are 0.609, 0.648 and 0.594, respectively. This mean of TEK states that firms are only able to produce, on average, 60.9% of the output that could be produced with current input and existing technology. Therefore, through the filling gap between the best producer in the same group, greenhouses could increase their production by 39.1 %.

TGR in different groups are comparable. In fact, estimates of the lower value of TGR demonstrate their greater distance from the superior technology. Prior to the elimination of energy input subsidies (2010), TGR for greenhouses was 0.917, which indicates the proximity of the technology level applied in this group of firms to the estimated technology from metafrontier function. However, after elimination of energy input subsidies (2011), this ratio decreased to 0.870, indicating the more distance to the efficient frontier.

CONCLUSIONS

Over the past years, a government support scheme for energy input price has resulted in an appropriate situation for greenhouse cucumber production and development of planted area in Iran and in particular in Fars Province; however, upon launching new policies for targeted subsidies in 2010, the crucial energy input lost the government support. The results of this study show that eliminating energy input subsidies has led to significant decrease in greenhouse cucumber production efficiency so that the mean technical efficiency declined from 98% to 67% during 2010-2011, when evaluated based on panel data. Furthermore, subsidies elimination has also led to decrease of the mean technology gap ratio in greenhouses from 0.917 to 0.870. In other words, it has caused greenhouses far apart from efficient production frontier. Accordingly, it would be better for energy input subsidies to be decreased gradually. It is also suggested that government provides the greenhouse owners with long term loans in order to equip their greenhouses with more energy efficient equipment.

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