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RESEARCH ARTICLE

# An Efficiency Analysis of Off-Season Tomato Production in Punjab: A Data Envelopment Analysis Approach

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**ABSTRACT**

This study was conducted to assess the technical, allocative and economic efficiency and inefficiency determinants of off-season tomato growing farmers in districts Faisalabad and Toba Tek Singh of Punjab province, Pakistan. Primary data were collected from 70 off-season tomato growers by using the simple random technique of sampling in 2014. Data Envelopment Analysis (DEA) showed that mean values of technical, allocative and economic efficiencies were 88.9%, 44.7% and 40%, respectively. The minimum scores of technical, allocative and economic efficiencies were 53.1%, 24.7% and 17.6%, respectively. The results demonstrated the presence of considerable potential in order to increase the production efficiencies. Input level could reduce by 11.1% and cost of production could reduce by 55.3% to get the same level of output by using available technology. Inefficiency determinants showed that farmer's education, off-season tomato growing experience, credit availability, contacts with extension agents and off-season tomato area had a negative and significant impact on production inefficiencies while the impact of age, family size, and market distance was positive and significant on production efficiencies. It is speculated that government should promote education, credit availability, extension services and quality of inputs, and subsidize small farmers for tunnel material and encourage the large farmers to earn foreign exchange.

## INTRODUCTION

The government takes different initiatives to improve the quantity and quality of agricultural crops by using new technologies. The share of agriculture was 18.9% in gross domestic product and 42.3% labor force was engaged in this sector. Role of agriculture is inevitable for the socio-economic development of the economy. Increase in the production and yield of agricultural crops is required to ensure food security (Government of Pakistan, 2015a, 2017a) because the forecasted population will be 234 million by 2025 in Pakistan (Ali et al., 2016a). Vegetables have an important place in agriculture and occupied 0.386 million ha in Pakistan (Khan et al., 2017). These are beneficial for health, nutrition level and resistance against diseases. It is a livelihood source and earner of foreign exchange for a country (Akter et al., 2011; Ogunniyi and Oladejo, 2011; Ibrahim and Omotesho, 2013). Pakistan earned 47895.6 million rupees by exporting vegetables and fruits in 2010-11 while the figure becomes 59241.8 million rupees in 2016-17, showing a maximum 67864.3 million in 2014-15 (Government of Pakistan, 2015b, 2017b). Malnutrition, poverty and unemployment are main problems in developing country and vegetable sector have the ability to solve these problems (Akter et al., 2011). The per capita recommended use of vegetables was 73 kg but Pakistan faces 27.4 kg per capita shortage per annum (Shaheen et al., 2011).

Tomato (*Lycopersi conesculentum* Mill) is an important fruit and vegetable with 124.75 million tonnes of production. Food and Agriculture Organization ranked tomato at number six on the basis of production. It is an essential component in all dishes and cooking. Increase in population is responsible for the increase in demand, seasonality in production, and availability in markets

(Chohan and Ahmad, 2008; Ogunniyi and Oladejo, 2011; Khan, 2012). It provides nutritional elements like Vitamin A and C, potassium, fiber and especially lycopene which is useful against cancer (Adenuga et al., 2013). Tomato production increases the employment and income in the rural areas (Ali et al., 2017b). In Pakistan, tomato area was 62536 ha in 2015-16 with 587111 tonnes production. In Punjab, tomato area was 8170 ha in 2015-16 with 106229 tonnes production. Since 2011-12, tomato area and production rises by 24.94% and 23.55%, respectively (Government of Pakistan, 2017c). In 2015-16, a rural person with 6.47 family members uses 0.47 kg tomato per month while an urban person with 6.03 family members uses 0.54 kg tomato per month (Government of Pakistan, 2017d).

High prices at the start and end of the season can be reduced by vegetable cultivation in the off-season. Off-season/tunnel farming is done in a tunnel in which moisture and temperature are controlled (Government of Pakistan, 2013). The duration of vegetable cultivation is increases with off-season cultivation. Tunnel vegetables reach 1 to 2 week earlier in the market and give 2 to 3 times extra yield (Iqbal et al., 2009). There is a huge difference in the yield obtained by different farmers due to the difference in the input use. The difference in the output indicates inefficiency in input use (Khan and Ghafar, 2013).

Various studies measured technical efficiency of agricultural crops like cucumber (Ali et al., 2016b), open-field tomato (Ali et al., 2017a) by using production function, frontier function and mathematical programming (Bozoglu and Ceyhan, 2007). Ogunniyi and Oladejo (2011), Khan (2012), Khan and Ali (2013), and Khan and Ghafar (2013) explored the technical efficiency in tomato production. The determinants of production efficiencies were the age of farmer, latest technology, improved inputs, education, training and extension services, credit availability and farming experience. Adenuga et al. (2013) explored the technical efficiency in case of dry season tomatoes. A better option for increasing the living standard of farmers is to increase the technical efficiency (Ibrahim and Omotesho, 2013).

The present study measures the efficiency of off-season tomato growers and checked the possibility of input use reduction or expansion in the level of output. The study aims to provide policy implications about how to increase the efficiency of off-season tomato growers in Pakistan. The efficiency estimates are further divided into technical, allocative and economic efficiency. Efficiency scores and the sources of inefficiency are beneficial because farmers could use this information for improving themselves and policymakers could use this information to make possible interventions for improvement in the yield and farm income.

## MATERIALS AND METHODS

### Sampling procedure and study area

The current study was conducted in Faisalabad and Toba Tek Singh districts of Punjab province in 2014. A comprehensive questionnaire was used to collect primary data by using simple random sampling. Off-season tomato growing farmers were less in the study area but their strength increases due to attractive yield in tunnels. According to (Poate and Daplyn, 1993, Mari, 2009), a sample size of 60 was feasible for decision making in case of large sized population. Due to financial and time constraints, total 70 off-season tomato farmers were interviewed, including 30 from Faisalabad and 40 from Toba Tek Singh. Faisalabad is third largest city of Pakistan while Toba Tek Singh has large population of off-season tomato growers. The selected farmers were distributed as large (operational land>25 acres), medium (12.5 acres<operational land<25 acres), and small (operational land<12.5 acres) farmers (Hassan et al., 2005). Software(s) Microsoft Excel, Data Envelopment Analysis Procedure (DEAP)-2.1, SPSS-15, and Eviews 7 were used for empirically analysis.

### Efficiency background

Production frontier is used to find the maximum productivity of a firm. Stochastic frontier analysis (SFA) (parametric) and data envelopment analysis (DEA) (nonparametric) are used in order to find the production frontier. DEA model is working on the basis of linear mathematical programming techniques. The gap between actual data point and frontier is calculated to estimate the efficiency of a farm. When this gap increases than the inefficiency score of a firm increases (Javed, 2009). (Coelli, et al, 1998) said that the DEA model was input-oriented as well as output-oriented and suggested to choose the orientation on the basis of manager control over inputs and output. As a farmer has more control over inputs. Therefore, this study used input-oriented DEA model to address the study objectives.

For a production unit, obtaining maximum possible product by using given input resources on the basis of production model is called as technical efficiency (Javed, 2009). Constant returns to scale or variable returns to scale DEA model were used to calculate the scores of technical efficiency. Coelli, et al. (1998) pointed out that DEA model with constant return to scale was appropriate only if all firms were working at an optimal scale otherwise it gives technical efficiencies which are confounded by scale efficiencies. Therefore, Bankers et al. (1984) used DEA model based on variable returns to scale by incorporating convexity constraints. We used both models in current study to find technical efficiency.

### Analytical framework and empirical models

For the estimation of total technical and pure technical efficiency, input-oriented DEA model was used, based on constant returns to scale and variable returns to scale, respectively. The output variable was total revenue (Y) in order to calculate the technical efficiency and it was obtained by multiplying the off-season tomato production with prices. The inputs like land (X1), tractor (X2), seed (X3), fertilizer (X4), pesticide (X5), irrigation (X6), labour (X7), polythene sheet (X8) and mulch sheet (X9) were incorporated in this study.

**(a) DEA model for estimation of technical efficiency**

Input-oriented DEA model based on constant return to scale was used to find the technical efficiency (Javed, 2009) and it was of the form:

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

$-y_i + Y\lambda \geq 0$

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

$\lambda \geq 0$

Where:

$Y$ shows a matrix of output for N farmers.

$\theta$ shows the total technical efficiency of the ith farmer.

$\lambda$ shows Nx1 constants.

$X$ shows a matrix of inputs for N farmers.

$y_i$ shows the total revenue of the ith farmer in Rs.

$x_i$ shows the input vector for x1i, x2i,……x9i inputs used by the ith farmer.

$x_{1i}$ shows the area under off-seasonal tomato in acres of the ith farmer.

$X_{2i}$ shows the total hours of tractor used in different operations like ploughing, rotavator, planking, leveling of land and ridge making by the ith farmer.

$X_{3i}$ shows the total seed quantity measured in kg used by the ith farmer.

$x_{4i}$ shows the weight of fertilizer (NPK) in kg used by the ith farmer.

$x_{5i}$ shows the number of chemical applications performed by the ith farmer.

$X_{6i}$ shows the total hours of irrigation by the ith farmer.

$X_{7i}$ shows the total labor man-days required for different operations in off-season tomato production by the ith farmer.

$x_{8i}$ shows the weight of polythene sheet in kg used by the ith farmer.

$x_{9i}$ shows the weight of mulch sheet in kg used by the ith farmer.

**(b) DEA model for estimation of pure technical efficiency**

Input-oriented DEA model based on variable return to scale was used to find the pure technical efficiency (Coelli et al., 1998). The model used was as follows:

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

subject to

$-y_i + Y\lambda \geq 0$

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

$N1' \lambda = 1$

$\lambda \geq 0$

Where:

$\theta$ shows the pure technical efficiency for ith farmer.

$N1'\lambda = 1$ was a convexity constraint to make sure that an inefficient firm was benchmarked against same size firms.

**(c) Estimation of scale efficiency**

It was a ratio of total technical efficiency ($TE_{CRS}$) with pure technical efficiency ($TE_{VRS}$) and mathematically:

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

If Scale efficiency is equal to 1 than it shows constant return to scale (CRS) or scale efficiency while if its value is less than 1 than it represent scale inefficiency. Scale inefficiencies exist when a farmer operating either at increasing or decreasing returns to scale.

**(d) DEA model for estimation of economic efficiency**

The economic efficiency is calculated by taking the ratio of minimum to observed cost (Javed, 2009). The minimum cost is obtained by solving the cost minimization problem with DEA. According to Javed (2009), DEA model for minimization of cost:

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

subject to

$-y_i + Y\lambda \geq 0$

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

$N1'\lambda = 1$

$\lambda \geq 0$

Where:

$w_i$ shows input price vector w1i, w2i ,………,w9i of the ith farmer.

$x_i^E$ shows the cost minimizing vector of input quantities for the ith farmer.

N shows the total off-season tomato farmers in the sample.

$w_{1i}$ shows rent of land paid by ith farmer in Rs.

$w_{2i}$ shows total amount paid for tractor use by ith farmer in Rs.

$w_{3i}$ shows total seed cost by ith farmer in Rs.

$w_{4i}$ shows total NPK cost by ith farmer in Rs.

$w_{5i}$ shows total pesticide cost by ith farmer in Rs.

$w_{6i}$ shows total irrigation cost by ith farmer in Rs.

$w_{7i}$ shows total labour cost by ith farmer in Rs.

$w_{8i}$ shows total polythene sheet cost by ith farmer in Rs.

$w_{9i}$ shows total mulch cost by ith farmer in Rs.

Economic efficiency was obtained by dividing minimum cost with observed cost.

Economic Efficiency = minimum cost/observed cost

$EE = w_i x_i^E / w_i x_i$

**(e) Estimation of allocative efficiency**

A ratio of economic efficiency to technical efficiency gives allocative efficiency.

Allocative Efficiency = Economic Efficiency / Technical Efficiency

AE = EE/TE

**(f) Tobit regression model**

Identification of the determinants of inefficiency among the farmers is an important part of efficiency improvement studies (Ibrahim and Omotesho, 2013). The inefficiency scores were calculated by subtracting the efficiency scores from 1. The scores of technical, allocative and economic inefficiencies were individually regressed on farm specific and socio-economic variables. DEA model gives efficiency score from 0 to 1. Therefore, normal distribution was not observed for dependent variable and ordinary least square method was not useful because it gives biased results (Javed, 2009). Therefore, Tobit regression model (Tobin, 1958) was used by using socio-economic and farm-specific variables like age, family size, education, farming experience, contact with extension agents, off-season tomato area and vegetable market distance. To assess the inefficiency, Tobit regression model is given as:

$E_i = E_i^* = \beta_0 + \beta_1 Z_{1i} + \beta_2 Z_{2i} + \beta_3 Z_{3i} + \beta_4 Z_{4i} + \beta_5 Z_{5i} + \beta_6 Z_{6i} + \beta_7 Z_{7i} + \beta_8 Z_{8i} + \mu_i$

If $E^* > 0$

$E = 0$ if If $E^* \leq 0$

Where

i refers to the ith farmer in the sample.

Ei shows the technical, allocative, and economic inefficiency of the ith farmer.

Ei* is the latent variable.

$Z_{1i}$ shows the age of the ith farmer (years)

$Z_{2i}$ shows the education of the ith farmer (years)

$Z_{3i}$ shows the total family size of the ith farmer (no.)

$Z_{4i}$ shows the off-season tomato experience of the ith farmer (years)

$Z_{5i}$ shows contact with extension agents by the ith farmer (no.)

$Z_{6i}$ shows off-season tomato area by the ith farmer (acres)

$Z_{7i}$ shows the distance of vegetable market from ith farmer (km.)

$Z_{8i}$ represents the dummy for credit availability for ith farmer.

ß's are unknown parameters to be estimated.

µi is the error term.

## RESULTS AND DISCUSSION

### Descriptive analysis of socio-economic variables

Table 1 show that the descriptive statistics of socio-economic variables which were used as a determinant of technical, allocative and economic inefficiencies. There involved younger as well as older farmers but the mean age was 40.53 years. Both Illiterate and highly educated farmers were involved in this business but average education level was 9.45 years. The average family size of 9.07 members was observed ranging from 6 to 24. Fresh as well as experience farmers were involved in this activity, having average farming experience of 18.50 years. Contact with extension agent is important for the adoption of new technologies like tunnel farming. On average, off-season tomato farmers had 4.54 times meetings with extension agents. There exist variations in area under off-season tomato because both small and large farmers were operating in this business. The average area under off-season tomato was 1.54 acres due to large numbers of small farmers. Mostly farmers prefer to sell their produce in Faisalabad vegetable market due to high return. So, average distance of vegetable market from tomato farm was 74.04 km.

There are large variations in the use of inputs and output due to various reasons but Table 2 shows the mean value of each variable on per acre basis. The small farmers with financial constraint use less inputs and with resultant lesser production. On the other hand, the settled farmers with financial availability used maximum amount of inputs and get maximum output. Access to credit is an option but many farmers refused to get financial support due to interest payments. The revenue from vegetables is not predictable because there is no support price in case of vegetables. The large fluctuation in the price of vegetables is a reason behind less investment in vegetables. The average production of off-season tomato was 28714.84 kg and the variation in yield was due to input use variations. The mean value of revenue was Rs. 1.324 million with minimum Rs. 0.731 million and maximum Rs. 1.780 million due to variation in output. The variations in output strengthen the concept of production inefficiency. Average variable cost was Rs. 422284.90 and average total cost was Rs. 455418.90. Generally, farmers used tunnel material like iron pipes, bamboo, t-iron, iron wire, nut bolt for more than one year. However, polythene sheet and mulch sheet were purchases for each crop. So, this study estimated the depreciation of tunnel material by using its life information and incorporated tunnel cost in the variable cost. However, the Table 2 showed the value of initial purchase of tunnel material but this study does not include the total tunnel material cost in variable cost due to its long life. Moreover, tunnel cost had variations because some farmers used bamboo instead of iron pipes and t-iron due to low prices. There are three main types of tunnel like small tunnel with 4-5 ft height, walk-in tunnel with 6-7 ft height and large tunnel with 10-12 ft height. More resources are required for large tunnel and less resource are required for small tunnels. Average value of land rent was Rs. 33038.10 calculated for eight months in off-season tomato production. Tractor cost was Rs. 13873.93 on average and it was used for ploughing, planking, ridge making, with rotavator and for leveling. Number of ploughing and planking had variations depending upon the type of land and financial resources. Many seed varieties are available in the market such as local and hybrid. Hybrid seed provides more production but it is expensive. On average, a farmer used Rs. 47574.64 for the purchase of seed. Another important input was fertilizer with average

**Table 1: Descriptive statistics of variables used in Tobit model**

| Variables | Mean | Maximum | Minimum | Standard Deviation |
|---|---|---|---|---|
| Age (year) | 40.53 | 80 | 15 | 13.63 |
| Education (year) | 9.45 | 18 | 0 | 4.72 |
| Family size (No.) | 9.07 | 24 | 6 | 2.83 |
| Farming experience (year) | 18.50 | 50 | 3 | 11.68 |
| Contact with extension agent (No.) | 4.54 | 10 | 2 | 1.42 |
| Off-season tomato area (acre) | 1.54 | 9 | 0.5 | 1.62 |
| Distance of vegetable market (Km) | 74.04 | 100 | 15 | 29.76 |

**Table 2: Descriptive statistics of variables used in DEA model of off-season tomato**

| Variables | Mean | Maximum | Minimum | Standard Deviation |
|---|---|---|---|---|
| Yield (Kg/acre) | 28714.84 | 40800.00 | 13500.00 | 5732.83 |
| Revenue (Rs./acre) | 1324630.00 | 1870000.00 | 731250.00 | 255064.50 |
| Variable cost[1] (Rs./acre) | 422284.90 | 575175.00 | 290440.00 | 59525.45 |
| Total cost[2] (Rs./acre) | 455418.90 | 608598.30 | 317206.70 | 63404.09 |
| Tunnel material cost[3] (Rs.) | 233270.4 | 367,700.00 | 46,240.00 | 103,852.00 |
| Land rent (Rs./acre) | 33038.10 | 46666.67 | 16000.00 | 7410.13 |
| Tractor use cost (Rs./acre) | 13873.93 | 25500.00 | 7250.00 | 2806.11 |
| Seed cost (Rs./acre) | 47574.64 | 122000.00 | 10000.00 | 22223.22 |
| NPK cost (Rs./acre) | 69067.50 | 124750.00 | 27350.00 | 23364.78 |
| Chemical cost (Rs./acre) | 24614.29 | 45000.00 | 7000.00 | 6808.55 |
| Irrigation cost (Rs./acre) | 10243.86 | 50100.00 | 2100.00 | 6694.62 |
| Labor cost (Rs./acre) | 95785.71 | 175700.00 | 26800.00 | 24477.67 |

[1]Variable cost (VC) includes cost of tunnel preparation, land preparation, seed, seedling transplantation, hoeing, pesticide, irrigation, fertilization, picking and marketing. [2]Fixed cost includes land rent and abyana (water charges by Govt.). [3]Tunnel materials are used for many years except polythene and mulch sheet. We incorporate tunnel cost in variable cost by taking the depreciation value of each part.

expenditure of Rs. 69067.50. The farmers used different combination of fertilizers like farm yard manure, poultry manure, urea, DAP, NP, SSP and guara, according to the nature of crop and financial resources. Cultivation of vegetable requires deep attention toward disease and viral attack. Chemical cost was Rs. 24614.29 on average. Cultivation of vegetable is also a water intensive work and on average basis a farmer spends Rs. 10243.86 as irrigation charges. Water from tube well was found costly than canal water. But due to scarcity of canal water, farmers were bound to purchase tube well water. Some poor farmers avoided tube well water and the result was low production. Labor is most important input in this business and they performed different practices like ploughing, planking, ridge making, leveling, nursery sowing, transplanting, spraying, irrigation, weeding, transportation and picking. On average, a farmer spends Rs. 95785.71 in the form of labour charges. There were variations in all labour activities from ploughing to marketing. Some large farmers had permanent labour for performing these activities.

**Estimation of efficiency scores**

According to Javed (2009), data envelopment analysis (DEA) technique was beneficial because it does not use functional form assumption among inputs and outputs relation. Table 3 shows that the mean score of technical efficiency in off-season tomato farming was 88.90%, which implies the possibility of 11.1% reduction in the use of inputs for technically efficient farmers keeping the level of output and technology constant. Mean value of technical efficiency was 42.3% (Ogunniyi and Oladejo, 2011), 78.94% (Adenuga et al., 2013), 65% (Khan and Ali, 2013) and 92% (Khan and Ghafar, 2013). About 55.71% off-season tomato farmers had technical efficiency above 90% while remaining 44.29% farmers had technical efficiency between 50% and 90%. So, there are considerable chances to decrease the level of inputs to obtain same output level or obtaining more output by using same input level. The average allocative efficiency was 44.7%, which implies the reduction in production cost by 55.3% if they become allocatively efficient while output level and technology remain unchanged. About 40% off-season tomato growing farmers had allocative efficiency between 41% and 50%. The average value of pure technical efficiency was 97.9% with a low of 85.1% and high of 100%. It is higher because it is free from scale of production. A large number of previous studies ignored the distinction between technical efficiency on constant return to scale and technical efficiency on variable return to scale. The value of scale efficiency was 90.7% on average ranging from 53.1% to 100%. It was noted that only 37.14% off-season tomato growing farmers were scale efficient but other 62.86% farmers were scale inefficient. On average, economic efficiency was 40% ranging from 17.6% to 100%. Only 8.57% off-season tomato growing farmers had economic efficiency

**Table 3: Frequency distribution of production efficiencies**

| Efficiency range | Technical efficiency | | Allocative efficiency | | Economic efficiency | |
|---|---|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage |
| 0.21-0.30 | 0 | 0 | 7 | 10 | 7 | 10 |
| 0.31-0.40 | 0 | 0 | 16 | 22.86 | 16 | 22.86 |
| 0.41-0.50 | 0 | 0 | 28 | 40.00 | 28 | 40.00 |
| 0.51-0.60 | 4 | 5.71 | 13 | 18.57 | 13 | 18.57 |
| 0.61-0.70 | 5 | 7.14 | 4 | 5.71 | 4 | 5.71 |
| 0.71-0.80 | 7 | 10 | 1 | 1.43 | 1 | 1.43 |
| 0.81-0.90 | 15 | 21.43 | 0 | 0 | 0 | 0 |
| 0.91-1.00 | 39 | 55.71 | 1 | 1.43 | 1 | 1.43 |
| Total | 70 | 100 | 70 | 100 | 70 | 100 |
| Mean | 0.889 | | 0.447 | | 0.400 | |
| Maximum | 1 | | 1 | | 1 | |
| Minimum | 0.531 | | 0.247 | | 0.176 | |

**Table 4: Estimation of production efficiencies according to farm size**

| Farm size | Efficiency estimates | | | | |
|---|---|---|---|---|---|
| | $TE_{(CRS)}$ | $TE_{(VRS)}$ | SE | AE | EE |
| Small | 0.920 | 0.993 | 0.925 | 0.476 | 0.445 |
| Medium | 0.974 | 0.999 | 0.974 | 0.546 | 0.535 |
| Large | 0.946 | 0.998 | 0.947 | 0.650 | 0.613 |

CRS=Constant Returns to Scale, VRS=Variable Returns to Scale

above 50%. Increase in economic efficiency is also an important area of concern for policy makers. The allocative and economic efficiencies were 56% and 35% (Khan, 2012).

In order to check the influence of farm size on efficiency scores in off-season tomato growing, all types of efficiency estimates were calculated in case of small, medium and large farmer (Table 4). The value of production efficiency shows an increasing trend with farm size. The average value of total technical efficiency was 97.4% for medium farmers, 92.0% for small farmers and 94.6% for large farmers. The mean value of allocative efficiency was 47.6% for small farmers, 54.6% for medium farmers and 65% for large farmers. Similarly, economic efficiency was higher in case of large farmers and it was 61.3% on average while its value was 53.5% and 44.5% for medium and small farmers, respectively. Small farmers are main characteristic in Pakistani agriculture. Small farmer's prosperity is very important for the wellbeing of Pakistani society. Small farmers with less than 12.5 acres land owned 30.5 million acre area in Pakistan while 47.58 million is the total area (Adil et al., 2004). The values of productive efficiencies were higher for large farmers because large farmer had more financial resources and used quality inputs than small farmers. Moreover, large farmers also enjoyed the benefits of economies of scale.

**Estimation of Inefficiency determinants**

**Age**

Age was included as a determinant of technical, allocative and economic inefficiency to check the hypothesis that younger farmers had more attraction toward latest technologies and had less production inefficiency. The results showed that the coefficient of age was positive and significant for technical and economic inefficiency. It revealed that younger off-season tomato growers were more efficient as compared to old farmers. It confirmed the hypothesis that younger farmers had more attraction toward technology. These results have also a support from previous studies (Bozoglu and Ceyhan, 2007; Shaheen et al., 2011; Khan, 2012; Khan and Ali, 2013). Some other studies also showed opposite results (Ogunniyi and Oladejo, 2011; Khan and Ghafar, 2013).

**Education**

Education was included as a determinant of technical, allocative and economic inefficiency in order to check the hypothesis that educated farmers are more efficient. The results showed that the coefficient of education was negative and significant for technical, allocative and economic inefficiency. So it strongly accepts the hypothesis that an educated farmer had less inefficiency. An educated farmer efficiently utilizes the information about the use of inputs. These finding are in line with the findings of (Bozoglu and Ceyhan, 2007; Ogunniyi and Oladejo, 2011; Shaheen et al., 2011; Khan, 2012; Adenuga et al., 2013; Khan and Ali, 2013) and against the findings of Ibrahim and Omotesho (2013).

**Family Size**

Family size was incorporated as a determinant for technical, allocative and economic inefficiency to check the hypothesis that a farmer with more family member had high level of inefficiency. The results showed that the coefficient was positive and significant for allocative and economic inefficiency. So, it confirmed our hypothesis and revealed that as the family size increases the inefficiency score increases. A large family requires more financial assistance and farmer

**Table 5: Sources of inefficiencies in off-season tomato production**

| Variables | Units | Technical inefficiency | | Allocative inefficiency | | Economic inefficiency | |
|---|---|---|---|---|---|---|---|
| | | β | Prob. | β | Prob. | β | Prob. |
| Age | years | 0.010 | 0.001 | -0.001 | 0.937 | 0.002 | 0.005 |
| Education | years | -0.005 | 0.104 | -0.003 | 0.037 | -0.004 | 0.003 |
| Family size | no. | 0.002 | 0.609 | 0.004 | 0.036 | 0.007 | 0.001 |
| Off-season tomato experience | years | -0.008 | 0.016 | 0.003 | 0.120 | 0.001 | 0.298 |
| Contact with extension agent | no. | -0.004 | 0.093 | -0.002 | 0.054 | -0.004 | 0.001 |
| Off-season tomato area | acre | -0.006 | 0.022 | 0.002 | 0.128 | 0.001 | 0.517 |
| Distance of market | km | 0.003 | 0.038 | 0.005 | 0.000 | 0.002 | 0.000 |
| Credit availability (Dummy) | 0,1 | -0.058 | 0.073 | 0.008 | 0.678 | 0.022 | 0.234 |

have less available resources to spend for the use of new technology. It is cleared that new technologies like tunnels are generally expensive. These results were matched with (Bozoglu and Ceyhan, 2007).

**Off-season tomato experience**

"Experience makes a man perfect" is a reason behind the inclusion of experience as a determinant of inefficiency to test the hypothesis that an experienced farmer is more efficient. The results showed that the coefficient of experience was negative and significant for technical inefficiency. So, it confirmed the hypothesis that experienced farmers are more efficient. Finding of this study are in line with findings of studies reported previously (Bozoglu and Ceyhan, 2007; Ogunniyi and Oladejo, 2011; Khan and Ghafar, 2013).

**Contact with extension agent**

Contact with extension agent was used as a determinant of inefficiency to test the hypothesis that a farmer becomes more efficient when he receive extension services or technical guidance. The results showed that the coefficient was negative and significant for technical, allocative and economic inefficiencies. In the presence of extension services, a farmer is much aware about the combination of inputs and critical stages of a crop. So, it supported the hypothesis and we may conclude that as the number of extension visits increases than production inefficiency score decreases. The same results were concluded by previous studies (Bozoglu and Ceyhan, 2007; Khan, 2012; Khan and Ali, 2013).

**Off-season tomato area**

Off-season tomato growing area was included as a determinant of inefficiency. The coefficient was negative and significant for technical inefficiency, which revealed that inefficiency decreases as the area of off-season tomato increases. Generally, it is considered that the small farmers are more efficient but in this activity large farmers were more efficient because this business require large initial investment for the purchase of inputs. A farmer with greater area can easily afford the expenditures. Moreover large farmers owned machinery and permanent labors as well. The results are in the same line with (Bozoglu and Ceyhan, 2007) and not matched with (Ibrahim and Omotesho, 2013; Khan and Ghafar, 2013).

**Distance of market**

Distance of vegetable market from farm is included to explore the hypothesis that a distant farm had more inefficiency than a nearby farm. The results showed that the coefficient of market distance was positive and significant for technical, allocative and economic inefficiency. So, it explored that as the distance form vegetable market increase than the inefficiency scores also increases, due to increase in labor and transportation cost.

**Credit availability**

It is important for a business which requires large initial investment for the purchase of tunnel material. This study included the dummy variable for credit availability to test the hypothesis that a farmer with credit access has low inefficiencies score. The coefficient was negative and significant for technical inefficiency. So, it supports our hypothesis and in line with the findings of (Bozoglu and Ceyhan, 2007; Khan, 2012; Adenuga et al., 2013; Khan and Ali, 2013). But it was not matched with Shaheen et al. (2011).

**Conclusion and recommendations**

Based upon findings of this study, it was concluded the presence of inefficiency in the production of tomato under tunnel farming. It implies the possibility of reduction in inputs use and production cost for an efficient farmer in off-season tomato production. The government should subsidize the tunnel material, and ensure the quality of seeds, chemical spray and fertilizers. The government should provide extension services, technical education, and credit access in order to increase in production efficiency.

**Authors' contributions**

This research study was a collaborative effort of all authors. Author QA conceived the idea, designed the study, performed statistical analysis and wrote this manuscript. Authors MA and KB provided technical guidance and checked the work. Authors MTIK and MW supported in data collection, data entry and analysis. All authors read and approved the manuscript.

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