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STOCHASTIC FRONTIER ANALYSIS OF CUCUMBER PRODUCTION UNDER DIFFERENT CULTIVATION SYSTEMS IN ISMAILIA GOVERNORATE, EGYPT

Alboghdady, M. A.A.* and M. A. Shata**
*** Agriculture economics dept. -Suez Canal university**
**** Agriculture economics dept. – Mansoura university**

ABSTRACT

The main purpose of the present studyis to examine the technical efficiency of cucumber production in Ismailia governorate under different cultivation systems including open system, plastic tunnels, and greenhouses system. Stochastic frontier analysis of production has been adopted to achieve this objective by using the data obtained from field survey conducted in year 2012. The production frontiers involve the inputs of cultivated area, quantities of seeds, volume of farmyard manure, chemical fertilizers, and labor. Most estimates have expected signs. Bymeasuring the importance of inputs in the production function, the cultivated area and farmyard manure open cultivation system, cultivated area and labor in low plastic tunnels, and farmyard manure in greenhouse systemare the most important inputs according to their statistical significant and higher partial elasticities. The results of the efficiency analysis showed remarkable differences in efficiency across the farms within each cultivation system and among the cultivation systems. Therefore, there are potentialities for improving cucumber farm productivity. In the inefficiency model, the results reveal that age of the farmers has negative impact on the production efficiency, while the educational level and accessing to the agricultural extension services, and agricultural education have favorable impact on the efficiency.

INTRODUCTION

Since 1986, the Egyptian government has undertaken a series of economic reforms to reduce external and internal imbalances, to eliminate distortions in the economy, and to promote sustainable growth in the productive sectors. Nowadays, great efforts being made in Egypt to meet theincreasing demand of food and to sustain food security.Its importance stems from important political and socio-economic dimensions. One of the important programs in the Egyptian agricultural reform policy is the program ofincreasing the use efficiency of economic resources in agricultural production.

Specifically, technological progress is the changes in production technology or production processes as a result of new information or changed operating conditions. However, it is important to recognize that many other factors, including choice of method and measurementerrors, can also affect productivity measurement(Nossal and Gooday, 2009).Protected cultivation in Egypt is one of the agriculturaltechnologiesthat areexpanding rapidly. The common types of protected cultivation in Egypt are the plastic low tunnels and the single span plastic houses. The number of single-arch greenhouses reached about twenty thousand, when about 12000 (60%) are used for cucumber production (EL-Zawely and EL-Sawy, 2007).

According to FAO database, the sector of Fruit and Vegetable production plays a major role in the Egyptian agriculture. They represent 13 % and 11 % respectively, on average of the period 2005-2010, of the total value of the Egyptian agricultural production. Egypt is ranked eighth among the world countries in the production of cucumber coming after china, Iran, Turkey, Russia, USA, Ukraine, and Spain(FAO, 2012). Nevertheless, Egypt is only self-sufficient of cucumber production and very little quantities are exported to the foreign markets reached about 395 ton in year 2010. Ismailia governorate is one of the major districts of cucumber production in Egypt. It ranked seventh among Egyptian governorates. Ismailia produced cucumber that worth about 53 million Egyptian pound in year 2010 (figure 1).

The main aim of the current study is to examine the technical efficiency of cucumber production in Ismailia governorate under different cultivation systems. Stochastic frontier analysis of production has been adopted to achieve this objective.

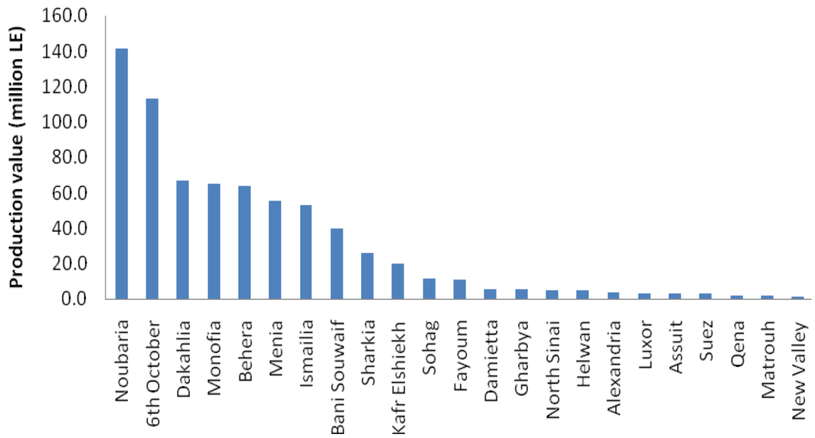

Figure 1:Value of cucumber production in the Egyptian governorates in year 2010

METHODOLOGY

The level of technical efficiency of a particular firm is characterized by the relationship between observed production and some ideal or potential production(Greene, 1993). AlthoughFarrell (1957)introduced a methodology for measuring efficiency since fifty years ago, his methodology is still undermodification and improvement. There are two approaches to estimate technical efficiency, parametric and nonparametric. The stochastic production frontier (SPF) developed by Aigner et al. (1977)and Meeusen and van Den Broeck (1977) is a parametric approach. Data envelopment analysis (DEA), developed by Charnes et al. (1978), is a non-parametric approach. SPF uses a parametric function,whereas DEA is based on a linear programming technique. The production frontier in DEA is deterministic, so any deviations from it are related to inefficiency. In an SPF, the production frontier function is sensitive to random shocks by including a random error term to the production frontier. As a consequence, only deviations caused by controllable decisions can be attributed to inefficiency(Esmaeili, 2006).

Following the proposed model by Aigner et al. (1977)the original specification of the stochastic frontier production function specified for cross-sectional data can be expressed as,

$$\mathbf{Y_i = f(x_i;\beta) + \varepsilon_i} = \exp(\mathbf{x_i\beta + \varepsilon_i}) \qquad \mathbf{i = 1, ..., N} \qquad (1)$$

Where Y_i is the production of i-th farmer, x_i is a (K×1) vector of input quantities of the i-th farmer, β is a (K×1) vector of unknown parameters representing production elasticity parameters to be estimated, and ε_i is the double component error term as,

$$\varepsilon = \mathbf{v_i} - u_i \qquad (2)$$

Where, v_i represents the classical symmetric disturbance term, and u_i is the technical inefficiency component to be estimated. The symmetric error component is assumed to be independently and identically distributed (iid). $N(0, \sigma_v^2)$. The technical inefficiency in production u_i is non-negative random variable and often assumed to be truncated normally with variance σ_u^2 and the mean $u_i = \delta_i Z_i$ is represented as a linear combination of the inefficiency variable. Both v_i **and** u_i are independent of each other.

The inefficiency determinant function is

$$u_i = \delta_0 + \delta Z_i + w_i, \qquad (3)$$

where Z_i is a vector of factors affecting the efficiency level, δ is a vector of parameters, and w_i is the error term. We utilize the parameterization of Battese and Corra (1977)and Battese and Coelli (1993)who replace σ_v^2 and σ_u^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \dfrac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$. Gamma ($\gamma$) is the ratio of the variance parameters of the random errors and technical efficiency effects, σ_v^2 and σ_u^2, which ranges between zero and one. This is done with calculation of the maximum likelihood estimates in consideration.The SFA allows us not only to measure the productive frontier but also to analyze theefficiency/inefficiency of each farm calculating its distance from the efficient frontier (Auci *et al*., 2013).The technical efficiency of the ith sample farm, denoted by TE, is defined in terms of the ratio of the observed output to the corresponding frontier output, conditional on the levels of inputs used by that farmer. According to Battese and Coelli (1988), the technical efficiency of the i-th farm can be expressed as,

$$TE = \frac{Y_i}{exp(x_i\beta + v_i)} = \frac{exp(x_i\beta + v_i - u_i)}{exp(x_i\beta + v_i)} = \exp(-u_i) \quad (4)$$

Where $exp(x_i\beta + v_i)$ is the stochastic frontier production.

The frontier efficiency model (Equation (1)) and inefficiency model (Equation (3)) can be estimated together by maximum likelihood. The particular frontier software used is FRONTIER 4.1, developed by Coelli (1996), which uses a three-step estimation method to obtain final estimates of maximum likelihood. First, unbiased estimates of the parameters are obtained via OLS (ordinary least squares). A two-phase grid search of γ is conducted in the second step, with b set to the OLS estimates and other parameters set to zero. The third step involves an iterative procedure to obtain the estimated maximum likelihood.

The stochastic frontier production function model which we specify for the farming operations in a given farm is

$$\ln y_i = \beta_0 + \beta_1 \ln(area) + \beta_2 \ln(seed) + \beta_3 \ln(MF) + \beta_4 \ln(CF) + \beta_5 \ln(labor) + v_i - u_i \quad (5)$$

Where y represents the output;
Area represents the cucumber cultivated area in feddan that is equal 4200 m^2);
Seed is the quantity of seed in kg unit;
MF is the manure farm yard fertilizers in cubic meter;
CF represents the chemical fertilizers expressed in kg units;
Labor represents the total quantity ofhuman labor for family members and hired laborers (in man days).

To determine changes in technical efficiency among farms, six variables are used in the model. The inefficiency model used is:

$$u_i = \delta_0 + \sum_{k=1}^{6} \delta_k Z_{ki} + w_i \quad (6)$$

where u_i is the inefficiency of the i-th farm. Z_{1i} refers to education level of the farm owner (Z_{1i}=1 if the owner is illiterate ,2 for primary school,3 for secondary school,4 for university educated); Z_{2i}, age of farm manager; Z_{3i}, the distance in kilometers between the owner's house and his/her farm; Z_{4i} denoteseducational specialization ($Z_{4i}=1$ if the educational specialization of the manager is agriculture otherwise, Z_{4i}=0); Z_{5i} refers to protective procedures of plant diseases (Z_{5i}=1 if the protective procedures have been adopted, otherwise Z_{5i}=0); Z_{6i} refers to the accessing of agriculturalextension recommendations (Z_{6i} =1 if yes, otherwise Z_{6i} =0).

Data

The data of the present study was obtained from field survey in Ismailia governorateduring year 2012. The survey encompassesof 161 farms divided into three groups of cucumber cultivation systems;60 farms that are adopting open area cultivation in spring season, 52 farms are using low plastic tunnels system, and 49 farmsare using greenhouses during the winter season.

RESULTS AND DISCUSSIONS

The mean differences of the input and output of cucumber production under the three technologies are presented in table 1. The result showed that there are significant differences among the three cultivation types. Greenhouse cultivation showed a highest productivity per feddan followed by cultivation under plastic tunnels and open area cultivation. The averages of the harvested areas also showed significant differences between the open area (2.07)and the two other cultivation systems, while there is no significant difference between the area of plastic tunnels and greenhouse systems.

The quantity of seeds used in the mentioned cultivation systems showed significant difference as the greenhouses cultivation revealed a highest plant density by 4.37 kg/feddan versus 0.6 and 0.87 kg for open system and plastic tunnels respectively. With respect to farmyard manures, there are significant differences among the three cultivation systems asthe volume of farmyard applied to the plastic tunnels system was smaller (20.85 m^3/feddan) than those applied to open system (45.28) and greenhouse (31.57).

Chemical fertilizers presented in table 1 were transformed to the applied effective units. There are also significant differences among the threesystemsas the greenhouses showed highest applied chemical fertilizers (306 kg/feddan) followed by open area (207.72) and plastic tunnels system (187.44) respectively.

Labors are computed in terms of man-day/feddan. There are significant differences between the labors used in open area cultivation versus the two rest cultivation types. Furthermore, there is no significant difference between numbers of man-days used in plastic tunnels and greenhouse cultivations.

The stochastic frontier and inefficiency models are estimated in a single stage by the econometric package FRONTIER 4.1 (Coelli, 1996). The maximum-likelihood estimates for the parameters in the stochasticfrontier and inefficiency model for the three cultivation systemsare presented in Table 2. In both models, the coefficients estimated for many parameters have the anticipated impacts on production and efficiency.

In the frontier model, harvested area and farmyard manure are significant and have the anticipated positive sign in open cultivation system implying that any increase in each variable would cause higher production. By the contrary, the sign of both quantities of seeds and chemical fertilizers were not according to expectation and were not significant. This means that the amount of seed and chemical fertilizers are already greater than the optimum quantities. In plastic tunnels cultivation system, harvested area is significant and also have positive signs. In greenhouse cultivation system, farmyard manure are significant and has positive sign while variable of labors is also significant but has negative sign implying that labors are used inefficiently.

Table 1: Analysis of variance (ANOVA) of inputs and outputs for cucumber production under different cultivation systems.

Item	Units	Cultivation system			F
		open	tunnels	Greenhouse	
Productivity	Kg/feddan	7680.00(a)	10892.31(b)	18459.18(c)	42.85
Area	Feddan*	2.07(a)	1.48(b)	1.23(b)	15.06
Seed	Kg	0.60(c)	0.87(b)	4.37(a)	682.71
Farmyard Manure	M^3	45.28(a)	20.85(c)	31.57(b)	46.45
Chemical fertilizers	Kg	207.72(b)	187.44(c)	306.73(a)	176.23
Labor	Man-day	248.10(a)	116.38(b)	146.43(b)	42.36

*** 1 feddan = 4200 m^2 = 0.42 hectare.**
Different letters refer to significant difference between means of different type of cultivation systems (P<0.05).

As the functional form used in the efficiency model was Cobb-Douglas, the coefficients are representing the production elasticities for each variable. The elasticity for each input is less than one except for labor in plastic tunnel and greenhouse systems, implying that a 1% increase in each input would lead to a less than 1% increase in the cucumber production.

Alternatively, the returns to scale were 0.68 for the open system, implying that 10 percent increasing in all inputs would cause 6.8% increase of output, and it was 1.4 for plastic tunnels cultivation system. The return to scale for greenhouse cultivation showed a notable different value -0.50 that reflects the over usage of input especially labors coefficient that was -.87.

The results of efficiency analysis revealed that technical efficiency scores of sample farms, estimated as $e^{(-u_i)}$, varied from 0.74on average for the open cultivation system (0.33 minimum to 0.97 maximum, 0.86 on average for the plastic tunnels system (0.34 to 0.99 maximum), to 0.94 for the greenhouse system (0.51 minimum to 1 maximum). This implied that there was substantial technical inefficiency in cucumber farming in Ismailia governorate.The main implication of these resultswere that cucumber farms could reduce their inputs by around 26% for the open system, 14% for the plastic tunnel system, and 6% for the greenhouse system without reducing their cucumber production, simply by improving technical efficiency.

The estimated value of γ in the stochastic frontier is estimated to be greater than 0.9 in all of the three cultivation systems and statistically significant at five percent level. Coelli and Battese (1996)also argued that γ cannot be considered to be proportion of the variance of the technical inefficiency effects in relation to the total of the variances of the technical inefficiency effects and the random variation. The result implies the presence of random component of the technical inefficiency effects and provides a better estimation of the technical efficiency of cucumber production in Egypt.

A relevant question is what factors can influence the farm technical efficiency. The answer of such question is presented in the inefficiency model presented in Table 2. The suggested factors are education level, age, distance between farm owner's house and his or her farm, is the farmer studied agricultural education or not , weather the farmer applied plant diseases protective procedures or not, and the accessibility to the agricultural extension. A positive sign on the parameters in the inefficiency model implies negative effects on technical efficiency, and vice versa.

Table 2: Maximum-Likelihood Estimates for Parameters of the stochastic frontier for cucumber productionunder different cultivation technologies

Parameter	Estimation/s.e		
	Open system	**Plastic tunnels**	**Greenhouse**
Frontier model			
Constant	3.22** (0.27)	1.46** (0.09)	5.63** (0.19)
Area	0.42** (0.10)	0.05* (0.02)	0.00 (0.01)
Seed	-0.10 (0.14)	0.03 (0.06)	0.01 (0.01)
Farmyard Manure	0.59** (0.15)	0.02 (0.04)	0.31** (0.04)
Chemical fertilizers	-0.24 (0.16)	0.07 (0.07)	0.06 (0.04)
Labor	0.01 (0.12)	-1.18** (0.09)	-0.87** (0.06)
Inefficiency model			
constant	1.18 (1.05)	-3.50** (0.75)	-1.06* (0.31)
Education level	-0.03 (0.17)	-0.29* 0.11	-0.12* (0.05)
Age	-0.03 (0.02)	0.04** (0.01)	0.01* (0.01)
Distance	0.00 (0.00)	0.01** (0.001)	0.00 (0.00)
Agri-education	-1.77 (1.36)	-0.16 (0.16)	-0.38** (0.08)
Protective procedures	0.44 (0.35)	-1.41** (0.18)	0.13 (0.08)
Access to agricultural extension	-0.20 (0.43)	-0.46* (0.13)	-0.25* (0.07)
σ^2	0.34 (0.27)	0.09** (0.02)	0.03** (0.00)
γ	0.98** (0.02)	0.999** (0.002)	0.998** (0.00)

Estimated standard errors aregiven below the parameter estimates. * and ** refer to significance levels at 0.05 and 0.01 respectively.

The educational level showed significant and positive impact on the farm efficiency in plastic tunnels and greenhouse cultivation systems. On the contrary, age showed significant and negative impact in the cultivation systems of plastic tunnels and greenhouses. The negative and significant impact of distance between farm owner's house and his or her farm has been proved only in the plastic tunnel system. Negative signs on the estimated parameters of the agricultural education of the farmers were consistent in all cultivation systems – implying positive impact on the cucumber farm productivity- but only statistically proved in greenhouse system.

The protection procedures of plant diseases showed consistent negative sign and statistically significant in the plastic tunnels system, while the signs on those in open area and greenhouses system were not as expected. The negative signs on the estimated parameters for the variable of the ease of accessing to agricultural extension recommendations were consistent in the three types of cultivation system but statistically proved in plastic tunnels and greenhouse systems.

Four null hypotheses associated with the inefficiency effects are presented in Table 3. The first three null hypotheses that there is no technical inefficiency, $H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \cdots = \delta_6 = 0,$ $H_0: \gamma = 0$, and $H_0: \delta_0 - \delta_1 - \delta_2 = \cdots - \delta_6 = 0$, are rejected for all mentioned cultivation systems. Thus the averageresponse function, in which all farms areassumed to be fully technically efficient, isnot an adequate representation of cucumber production in Egypt. The fourth null hypothesis, $H_0: \delta_1 = \delta_2 = \cdots = \delta_6 = 0$, specifies that all the coefficients of explanatory variables in the inefficiency model are equal to zero. If the null hypothesis is true, the technical inefficiencyeffects have the same truncated-normal distribution.The null hypothesis is rejected atthe 1%significance level for each cultivation system.Thus, given the specification of the stochasticfrontier and inefficiency model, the inefficiency effectsof the Cucumber production in Egypt cannotbe regarded as independently and identicallydistributed random variables that arise fromthe truncation of a normal distribution withzero mean.

CONCLUSIONS

The purpose of this paper was to estimate the stochastic production function for each of three cucumber cultivation systems in Ismailia governorate in Egypt. The production frontiers involve the inputs of cultivated area, quantities of seeds, volume of farmyard manure, chemical fertilizers, and labor. All estimates have expected signs, with exception of the coefficients of seeds and chemical fertilizers in the open cultivation system, and labor in plastic tunnels and greenhouse systems. Such results implying the excessive usage of the two mentioned inputs. With respect to the importance of inputs in the production function, the cultivated area and farmyard manure open cultivation system, cultivated area and labor in low plastic tunnels, and farmyard manure in greenhouse systemare the most important inputs according to their statistical significant and higher partial elasticities.

Table 3: Generalized Likelihood ratio test of the hypotheses of the stochastic production frontier and technical inefficiency.

	Null Hypothesis	df	Test statistics λ *	Critical value †	Decision
1	$H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \cdots = \delta_6 = 0$				
	Open		51.43		Reject
	Plastic tunnels	8	85.10	14.85	Reject
	greenhouse		75.25		Reject
2	$H_0: \delta_0 = \delta_1 = \delta_2 = \cdots = \delta_6 = 0$				
	Open		50.97		Reject
	Plastic tunnels	7	85.07	13.40	Reject
	greenhouse		71.12		Reject
3	$H_0: \gamma = 0$	1			
	Open		20.21		Reject
	Plastic tunnels		51.17	2.71	Reject
	greenhouse		55.34		Reject
4	$H_0: \delta_1 = \delta_2 = \cdots = \delta_6 = 0$				
	Open		47.92		Reject
	Plastic tunnels	6	75.14	11.91	Reject
	greenhouse		68.28		Reject

* $\lambda = -2[\ln\{L(H_0)\} - \ln\{L(H_1)\}]$.

† According to critical value determined by (Kodde and Palm, 1986).

From an efficiency analysis viewpoint, the results indicate remarkable differences in efficiency across the farms within each cultivation system and among the cultivation systems. Therefore, there are potentialities for improving cucumber farm productivity. In the inefficiency model, the results reveal that age of the farmers has negative impact on the production efficiency, while the educational level and accessing to the agricultural extension services, and agricultural education have favorable impact on the efficiency.

A possible suggestion that can be drawn from the present study is that Egyptian agricultural policies makers should bear in mind some of the programs that would raise capacity of farmers to apply technological innovations. This can be done by better access to agricultural extension services, raising the educational level of the farmers, and widening the agricultural education, as the results proves that agricultural education has a noticeable and positive impact on the technical efficiency of cucumber production in greenhouse cultivation system.

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تحليل الحدود العشوائية لإنتاج الخيار تحت نظم زراعية مختلفة بمحافظة الإسماعيلية، مصر

محمد التابعي علي البغدادي* و محمد علي شطا**
*** قسم الاقتصاد الزراعي – جامعة قناة السويس**
**** قسم الاقتصاد الزراعي – جامعة المنصورة**

تهدف الدراسة الى تقدير الكفاءة الفنية لإنتاج الخيار بمحافظة الإسماعيلية تحت نظم زراعية مختلفة و هي الزراعة المكشوفة و الزراعة تحت الأنفاق البلاستيكية و الصوب الزراعية،و كذلك اختبار اهم العوامل التي يمكن ان تؤدي الى عدم الكفاءة. و اعتمدت الدراسة على بيانات اولية تم جمعها من مسح ميداني لعدد ١٦١ مزارعخيار بالمحافظة عام ٢٠١٢. و قد تم استخدام تحليلالحدودالعشوائيةللإنتاجلتحقيقهذاالهدف.و يتميز تحليل الحدود العشوائية لدالة الإنتاج بأنه ذو حساسية جيدة للتغيرات العشوائية الفجائية التي تحدث لحدود دالة الإنتاج و بالتالي يمكن ارجاع الإنحرافات التي تحدث - بسبب عوامل يمكن ادارتها- الى عدم الكفاءة. و لذلك يمكننا معرفة اهم العوامل التي تؤثر في انتاج الخيار بالإضافة الى معرفة و قياس اهم عوامل عدم الكفاءة. قد اشتمل تقدير النموذج على جزئين رئيسيين هما نموذج الدالة الحدودية و نموذج عدم الكفاءة.

شملت دالة الإنتاج الحدودية العديد من المدخلات هي المساحة المزروعة وكميات التقاوي والسمادالبلدى،والأسمدة الكيماوية،والعمل. توافقت معظمالتقديراتمع المنطق الاقتصادي حيث كانت اشارة المعلمات المقدرة موجبة فيما عدا مدخل العمل في الزراعة تحت الأنفاق البلاستيكية و الصوب الزراعية مما يدل على زيادة مدخل العمل عن الحجم الاقتصادي. و بتقديرأهميةالمدخلاتفيدالة إنتاج محصول الخيار في المحافظة، تبين ان المساحةالمزروعةوالسمادالبلدىفي نظامالزراعةالمكشوفة،المساحةالمزروعةفي نظامالأنفاقالبلاستيكيةوالسمادالبلدىفينظامالصوبهيأهمالمدخلاتوفقاللدلالة الإحصائية و مروناتهم الإنتاجية.

تفاوتت قيمة الكفاءة الفنية فيما بين مزارع نظام الزراعة الواحد كما تفاوتت ايضاً بين نظم الزراعة المختلفة، حيث تراوحت الكفاءة الفنية بين ٠.٣٣ كحد ادني – ٠.٩٧ كحد اقصى في نظام الزراعة المفتوحة و بمتوسط هندسي بلغ نحو ٠.٧٤، في حين تراوحت بين (٠.٣٤-٠.٩٩) في الزراعة تحت الأنفاق البلاستيكية بمتوسط هندي قدره ٠.٨٦ في حين تروا حت بين (٠.٥١-١) و بمتوسط بلغ نحو ٠.٩٤ لنظام الزراعة تحت الصوب، مما يؤكد على انه مازالت هناكإمكانياتلتحسينالإنتاجيةالزراعيةللخيار في محافظة الإسماعيلية.

و بدراسة اهم العوامل التي تؤثر على الكفاءة الفنية، فقد اشارت النتائجالمنبثقة من نموذجعدمالكفاءة الى أنزيادةعمرالمزارعينلهاتأثيرسلبيعلىكفاءةالإنتاج،فيحينأنارتفاع المستوىالتعليمي و سهولة الوصولإلىالخدماتالإرشادالزراعي،والتعليمالزراعيو تطبيق اجراءات الحماية الوقائية من الأمراض يكونلهاتأثيرإيجابيعلىالكفاءة الفنية. من ناحية اخرى فقد ثبتت المعنوية الإحصائية للعلاقة العكسية بين المسافة الكيلوميترية بين مسكن مالك المزرعة و المزرعة و الكفاءة الفنية لإنتاج الخيار بمحافظة الإسماعيلية و ذلك في نظام الزراعة تحت الأنفاق البلاستيكية.