EFFICIENCY ANALYSIS OF OPEN FIELD TOMATO PRODUCTION IN PUNJAB: A NON PARAMETRIC DATA ENVELOPMENT ANALYSIS APPROACH

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ABSTRACT: This study was designed to calculate production efficiency (technical, economic and allocative) and determinants of inefficiency in open field tomato production in Punjab, Pakistan. Simple random sampling was used for primary data collection from 70 farmers in 2014. Data envelopment analysis explored the mean of technical (79.4%), allocative (58.1%) and economic (45.9%) efficiency. It showed the capability of 21.6 and 41.9% reduction in inputs and total cost, respectively with same output and technology. For sub groups, technical efficiency (92.1%) was more for medium farmer while allocative (74.2%) and economic efficiency (63.8%) was higher for large farmer. Tobit model explored the negative impact of education, experience, extension services and credit availability on inefficiency. Impact on inefficiency was positive for family size, area and vegetable market distance.

Keywords: Farmers, Production efficiency, Tobit model, Tomato and Vegetables.

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INTRODUCTION

Food security is a global issue and key determinant in the sustainable development. In Pakistan, the daily food deficit was 167 K calories per capita in 2010 but it become 172 K calories per capita per day in 2016 (Anonymous, 2017a). It implies the increasing food insecurity in Pakistan. It is required to increase the level of food availability because the population will be 234 million by 2025 (Ali *et al.*, 2017a). Vegetables are fundamental part of food security (Khan *et al.*, 2017) and also helpful for poverty elimination (Ali *et al.*, 2017b). The per capita annual vegetable use in Pakistan is less by 27.4 Kg as compared to recommended vegetable use which is 73 Kg per year (Shaheen *et al.*, 2011).

Agriculture is a fundamental component of gross domestic product (GDP) in Pakistan sharing 19.5% in GDP with the involvement of 42.3% labor force (Anonymous, 2017b). Government aims for improving agricultural productivity by enhancing yield, better utilization of inputs and adoption of modern technology (Anonymous, 2016).

Vegetables are inevitable in dietary guidance for human beings due to provision of vitamins (A and C), minerals and dietary fiber (Slavin and Lloyd, 2012). The consumption of vegetables provides resistance against cancer, cardiovascular disease, stroke and hypertension (Wang *et al.*, 2016). Pakistan earned Rs. 48,321.8 million in 2011-12 by exporting fruits and vegetables and Rs. 66,839.5 million in 2015-16 (Anonymous, 2017c).

Tomato (*Lycopersicon esculentum*) is a popular vegetable. Area under fresh tomato production is 4.58 million ha with 150.5 million tons production (Zalkuw *et al.,* 2014). Tomato is a source of major nutrients like lycopene, flavonoids, beta-carotene, hydroxycinnamic acid derivatives and vitamin C. Tomato crop gains popularity after the discovery of lycopene which is beneficial against cancer (Gerszberg *et al.*, 2015).

In 2014-15, Pakistan had 16.89 thousand ha area under tomato in Kharif season while it was 16.42 thousand ha in 2010-11. In kharif season there was 142.11 thousand tonnes tomato production in 2014-15 while it was 123.05 thousand tonnes in 2010-11. Kharif season tomato yield is increases from 7,494.12 Kg ha^{-1} in 2010-11 to 8,414.03 Kg ha^{-1} in 2014-15. In 2014-15, Pakistan had 38.55 thousand ha area under tomato in Rabi season while it was 34.24 thousand ha in 2010-11. Rabi season had 423.93 thousand tonnes tomato production in 2014-15 while it was 406.57 thousand tonnes in 2010-11. Rabi season tomato yield decreased from 11,875.63 Kg ha^{-1} in 2010-11 to 10,997.17 Kg ha^{-1} in 2014-15. Punjab province had 7.40 thousand ha under tomato in 2014-15 while it was 6.65 thousand ha in 2010-11. Tomato production in Punjab was 94.55 thousand tonnes in 2014-15 while it was 87.79 thousand tonnes in 2010-11. Yield of tomato was 12,783.80 Kg ha^{-1} in 2014-15 and 13,202.11 Kg ha^{-1} in 2010-11 (Anonymous, 2015a).

Different farmers show different levels of yield due to difference in the quantity of inputs. It reveals the inefficiency in production (Khan and Ghafar, 2013).

Efficient utilization of input resources is considered as a main asset in sustainable agricultural production (Jadidi *et al.*, 2012). Increase in the production efficiency will also be helpful for the elimination of food deficit.

The objective of this research was the estimation of production efficiencies in open field tomato production. The production efficiency was decomposed into technical, allocative and economic efficiency. It also aimed to find the elasticity score for different farm sizes.

MATERIALS AND METHODS

A comprehensive questionnaire was used for primary data collection from open field tomato growers in Faisalabad and Toba Tek Singh districts of Punjab, Pakistan in 2014. Stratified random sampling was adopted for the data collection. In stratifies random sampling, total population was divided in three sub groups such as small, medium and large and then the samples were selected randomly from each strata or sub group following (Teddlie and Yu, 2007). The respondents were interviewed about the price and quantity of inputs and output as well as socio-economic variables. A sample of 60 respondents was appropriate for decision making when population size was large (Mari, 2009). Due to this, sample size of current study was 70 open field tomato growers including 28 small, 19 medium and 23 large farmers. The sample of each sub group was different due to the difference in the population of each sub-group. Small farmers had less than 12.5 acre, medium farmers had less than 25 and more than 12.5 acre while large farmers owned more than 25 acre of operational land (Ali *et al.,* 2017b). Software, Microsoft Excel, SPSS-15, DEAP-2.1 and Eviews 7 were used for data analysis.

Empirical Models: Data envelopment analysis model with constant (CRS) and variable return to scale (VRS) were used for the estimation of total technical efficiency (TE) and pure technical efficiency (PTE), respectively. Total revenue (Y) was treated as output variable while land (X_1), tractor (X_2), seed (X_3), fertilizer (X_4), pesticide (X_5), irrigation (X_6) and labour (X_7) were treated as input variables in efficiency scores estimation.

(a) TE Estimation: Input oriented DEA model with CRS was employed for TE estimation according to Javed (2009):

$$\min_{\theta,\lambda} \theta,$$

subject to

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$\lambda \geq 0$$

Where, Y was output matrix for N open field tomato growers, θ showed the score of TE, λ was Nx1 constants, X was input matrix for N open field tomato growers, y_i depicted total revenue (Rs.), x_i described the vector of inputs $x_1i, x_2i, \ldots\ldots x_7i$, X_{1i} showed the area under open field tomato (acres), X_{2i} showed the total use of tractor (hours), X_{3i} showed the quantity of seed (kg), X_{4i} showed weight of NPK (kg), X_{5i} showed the chemical applications (No.), X_{6i} showed the total irrigation (hours) and X_{7i} showed the total labour man days.

(b) PTE Estimation: Input oriented DEA model with VRS was used by Coelli *et al.* (1998), cited in Javed (2009) for the estimation of PTE expressed as:

$$\min_{\theta,\lambda} \theta,$$

subject to

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

Where, θ described the PTE of ith open field tomato grower, $N1'\lambda = 1$ was convexity constraint to ensure that an inefficient farmer was benchmarked against the farmers of same size.

(c) SE Estimation: SE was estimated by dividing TE with PTE which is expressed as:

$$SE = TE_{CRS}/TE_{VRS}$$

A firm was called scale efficient if its value was equal to 1 and it became scale inefficient when its value was less than 1. A firm working either at increasing (IRS) or decreasing (DRS) return to scale creates scale inefficiency.

(d) EE Estimation: Cost minimization DEA model was used for the estimation of economic efficiency and it was a ratio between minimum to observed cost (Javed, 2009) and expressed as under:

$$\min_{\lambda, x_i^E} w_i x_i^E$$

subject to

$$-y_i + Y\lambda \geq 0$$

$$x_i^E - X\lambda \geq 0$$

$$N1'\lambda = 1$$

$$\lambda \geq 0$$

Where, w_i described the input price vector $w_1i, w_2i, \ldots\ldots\ldots, w_7i$, x_i^E was a vector of cost minimizing input quantities, N depicted the total open field tomato growers, w_{1i} was land rent (Rs.), w_{2i} was total money spent on tractor use (Rs.), w_{3i} was total seed cost (Rs.), w_{4i} was total cost of NPK (Rs.), w_{5i} was total cost of pesticide (Rs.), w_{6i} was total irrigation cost (Rs.) and w_{7i} was total labour cost (Rs.).

EE was a ratio and estimated by the division of minimum cost with observed cost.

Economic Efficiency = minimum cost/observed cost

$$EE = w_i x_i^E / w_i x_i$$

(e) AE Estimation: It was obtained by dividing economic efficiency with technical efficiency (Javed, 2009).

$$AE = EE/TE$$

(f) Tobit Regression Model: The causes of variation in efficiency were also explored in efficiency improvement following (Ibrahim and Omotesho, 2013). Inefficiency score for individual farmer was estimated by subtracting their efficiency score from 1. The inefficiency score (technical, economic and allocative) was separately regressed on selected socio-economic and farm related variables. The efficiency score obtained with DEA model lie between 0 and 1 which indicated that the dependent variable was not normally distributed. Ordinary least square showed biased results (Javed, 2009). Therefore, present study employed Tobit regression model (Tobin, 1958). Socio-economic and farm related variables were used as determinants of production inefficiency in Tobit regression model (Javed, 2009) expressed as:

$$E_i = E_i^* = \beta_0 + \beta_1 Z_{1i} + \beta_2 Z_{2i} + \beta_3 Z_{3i} + \beta_4 Z_{4i} + \beta_5 Z_{5i} + \beta_6 Z_{6i} + \beta_7 Z_{7i} + \mu_i$$

$$\text{If } E^* > 0$$

$$E = 0 \quad \text{if} \quad \text{If } E^* \leq 0$$

Where, i showed ith open field tomato farmer, Ei described the technical, allocative, and economic inefficiency, Ei^* depicted the latent variable, Z_{1i} was education (years), Z_{2i} was family size (no.), Z_{3i} was open field tomato experience (years), Z_{4i} was contact with extension agents (no.), Z_{5i} was open field tomato area (acre), Z_{6i} was vegetable market distance (km) from ith farm, Z_{7i} was dummy variable for credit availability, ß's described unknown parameters and µi denoted the error term.

RESULTS AND DISCUSSION

Descriptive analysis of socio-economic and DEA model variables: Mean value of socio-economic, farm-related, revenue and cost related variable in the production of open field tomato was explored. The mean age was 41.80 years, and it was maximum for large farmers and minimum for small farmers. It showed that small farmers were younger. On an average, the higher level of education was observed in medium farmers with the overall average of 8.51 years. The average education was less than matriculation which implied the need of improvement in education. The average family size in the sample was 7.16 and the family size was more for medium farmers and lower for small farmers. The average size of household was 6.49 persons in rural area in 2013-14 (Anonymous, 2015b). The large farmers showed more experience in this activity and small farmers had less experience in open field tomato. The instability in tomato prices and disease attack were major reason behind the less experience in the case of small farmers. The large farmers also had more contact with extension agents (4.70) while the average extension contacts were 3.79. The large farmers had more area under this crop and sold their crop in the distant market. On average, area under open field tomato was 2.68 acres and distance of vegetable market was 29.68 km.

On average, total production was 14011 kg $acre^{-1}$ with minimum (6000 kg $acre^{-1}$) and maximum (20000 kg $acre^{-1}$). This wide range of tomato yield supported the concept of inefficiency in this activity. The tomato yield was less as compared to tomato yield in Egypt (16006.9 Kg $acre^{-1}$) (Alboghdady, 2014). On average, revenue was Rs. 450,507.57 $acre^{-1}$. The per acre tomato revenue was more as compared to 28492.28 Egyptian Dollars (Rs. 167,086.69) in Egypt (Alboghdady, 2014). Total variable cost and total cost were Rs. 140,535.06 and Rs. 170,582.80, respectively on per acre basis. The variable cost was 13040 Ethiopian Birr (Rs. 58,935.78) per acre in tomato production in Ethiopia (Beshir and Nishikawa, 2012). A farmer paid Rs. 19207.14 as land rent estimated for seven months. On an average, open field tomato farmer spend money on tractor usage (Rs. 11253.57), seed (Rs. 7,178.43), fertilizer (Rs. 20,685.00), chemical (Rs. 11,507.14), irrigation (Rs. 9,771.96) and labour charges (Rs. 40,686.79).

Efficiency score estimation: The average TE score was 79.4%, which implied the 20.6% decrease in the use of inputs to get the same level of output for a technically efficient farmer. It showed the potential of increasing production by improving technical efficiency. The TE score in Punjab, Pakistan was higher as compared to 78.94% in Nigeria (Adenuga *et al.*, 2013), 77.67% in India (Murthy *et al.*, 2009), 77.5% in Swaziland (Malinga *et al.*, 2015), 71% in Ghana (Donkoh *et al.*, 2013), 71% in Egypt (Alboghdady, 2014), 65% in Kenya (Najjuma *et al.*, 2016), and 42.3% in Nigeria (Ogunniyi and Oladejo, 2011). The average PTE was 90.8% and SE was 86.8%. Generally, PTE value was higher due to absence of production scale. On an average, the AE was 58.1% in the sampled farmers which implied that probability of 41.9% reduction in the total cost of production to obtained same level of output for an allocatively efficient farmer. The EE score was also less among the sampled farmers which was only 45.9% in open field tomato production. The higher TE score (above 90%) was recorder for only 32.86% farmers. Similarly, the more than 90% level of allocative and economic efficiency was found in only 2.86% and 1.43% farmers, respectively. The minimum TE, AE and EE score was only 46.5%, 25.3% and 21.5%, respectively. All these finding revealed that the situation of efficiency in open field tomato production was not up to the mark and there exist significant potential for the improvement in the efficiency score.

Table 3 explained the trend of efficiency score with respect to three farm sizes. On average, the higher TE score was observed for medium farmer which was 92.1% while the TE score was 86.3% and 85.6% for small and large farmers, respectively. It implies that the potential of increase in production with same level of inputs and technology was 7.9% for medium farmers, 13.7% for small farmers and 14.4% for large farmers. The medium farmers also had high level of education. Average AE score revealed that the chance of cost reduction for same production level was 44.9% for small farmers, 35.6% for medium farmers and 25.8% for large farmers. On average, the EE score was also less for small farmers (47.4%) and more for large farmers (63.8%). It is required to uplift the efficiency score of small farmer because the prosperity of small farmers is required for the progress of Pakistan (Adil *et al.,* 2004).

Table 1: Summary of socio-economic and DEA model variables.

Variables		Mean	Max.	Min.	SD
Age (years)		41.80	85	19	14.14
	Small	37.54	85	19	15.49
	Medium	43.63	65	20	13.21
	Large	45.48	72	30	12.23
Education (years)		8.51	16	0	3.74
	Small	8.25	16	0	4.26
	Medium	8.79	14	0	3.58
	Large	8.61	12	0	3.33
Size of family (no)		7.16	20	4	2.88
	Small	6.43	14	4	2.36
	Medium	8.95	20	6	4.20
	Large	6.57	8	5	0.99
Open field tomato experience (years)		4.61	30	1	3.93
	Small	3.32	10	1	1.89
	Medium	5.00	15	2	3.11
	Large	5.87	30	2	5.68
Contact with extension agent (no)		3.79	10	1	1.82
	Small	3.32	10	2	1.74
	Medium	3.37	8	2	1.57
	Large	4.70	10	1	1.82
Open field tomato area (acre)		2.68	10	0.25	2.48
	Small	1.20	2	0.25	0.58
	Medium	2.97	8	1	2.35
	Large	4.24	10	0.50	2.98
Vegetable market distance (km)		29.68	40	5	10.87
	Small	27.23	40	5	11.49
	Medium	28.95	40	15	11.13
	Large	33.26	40	15	9.25
Yield (kg/acre)		14011.00	6000.00	20000.00	2758.82
Revenue (Rs./acre)		450507.57	292800.00	700000.00	87680.92
Variable cost[1] (Rs./acre)		140535.06	98142.50	231350.00	23805.79
Total cost[2] (Rs./acre)		170582.80	130746.76	262886.83	24799.51
Profit (Rs./acre)		279924.77	537631.50	111092.80	86134.51
Land rent (Rs./acre)		19207.14	12500.00	30000.00	4200.80
Tractor use cost (Rs./acre)		11253.57	7150.00	17200.00	2205.35
Seed cost (Rs./acre)		7178.43	1500.00	35000.00	7081.23
NPK cost (Rs./acre)		20685.00	7800.00	50500.00	7082.55
Chemical cost (Rs./acre)		11507.14	4000.00	21000.00	3813.11
Irrigation cost (Rs./acre)		9771.96	830.00	14900.00	2513.84
Labor cost (Rs./acre)		40686.79	22400.00	88600.00	11797.18

[1] Variable cost includes cost of land preparation, seed, pesticide, irrigation, fertilization, picking and marketing.
[2] Fixed cost included interest on variable cost, administration charges, land rent and water charges by Govt. (abyana).

Table 2: Frequency distribution of efficiencies.

Efficiency range	TE		AE		EE	
	N	%	N	%	N	%
0.01-0.30	0	0	2	2.86	8	11.43
0.31-0.40	0	0	3	4.29	20	28.57
0.41-0.50	3	4.29	10	14.29	21	30
0.51-0.60	8	11.43	26	37.14	10	14.29
0.61-0.70	12	17.14	21	30	8	11.43
0.71-0.80	13	18.57	5	7.14	1	1.43
0.81-0.90	11	15.71	1	1.43	1	1.43
0.91-1.00	23	32.86	2	2.86	1	1.43
Total	70	100	70	100	70	100
Mean	0.794		0.581		0.459	
Minimum	0.465		0.253		0.215	
Maximum	1		1		1	

Table 3: Score of production efficiency for sub groups.

Farm Size	Efficiency estimates				
	$TE_{(CRS)}$	$TE_{(VRS)}$	SE	AE	EE
Small	0.863	0.941	0.911	0.551	0.474
Medium	0.921	0.980	0.937	0.644	0.594
Large	0.856	0.998	0.857	0.742	0.638

Inefficiency determinants: For policy implication, it was required to explore the factors of technical, allocative and economic efficiency for the improvement in efficiency score. Table-5 revealed the regression analysis of inefficiency score by using Tobit regression model. A negative and significant coefficient of education confirmed the hypothesis and showed the decrease in inefficiency for an educated. The efficiency improvement due to education was in line with previous findings reported by (Murthy *et al.,* 2009; Ogunniyi and Oladejo, 2011; Adenuga *et al.,* 2013; Donkoh *et al.,* 2013; Khan and Ali, 2013; Usman and Bakari, 2013). The positive and significant coefficient of family size implied the increase in inefficiency due increase in family size and supported the hypothesis that a farmer with more family had high inefficiency. This result was in line with the findings of Bozoglu and Ceyhan (2007). The coefficient of experience was negative and significant for allocative and economic inefficiency, and it confirmed the hypothesis that efficiency improved for an experience farmer and in line with Bozoglu and Ceyhan (2007), Donkoh *et al.* (2013), Khan and Ghafar (2013) and Usman and Bakari (2013). The role of extension services for efficiency improvement was also mentioned in literature (Bozoglu and Ceyhan, 2007; Murthy *et al.,* 2009; Khan and Ali, 2013). The present finding confirmed this hypothesis due to significant decrease in inefficiency for an experienced farmer. The technical inefficiency rises due to increase in the area under open field tomato. It explored that the large farmers were more technical inefficiency and this relationship had a support from table 4. Generally, the small farmers used the scarce input resources more efficiently with a support form Ibrahim and Omotesho (2013) and Khan and Ghafar (2013). The positive and significant coefficient of distance of vegetable market implies that the increase in vegetable market distance was associated with more inefficiency due to the involvement of high transportation and labour cost. The regression coefficient of credit access was negative and significant. It implies the chances of efficiency improvement for the farmers having credit availability. It confirmed the hypothesis about improvement in efficiency in the presence of credit facility (Adenuga *et al.,* 2013; Khan and Ali, 2013; Usman and Bakari, 2013).

Table 5: Determinants of inefficiency.

Variables	Technical inefficiency		Allocative inefficiency		Economic inefficiency	
	β	Sig.	β	Sig.	β	Sig.
Education	-0.040	0.000	-0.005	0.562	-0.005	0.048
Family size	0.012	0.043	0.029	0.000	0.035	0.000
Open field tomato experience	0.033	0.162	-0.040	0.078	-0.045	0.093
Extension agent contacts	0.031	0.129	-0.072	0.000	-0.058	0.012
Open field tomato area	0.013	0.074	0.000	0.945	0.008	0.347
Vegetable market distance	0.005	0.000	0.007	0.000	0.010	0.000
Dummy for Credit facility	-0.335	0.002	-0.060	0.509	-0.182	0.094

Conclusions: There is a significant potential of increase in open field tomato production and reduction in production cost for technically and allocatively efficient farmer. The government should provide credit opportunities, technical education and extension services for the increase in production efficiency.

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