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EFFICIENCY ANALYSIS OF OFF-SEASON CAPSICUM/BELL PEPPER PRODUCTION IN PUNJAB-PAKISTAN: A DEA APPROACH

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ABSTRACT

The aim of present study was the estimation of technical, allocative and economic efficiency and inefficiency determinants in off-season capsicum/bell pepper production in Punjab, Pakistan. Primary data were collected from 70 off-season capsicum/bell pepper growers by simple random sampling in 2014. Data Envelopment Analysis Procedure revealed that mean technical efficiency was higher (78.8%) followed by allocative (56.6%) and economic efficiencies (44.3%). It indicates the possibility of 21.2% decrease in inputs and 43.4% decrease in total cost for technically and allocatively efficient farmers while output and technology remained unchanged. The lowest value of technical (40.8%), allocative (17.2%) and economic (17.2%) efficiencies were also calculated. Small farmers show high technical (89.0%), allocative (70.2%) and economic (62.5%) efficiencies. Tobit model shows that the education, experience in off-season capsicum/bell pepper production and meetings with extension staff had a significant and negative impact on inefficiency. The effect of family size, off-season capsicum/bell pepper area and distance of vegetable market was significant and positive on inefficiency. The government should improve the level of education, technical knowledge, extension services and quality of inputs. The government should provide a subsidy to small farmers in the purchase of tunnel material.

Keywords: Production efficiency; Farm size; Tunnel farming; Tobit Model; Off-season pepper.

INTRODUCTION

Progress in agriculture sector is a priority of government by introducing new technologies. This sector involved 42.3% labour force and its share was 19.8% in the gross domestic product in Pakistan. The role of agriculture was important for the improvement of all other sectors in the economy. For the purpose of food security, it was required to enhance the production and yield of crops (Government of Pakistan, 2015a & 2016a).

Vegetables are an inevitable component of the agriculture sector due to the provision of livelihood and foreign exchange earnings. It is also beneficial for health, nutritional level maintenance and disease resistance capabilities (Ogunniyi and Oladejo, 2011; Ibrahim and Omotesho, 2013). About 60% increase in the production of vegetables was observed over the past 20 years (Naik *et al.,* 2017). Poverty, unemployment, and malnutrition are serious issues faced by developing countries and vegetable sector have the ability to solve these problems in short run. These are a cheap source of nutrition and had the potential to grow on small farms. Small farmers were an important feature of developing countries. The period of cultivation for vegetables was short and made the possibility of many crops in one season (Akter *et al.,* 2011).

In 2010-11, Pakistan earned Rs. 47895.6 million by exporting vegetables and fruits but the export value was Rs. 66531.3 million in 2015-16 (Government of Pakistan, 2016b). Recommended vegetable consumption is 73 kg per capita on annual basis but it is 27.4 kg less in Pakistan (Shaheen *et al.,* 2011).

Capsicum (Capsicum annum L.) is also known as bell pepper or hot pepper and its family and genus are Solanaceae and Capsicum, respectively. Its local name is “shimla mirch” in Pakistan (Sreedhara *et al.,* 2013). Its global production has shown a rising trend in their availability in different varieties. It is a source of vitamin A, vitamin C, vitamin E, vitamin B6, thiamine, folic acid and beta carotene. People consume it in different forms such as green, spices, condiments, sauces and pickles. It provides a unique flavor, taste, and beauty in eating dishes (Komla, 2013).

Production of pepper is observed in all over the world except Antarctica and its history is also associated with the voyage of Columbus. Hot pepper was introduced by Columbus in Europe, Africa, and Asia. After quick spread in Europe, it reached in Japan, India and China (Jalu, 2014). In 1990, capsicum production was 11 million metric tons in the world but it was 28 million metric tons in 2009. China becomes the leading capsicum producer with 50% contribution in total production followed by Turkey (7%) and Mexico (7%). Total area under green pepper production was more than 1.8 million ha in the world (Tesfaw, 2013).

In 2013-14, the area under dry chilies production was 62,742 ha in Pakistan while it was 63,617 ha in

2012-13. Total chili production was 145,856 tonnes in 2013-14 and it was 149,162 tonnes in 2012-13. In 2013-14, the yield of dry chili was 2,108.9 kg per ha and it was 2,126.9 kg per ha in 2012-13. There were 1.38%, 2.22% and 0.85% decrease in the area, total production, and yield, respectively. In 2013-14, the area under dry chilies production was 5,612 ha in Punjab but it was 6,080 ha in 2012-13. Total production was 9,020 tonnes in 2013-14 but it was 9,625 tonnes in 2012-13. The yield was 1,458 kg per ha in 2013-14 but it was 1,436 kg per ha in 2012-13. There was 7.69% and 6.29% decrease in area and total production, respectively but 1.53% expansion in yield (Government of Pakistan, 2015b).

High prices at the beginning and end of the vegetable season could be controlled with the help of off-season vegetable cultivation. A farmer has more control over moisture level and temperature in tunnel farming (Government of Pakistan, 2013). Off-season cultivation of vegetables has expanded the season of the crop with a considerable increase in the yield. A farmer is able to supply their product in the vegetable market 7 to 14 days earlier (Iqbal *et al.,* 2009).

In order to fulfill the increasing food demand, it is required to eliminate the differences in the crop yield for different farmers. The difference in the yield of a particular crop explored the inefficient utilization of input resources and the presence of production inefficiency between the farmers. Therefore, it is important to explore the production efficiency by using different estimation techniques. In the case of vegetables, the improvement in the production efficiency can ensure the food security and also increase the living standard of vegetable farmers. Therefore, the present research was designed for the estimation of technical, allocative and economic efficiency in the production of off-season capsicum/bell pepper. This study also aims to investigate the estimation of production efficiency with respect to different farm size. It also explores the determinants of inefficiency in the production of off-season capsicum/bell pepper. This study also aims to present some policy implication in the light of results.

MATERIALS AND METHODS

Data and study area: Primary data were collected by using a comprehensive questionnaire forms from off-season capsicum/bell pepper growers in Toba Tek Singh and Faisalabad districts of Punjab, Pakistan in 2014. Off-season capsicum/bell pepper growers were interviewed about socio-economic variables, prices and quantity of inputs as well as output by using stratified random sampling technique. The population is divided into different subgroups like small, medium and large farmers in stratifies random sampling, then a sample is randomly selected from each sub group or strata (Ali *et al.,* 2017). The total population involved in the production of off-season vegetables is not much high, as it is a new technology and required high initial investment and proper care and management. A sample of 60 respondents was considered as suitable for decision making in the case of large population as pointed out by Poate and Daplyn (1993), cited in Mari (2009). Therefore, 70 off-season capsicum/bell pepper growers were interviewed in the study area and categorized as 23 small, 18 medium and 29 large farmers according to their farm size. The large farmers were more in the study area due to strong financial status, as off-season vegetable farming require high initial investment. According to Hassan *et al.* (2005), small farmers have less than 12.5 acres; medium farmers have less than 25 acres and more than 12.5 acres; and large farmers have more than 25 acres. Software like SPSS-15, Microsoft Excel, DEAP-2.1 and Eviews7 were used in this study.

Efficiency Background: Efficiency is a comparison between maximum and existing productivity of a firm (Farrell, 1957). Production frontier was used for the determination of maximum productivity of a firm. Two techniques were used for the estimation of production frontier named stochastic frontier analysis (SFA) and data envelopment analysis (DEA). DEA method was based on linear programming. Inefficiency exists when there was a gap between actual data and frontier of a firm (Javed, 2009). According to Coelli *et al.* (1998), the DEA model can be output or input oriented. Input oriented DEA model was used in this study because an off-season capsicum/bell pepper grower has more control over inputs.

Javed (2009) explained that technical efficiency is attaining of the maximum product by the use of given inputs with the help of production function. It is calculated with the help of DEA model based on variable or constant returns to scale. Coelli *et al.* (1998) suggested the use of DEA model based on constant returns to scale if all firms were working at optimal scale otherwise the value of technical efficiency was confounded by scale efficiency. Banker *et al.* (1984) give the concept of DEA model based on variable returns to scale by using convexity constraints. The present study used both variable and constant return to scale DEA models.

Analytical Framework and Empirical Models: The current study used the input-oriented DEA model based on a constant and variable return to scale for the calculation of total technical and pure technical efficiency, respectively. Total revenue (Y) was considered as a dependent variable in efficiency score calculation. Land (X1) in acres; tractor use (X2) in hours; seed rate (X3) in Kg; fertilizer use (X4) in Kg; pesticide use (X5) in numbers; irrigation (X6) in hours; labour use (X7) in days; polythene sheet use (X8) in Kg and mulch sheet use (X9) in Kg were input variables used in DEA.

(a) DEA Model for technical efficiency estimation: Input oriented DEA model with constant return to scale was used for the estimation of technical efficiency (Javed, 2009) and expressed as:

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

subject to

$-yi + Y\lambda \geq 0$

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

$\lambda \geq 0$

Where:

Y represents the output matrix for N off-season capsicum/bell pepper farmers.

θ represents the total technical efficiency.

λ represents Nx1 constants.

X represents input matrix for N off-season capsicum/bell pepper farmers.

yi represents the total revenue (Rs.)

xi represents the vector of inputs x1i,x2i,……x9i

X_{1i} represents the area under off-seasonal capsicum/bell pepper (acres)

X_{2i} represents the total tractor used (hours) in farm operations

X_{3i} represents the total quantity of seed (kg)

x_{4i} represents the weight of NPK (kg)

x_{5i} represents the chemical applications (No.)

X_{6i} represents the total irrigation (hours)

X_{7i} represents the total labour man-days required for all farm operations

x_{8i} represents the polythene sheet weight (kg)

x_{9i} represents the mulch sheet weight (kg)

(b) DEA Model for Pure Technical Efficiency Estimation

An input-oriented DEA model with variable return to scale was applied by Coelli *et al.* (1998), cited in Javed (2009) for the estimation of pure technical efficiency and expressed as:

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

subject to

$-yi + Y\lambda \geq 0$

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

$N1'\lambda = 1$

$\lambda \geq 0$

Where:

θ indicates the pure technical efficiency of ith off-season capsicum/bell pepper farmer.

$N1'\lambda = 1$ indicates a convexity constraint to ensure that an inefficient farmer was benchmarked against the same size farmers.

(c) Scale Efficiency Estimation

Scale efficiency was simply calculated by taking a ratio between total technical and pure technical efficiency and expressed as:

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

The firm was operating at scale efficient or constant return to scale (CRS) if the value of scale efficiency was 1. The value of scale efficiency was less than 1 for scale inefficient firms. Scale inefficiency showed that the firm was operating either at decreasing (DRS) or increasing returns to scale (IRS). An input-oriented DEA model was adopted under non-increasing return to scale (NIRS) expressed below (Coelli *et al.,* 1998, cited in Javed, 2009):

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

subject to

$-yi + Y\lambda \geq 0$

$xi - X\lambda \geq 0$

$N1'\lambda \leq 1$

$\lambda \geq 0$

(d) Economic Efficiency Estimation

Economic efficiency is simply a ratio between minimum cost and observed cost as found by Javed (2009). Minimum cost was found by using cost minimization DEA model expressed as:

$\min_{\lambda, xi^E} wixi^E$

subject to

$-yi + Y\lambda \geq 0$

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

$N1'\lambda = 1$

$\lambda \geq 0$

Where:

wi represents input price vector w1i, w2i,………,w9i

xi^E represents the vector of cost minimizing input quantities

N represents the total off-season capsicum/bell pepper farmers

w_{1i} represents land rent in Rs.

w_{2i} represents total money spent on tractor use in Rs.

w_{3i} represents the total cost of seed in Rs.

w_{4i} represents the total cost of NPK in Rs.

w_{5i} represents the total cost of pesticide in Rs.

w_{6i} represents the total cost of irrigation in Rs.

w_{7i} represents the total cost of labour in Rs.

w_{8i} represents the total cost of the polythene sheet in Rs.

w_{9i} represents the total cost of mulch sheet in Rs.

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

Economic Efficiency = minimum cost/observed cost

$$EE = wixi^E / wi\, xi$$

(e) Estimation of Allocative Efficiency

Allocative efficiency is a ratio between economic efficiency and technical efficiency.

$$AE = EE/TE$$

Allocative Efficiency = Economic Efficiency / Technical Efficiency

(f) Tobit Regression Model

Reasons of efficiency variations among different farmers were explored by different efficiency improvement studies (Ibrahim and Omotesho, 2013). Inefficiency score of the individual farmer was obtained by subtracting the score of efficiency score from 1. The score of technical, allocative, and economic inefficiency was independently regressed on selected variables. DEA model gives an efficiency score ranges from 0 to 1. It indicates the absence of normal distribution for the dependent variable. Results showed biasness if the ordinary least square technique was applied as mentioned by Javed (2009). An alternative option was the use of Tobit regression model suggested by Tobin (1958).

Socio-economic as well as farm-related variables were included in the model like education, size of family, contact with extension agents, area, and experience in off-season capsicum/bell pepper, and distance of vegetable farm from the vegetable market. Tobit regression model was adopted for the estimation of inefficiency determinants and expressed as:

$$E_i = E_i^* = \beta_0 + \beta_1 Z_{1i} + \beta_2 Z_{2i} + \beta_3 Z_{3i} + \beta_4 Z_{4i} + \beta_5 Z_{5i} + \beta_6 Z_{6i} + \mu_i \quad \text{If } E^* > 0$$

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

Where

i represents ith farmer in the sample

Ei represents the technical, allocative, and economic inefficiency

Ei^* represents the latent variable.

Z_{1i} represents the education (years)

Z_{2i} represents the total family size (no.)

Z_{3i} represents the off-season capsicum/bell pepper experience (years)

Z_{4i} represents the contact with extension agents (no.)

Z_{5i} represents the area under off-season capsicum/bell pepper (acres)

Z_{6i} represents the vegetable market distance (km) from ith farm

ß's represents unknown parameters.

μi represents the error term.

RESULTS AND DISCUSSION

Summary statistics: Table 1 reveals the summary statistics of socio-economic variables for capsicum/bell pepper growers. The average age was 40.86 years with minimum (15 years) and maximum (80 years). Average education was 9.07 years with minimum illiterate and maximum postgraduate. The average size of the family was 9.13 members with minimum (4) and maximum (24). Off-season capsicum/bell pepper growers had 6.73 years experience but some farmers were new entrants in this business. Services from extension staff are also important and off-season capsicum/bell pepper growers had 4.56contactswith extension staff. On average, the area under off-season capsicum/bell pepper production was 4.56 acres. On average, the distance of vegetable farm from the vegetable market was 75.50 km.

Table 1. Summary statistics of socio-economic variables.

Variables	Unit	Mean	Max.	Min.	Standard Deviation
Age	Year	40.86	80	15	13.70
Education	Year	9.07	18	0	5.00
Size of family	No.	9.13	24	4	3.33
Off-season capsicum/bell pepper experience	Year	6.73	20	1	4.21
Contact with extension agent	No.	4.56	10	2	1.42
Off-season capsicum/bell pepper area	Acre	3.99	30	0.50	4.41
Vegetable market distance	Km	75.50	100	20	27.59

Table 2 presents the summary statistics of variables used in input-oriented DEA model. The range of a variable shows the variation in the use of input (Table 3). Farmers use different combinations of input according to their financial strength and small farmers used fewer resources due to financial weakness. The credit facility was available but high-interest payments create some problems. Average production of off-season capsicum/bell pepper was 53,830.93kg per acre ranging from 20,020.00 kg per acre to 112,500.00 kg per acre. Its wide range also supported the presence of inefficiency in production between the farmers. Average revenue from per acre off-season capsicum/bell pepper production was Rs. 1,321,400.00 or Rs. 1.321 million. The variable cost consists of tunnel preparation cost, land preparation cost, seed cost, pesticide cost, irrigation cost, fertilization cost, picking cost and marketing cost. The total variable cost was Rs. 497,918.98 per acre while total cost was Rs. 619,709.02 per acre. Tunnel material cost was Rs. 60,705.51 per acre. Tunnel material cost includes cost of string, nut bolt, polythene sheet, mulch sheet, labour charges. Tunnel material cost does not include the cost of tunnel material having more than 1 year life. Fixed cost includes depreciation, interest on initial investment, interest on variable cost, administration charges, rent of land and water charges by Govt. (abyana). Depreciation was calculated for long life tunnel material and included in the fixed cost. On average, rent of land was Rs. 33,500.00 calculated for eight months in off-season capsicum/bell pepper production. Cost of tractor use was Rs. 14,497.50. On average, a farmer spends Rs. 33,590.00on the purchase of seed. Expenditure on fertilizers was Rs. 76,423.57 per acre. The chemical cost in the production of off-season capsicum/bell pepper was Rs. 23,900.00per acre while irrigation cost was Rs. 9,445.93. A farmer paid Rs. 79,663.21 for various farm practices performed by labours with minimum (Rs. 35,050.00) and maximum (Rs. 345,400.00). Table 2 also shows the mean of input cost used in DEA according to different farm size like small, medium, and large.

Table 3 presents the summary statistics of variables used in input-oriented DEA model according to their measuring units. On average, the area under off-season capsicum was 3.99 acres which was more in the case of large farmers and less in the case of small farmers. The tractor use hours were 8.57 hours on average in all farming operations and medium farmers used tractor for 9.26 hours in the farming operations. On average, the use of seed was 0.17 kg per acre. On average, the use of NPK fertilizer was 674.26 kg in the production of off-season capsicum while large farmers used more NPK (712.61 kg). Average number of chemical applications was 25.06 in this activity and medium farmers applied more chemical sprays. On average, this crop required 25.61 hours irrigation while medium farmers applied 29.59 hour irrigation. The total labour-man days were 308.66 days on average, while medium farmers also used more labour in the farming operations. The use of polythene sheet was 163.00 kg on average basis but large farmers used more (174.00 kg) polythene sheet. The use of mulch sheet was 49.33 kg on average basis but small farmers used more (52.78 kg) mulch sheet.

Table 2. Summary statistics of variables used in DEA model (Revenue-Cost basis).

Variables	Unit	Full Sample				By Farm Size (Mean Value)		
		Mean	Minimum	Maximum	SD	Small	Medium	Large
Yield	Kg/acre	53830.93	20020.0	112500.00	15779.60	55598.04	56976.53	50476.98
Revenue	Rs./acre	1321400.00	672000.00	2100000.00	299243.43	1401086.96	1355388.89	1237103.45
Variable cost	Rs./acre	497918.98	283260.00	830875.00	84594.93	500069.61	502494.81	493373.14
Total cost	Rs./acre	619709.02	356235.20	990594.58	101343.52	618632.53	622279.32	618967.44
Tunnel material cost	Rs.	60705.51	18140.00	103950.00	19144.86	57693.30	54269.39	67089.34
Land rent	Rs./acre	33500.00	20000.00	46666.67	6950.65	32826.09	30925.93	35632.18
Tractor use cost	Rs./acre	14497.50	7250.00	25500.00	3097.09	13958.70	15919.44	14042.24
Seed cost	Rs./acre	33590.00	20000.00	42000.00	4441.43	34984.78	34108.33	32162.07
NPK cost	Rs./acre	76423.57	27350.00	185900.00	29612.87	71878.26	70122.22	83939.66
Chemical cost	Rs./acre	23900.00	5000.00	70000.00	10783.98	25695.65	26944.44	20586.21
Irrigation cost	Rs./acre	9445.93	1100.00	37600.00	5520.38	10002.39	10989.58	8046.47
Labor cost	Rs./acre	79663.21	35050.00	345400.00	40605.54	85235.87	84561.11	72203.45

Per acre basis

Table 3. Summary statistics of variables used in DEA model (by measuring unit).

Variables	Unit	Full Sample				By Farm Size (Mean Value)		
		Mean	Minimum	Maximum	SD	Small	Medium	Large
Land (X1)	acre	3.99	0.50	30.00	4.41	1.62	2.79	6.60
Tractor use (X2)	Hours	8.57	4.97	14.00	1.61	8.43	9.26	8.24
Seed rate (X3)	Kg	0.17	0.10	0.20	0.02	0.18	0.17	0.17
Fertilizer use (X4)	Kg	674.26	234.40	1541.80	242.72	646.56	647.88	712.61
Pesticide use (X5)	No.	25.06	8.00	50.00	8.37	25.20	26.39	24.12
Irrigation (X6)	Hours	25.61	6.00	95.00	12.95	26.98	29.59	22.05
Labour (X7)	Man-days	308.66	146.00	1379.00	156.59	303.65	334.28	296.72
Polythene sheet (X8)	Kg	163.00	30.00	260.00	50.21	155.35	155.06	174.00
Mulch sheet (X9)	Kg	49.33	20.00	160.00	23.75	52.78	50.53	45.84

Per acre basis

Efficiency score estimation: Table 4 presents the average value of technical (78.8%), allocative (56.6%) and economic (44.3%) efficiency in off-season capsicum/bell pepper production. It shows the possibility of 21.2% reduction in the use of inputs and 43.4% reduction in input cost for a technically and allocatively efficient farmer while output and technology remain unchanged. Only 34.29% farmers had more than 90% value of technical efficiency but only 8.58% and 5.72% farmers had more than 70% value of allocative and economic efficiency, respectively. Mean value of pure technical efficiency and scale efficiency was 94.3% and

83.0%, respectively. The mean value of technical efficiency was 70% in capsicum production in Nigeria as found by Ifeanyi (2010).

Table 4. Frequency distribution of efficiencies.

Efficiency range	Technical efficiency		Allocative efficiency		Economic efficiency	
	N	%	N	%	N	%
0.01-0.30	0	0	3	4.29	10	14.29
0.31-0.40	0	0	7	10	25	35.71
0.41-0.50	2	2.86	12	17.14	17	24.29
0.51-0.60	11	15.71	15	21.43	6	8.57
0.61-0.70	16	22.86	27	38.57	8	11.43
0.71-0.80	8	11.43	3	4.29	1	1.43
0.81-0.90	9	12.86	1	1.43	1	1.43
0.91-1.00	24	34.29	2	2.86	2	2.86
Total	70	100	70	100	70	100
Mean	0.788		0.566		0.443	
Maximum	1		1		1	
Minimum	0.408		0.172		0.172	

Table 5 demonstrates the mean value of efficiency for small, medium and large off-season capsicum/bell pepper growers. The mean value of total technical efficiency was higher (89.0%) for small farmers followed by medium (84.3%) and large (83.3%) farmers. Similarly, a small farmer holds the greater value of allocative (70.2%) and economic (62.5%) efficiency. The proportion of small farmers was high in Pakistani agriculture and their well being is very important for the society (Adil *et al.,* 2004).

Table 5. Estimation of production efficiencies with respect to farm size.

Farm Size	Efficiency estimates				
	$TE_{(CRS)}$	$TE_{(VRS)}$	SE	AE	EE
Small	0.890	0.980	0.907	0.702	0.625
Medium	0.843	0.996	0.845	0.573	0.486
Large	0.833	0.961	0.865	0.663	0.550

Table 6 demonstrates the percentage of farms according to scale efficiency in off-season capsicum/bell pepper production. About 50% medium farms were found scale efficient while the scale efficient farms were only 21.74% and 17.24% in the case of small and large farms, respectively. Approximately 82.76% large farms were producing this crop under IRS which was more as compared to small (69.57%) and medium (50%) farms. The number of farms operating under DRS was less as only 8.70% small farm were found under DRS while no medium and large farm was found under DRS.

Inefficiency determinants

Education: It was incorporated to explore the hypothesis that an educated farmer is more efficient in off-season capsicum/bell pepper production. The results showed a significant negative effect of education on technical and economic inefficiency. It shows the reduction in technical and economic inefficiency as a result of an increase in schooling years. The result was in line with Bozoglu and Ceyhan (2007), Khan (2012), Khan and Ali (2013), Ifeanyi (2010), Ogunniyi and Oladejo (2011), Shaheen *et al.* (2011) and Shrestha *et al.* (2014).

Table 6. Farms under CRS, IRS, and DRS (by farms size).

Farm Size	Scale Efficient Farm (%)	Farm under IRS (%)	Farm under DRS (%)
Small	21.74	69.57	8.70
Medium	50.00	50.00	0.00
Large	17.24	82.76	0.00

Family Size: It was used to confirm the hypothesis that a farmer with large family size had more inefficiency score. Its coefficient was significant and positive for allocative and economic inefficiency. Generally, a farmer with large family spends more financial resource and has fewer resources left to invest in the business. Off-season capsicum/bell pepper production is profitable but requires more initial investment. The result was in line with Bozoglu and Ceyhan (2007).

Off-season capsicum/bell pepper experience: It was used to test the hypothesis that less inefficiency was associated with an experienced farmer. Its coefficient was significant and negative for production inefficiency. An experienced farmer learns from experience and obtained more product by using same resources.

Contact with extension agent: It was included to study the hypothesis that there is a decrease in production inefficiency due to increase in extension services. Its coefficient was significant and negative for technical inefficiency. It showed that the value of inefficiency decrease when a farmer increases the contact with extension staff. The impact of extension service was in line with the findings of Bozoglu and Ceyhan (2007), Khan (2012), Khan and Ali (2013) and Shrestha *et al.* (2014).

Off-season capsicum/bell pepper area: It was significant and positive for allocative and economic inefficiency. It shows an increase in inefficiency due to more area under control. Generally, small farmers were recognized as more efficient because they utilize the scarce resources more efficiently. It is also confirmed by the results in table 5.

Distance of vegetable market: It was included to rectify the hypothesis that a distant farm is associated with the high value of inefficiency. Its coefficient was significant and positive for technical, allocative and economic inefficiency. It confirmed the positive association between distant farm and inefficiency in production due to the presence of high labour and transportation cost.

Table 7. Determinants of inefficiency.

Variables	Unit	Technical inefficiency		Allocative inefficiency		Economic inefficiency	
		β	prob.	β	prob.	β	prob.
Education	year	-0.021*	0.001	-0.003	0.551	-0.013**	0.011
Size of family	no.	-0.002	0.759	0.021*	0.000	0.020*	0.000
Off-season capsicum/bell pepper experience	year	-0.055*	0.000	-0.019**	0.038	-0.019***	0.056
Extension agent contacts	no.	-0.044**	0.008	0.010	0.395	-0.011	0.406
Off-season capsicum/bell pepper area	acre	0.001	0.905	0.016*	0.000	0.015*	0.000
Vegetable market distance	km	0.004*	0.000	0.003*	0.000	0.005*	0.000

* significant at 1%, ** significant at 5%, *** significant at 10%

Conclusions: The research study demonstrates the technical, allocative and economic efficiency in off-season capsicum/bell pepper production by using the help of primary data from 70 respondents in Punjab, Pakistan. Data Envelopment Analysis explored a higher value for technical efficiency (78.8%) followed by allocative (56.6%) and economic (44.3%) efficiency. It describes the chances of 21.2% decrease in the use of inputs and 43.4% decrease in cost of production for a technical and allocative efficient farmer while output and technology remain constant. Tobit regression was used for the estimation of determinants of inefficiency in capsicum/bell pepper production. Results reveal that the education, experience of capsicum/bell pepper cultivation in the off-season, contacts with extension agents had a significant and negative impact on production inefficiency. The effect of the area under off-season capsicum/bell pepper, family size and vegetable market distance was significant and positive on inefficiency score. It shows a significant potential for the increase in technical, allocative and economic efficiency. The government should improve the technical education of off-season capsicum/bell pepper farmers. Extension department should improve their contact with farmers and create awareness about this profitable business. The government should control the prices of various inputs like fertilizers, hybrid seed, electricity, and chemicals. The government should also improve the quality of inputs like seed, sprays, and fertilizers. High initial investment on tunnel material is a problem for small farmers. The government should provide a subsidy to small farmers in the construction of tunnel structure.

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