



Research Article

Measurement of Allocative Efficiency in Tomato Production and its Determinants: Evidence from District Bajaur- Khyber Pakhtunkhwa, Pakistan

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Abstract | Current study was conducted to estimate allocative efficiency of tomato growers in district, Bajaur Khyber Pakhtunkhwa during crop season 2024. Data was collected from 214 tomato growers in tehsil Utman khel villages Gul Dehari and Matakko Gulibage through random sampling technique. Cost frontier was arrived by applying self-dual property of stochastic frontier Cobb– Douglas type production function. The estimated average allocative efficiency score was 78 percent, while only 18 % growers have achieved above the 90 % level. 28.51 % respondents' allocative efficiency varies from 71–80 %, followed by 22.4 % in the range of 81–90 %. Results illustrates, there is still scope to increase production and reduce cost by 22 % at existing level of inputs use and technology available. Tomato yield and inputs cost and land rent were explanatory variables, while total cost was dependent variable. Coefficient for yield is negative which shows that with one percent increase in yield decrease the cost by 0.069 percent. Estimated elasticities for land rent and inputs (seed, labor tractor hours, urea, DAP, farmyard manure, pesticides, and irrigation) cost has positive and significant effect on total cost of production. Optimal mix of inputs could reduce cost of production. In management variables, grower's age being a proxy for relevant experience and access to extension services were found significant contributors to allocative efficiency. On the other hand, allocative inefficiency has increased with increase in grower's formal education and family size. Through policies, keeping experienced growers involved in tomato production, reconsidering financial resources allocation to inputs by growers and their technical assistance via extension department could improve allocative efficiency score in study area.

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Introduction

Agriculture is the backbone of Pakistan economy since 1947. Currently it contributes 21 % to

GDP with an annual growth rate of 2.7 %, 44 % of the labor force's employment and 62 % of the country's rural population's livelihood. The agricultural sector contributes to food security, poverty alleviation and

industrial progress at national level. Cultivated and non-cultivated area totaling around 22 million and 8.3 million hectares respectively, across the country. Arable land and water resources sustain Pakistan's agriculture sector, which spans a variety of ecological and climatic zones (Azam and Shafiq, 2017).

Vegetables production contribute in food security and serve as a source of livelihood for masses. Tomato being an important and major vegetable throughout the world, commonly used in kitchen, as a supplement of fried food, paste, ketchup and juice etc. It contains rich amount of Vitamins A and C and an Antioxidant Lycopene an avoiding agent of different cancer types (Adenuga *et al.*, 2013). According to FAO (2016) its global production is about 177.04 million tons. In world ranking China is the leading tomato producer with 56.4 million annual productions, followed by India, USA, Turkey and Egypt. Pakistan stands its 35th position based on tomato production in world ranking (GOP, 2015).

The agro-climatic conditions and fertile land in Pakistan support vegetable production. Tomato is among major vegetables, grown all over the country and used around the year (Chohan and Ahmad, 2008). Small holders farmers are major contributors in tomato production (Furuya *et al.*, 2009). Tomato is grown as a cash crop all over the world, because of its short duration, high economic value and wide use in raw and processed form. Low market price at peak harvesting time, perishable nature and lack of processing facilities limits growers objective of high net returns (Kirby *et al.*, 2016).

Efficiency related studies on tomato crop were conducted by Khan and Ali (2013) at district Peshawar, Naveed *et al.* (2017) and Younas *et al.* (2024) at district Mohmand Ahmad *et al.* (2019) at district Mardan with different findings. Similarly, Ali *et al.* (2020) study on tomato cultivation in Khyber Pakhtunkhwa Peshawar, highlighted that tomato crop because of short yielding time and income has economic significance to farmers. The study reported, positive relationship between tomato production and growers socioeconomic characteristics, like education, work involvement, family size, farming experience, age, and land size by using Chi-Square. For enhancing productivity and efficiency the study recommends focus on the extension services, trainings, skill and basic education in study area. In term of references

Khan (2012) has reported allocative inefficiency of tomato crop in Khyber Pakhtunkhwa. They revealed that credit facility and education could increase crop productivity. Similarly, Byerlee (1987) has highlighted those new inputs are helpful to increase production but its application by untrained growers possible distress the returns adversely. Afridi *et al.* (2009) has reported high returns from short tenure crops (tomato, strawberry) compare to long tenure crops (wheat and sugarcane). Exploring such factors, the revenue of the growers can be multiplied in study area. Sanaullah and Urooba (2019) assessed the effect of agricultural extension trainings on crop productivity in district Bajaur. It was revealed that training imparted by the Bajaur Area Development Program, in vegetables, wheat and maize crop on targeted pesticide use and plant spacing has yield lucrative results. They further recommended easy access to credit for farming community in study area. These studies common conclusion and policy implication illustrate gap between minimum and maximum efficiency indices and existence of enough potential to increase the current performance level.

According to experts, decrease in inputs cost, development of high yielding technologies and improvement in management practices are possible option to increase net returns of growers. In Pakistan at national level, energy prices (electricity, gas, petroleum products) are getting revised upward continuously, which increase prices of agricultural inputs regularly. Similarly, variety development needs several years to develop and get accepted by the farming community. Therefore, only option to avail for decreasing cost of production and increasing productivity is focus on management practices. According to Bashir and Khan (2005) in context of economics improvement in management practices are investigated in term of in term of technical efficiency and allocative efficiency.

Major objectives of current study are to find cost inefficiency if any, determinants of cost of production, allocative efficiency score of sample respondents and to put forward recommendations based on findings of the study. Study carries both practical and theoretical importance. It would provide updated information to tomato growers, policy makers and others concerned. An in-depth analysis of factors effecting growers' performance at each district level is necessary to bridge the gap between minimum and maximum efficiency indices.

Materials and Methods

The study was conducted in Tehsil Utman Khal, district Bajaur this area is considered predominantly tomato valley region. Frost free climate, limited water resources and challenging agro ecological conditions are major characteristics. In study area farming, small business-like selling things on carts etc. throughout the country and remittances are main sources of livelihoods. People sale out their agriculture produce in local fruits and vegetable market Bajaur or take it to the markets like District Lower Dir, Peshawar, Rawalpindi and Lahore. Trend of vertical and high yielding tomato varieties is getting adopted in the area. Nursery raising and transplantation last up to end of February, while bearing and longevity depends on care, timely inputs application and management practices. Study is based on cross-sectional data, collected through questionnaire.

Yamane (1967) formula for sample size determination and Cochran (1977) proportional allocative technique was applied respondents selection in study area as given in Table 1.

Table 1: Sample size and proportional allocation in study area.

District	Tehsil	Villages	No. of farmers	Sample size
Bajaur	Utman khel	Gul Dehari	138	102 .6 $\approx$ 103
		Matako	153	110 .7 $\approx$ 111
		Gulibage		
Total		02	291	214

Source: Field Survey, 2024.

Cost frontier and allocative efficiency historical background

For cost function the stochastic cost frontier analysis method was used. Cost function is a relationship between cost of inputs and output produced at these costs. Availability of input prices reasonably presume that respondents thought as cost minimizers. The cost frontier would be an economic characteristics of production technology. Historical background of efficiency analysis and derivation of cost function from Cobb-Douglas type production function is discussed here:

Debreu (1951), Koopmans (1951) and Farrell (1957) are considered pioneers for theory and empirical investigation regarding efficiency. Farrell (1957) pioneer article on production frontiers, approaches

provide a way for researchers to investigate performance of observed production units. His measure of productive efficiency considered all inputs and overcome problems of index number approach, used prior to production function. During 1950 efficiency of agricultural production in all over 48 states of USA was investigated through Farrell (1957) model. In analysis land, labor (family plus hired), inputs (seed etc.) and capital were considered. Returns to growers were used as an output measure in analysis. Farrell (1957) also give the concept of technical, allocative efficiency and production frontier. He suggested efficiency as a relative term and rejected the concept of its absolute measurement based on data obtained from experimental plots.

Ultimate goal of econometricians is to develop models that are consistent with economic theory, being a foundation of production functions. Aigner and Chu (1968) and Aigner *et al.* (1977) translate Farrell's concept of frontier into a production function. It gets further modified to stochastic frontier approach (SFA) by Aigner *et al.* (1977), Charnes *et al.* (1978) and Battese and Corra (1977). Traditionally, Ordinary Least Square (OLS) regression method was used to describe production technology. OLS yield average values instead of maximum and minimum values. However, Farrell (1957) efficiency calculated represents maximum feasible output from a given quantity of inputs Ahmad and Bravo-Ureta (1996) pointed that Heady (1946) is first researcher who used production function to analysis performance of a producer. Schultz (1964) argued that farmers in developing countries may be poor but they are efficient, because of passing up of agriculture from generation to generation. In literature several studies has been conducted to test Schultz's hypothesis (Hopper, 1965).

Literature has pointed that in agricultural, efficiency related analysis has importance both for developed and developing economics. Historically, agricultural sector has also supplied productive resources to other agro-based industries with progress in its productivity and efficiency. Literature related to agricultural efficiency from back 1950 to date can be categorized into three distinct periods. Its review helps to understand purpose, methodologies, results and their implications for policy purpose. The period are as follow:

1950 to 1980 Period: Studies conducted during

this period has determine technical efficiency of agriculture production. While, due to lack of inputs prices allocative efficiency was not investigated.

1990 Period: Technical efficiency, allocative and scale efficiency were investigated during 1990. Efficiency, farm size and different estimation techniques were employed and focused in these studies.

2000 to Date: During this period different methodologies, effect of government policies, relative contribution of inputs growth and management practices were investigated in context of production efficiency.

Prior to the development of Data Enveloping Analysis (DEA) and Stochastic Frontier Analysis (SFA), simple econometric techniques and index numbers were employed. However, till the end of 1980 a mix of DEA and SFA, various functional form, estimation techniques, sample size impact and econometric error were incorporated and tried (Darku *et al.*, 2013).

In production economics the concept of duality correlated with optimization models, in optimization subject to certain constraints either maximum or minimum function can represent primal. If it is maximization function, the corresponding minimization function will be the dual and vice versa. In dual relationship information of primal can be obtained from dual, similarly, dual can be investigated from corresponding primal. In contemporary production theory the existence of Duality between the production function and the cost function was focused (Debertin, 2003). For single input production function, the dual cost function will be as follow:

Single input production function:

$$Y=x^b \quad \dots(1)$$

In physical terms it will be:

$$X=Y^{1/b}$$

While multiplying it with price it becomes.

$$VX = VY^{1/b}$$

Where; v represent inputs prices.

Bravo-Ureta and Pinheiro (1997) derived the corresponding cost frontier as follow:

$$Y=f(X_i, \beta_i) \quad \dots(2)$$

$$C \geq f(P, Y, \alpha) \quad \dots(3)$$

Equation 2 reflect that Y the output depends on X_i (inputs) used. Further Equation 3 specify that observed cost depends on input prices P and yield or output (Y). Equation 3 also illustrate that minimum cost is less than or equal to observed cost. Functional form for Equation 3 following Fatima *et al.* (2017) is as follow:

$$\ln C_i = \omega^0 + \sum_{n=1}^N \omega \ln P_i X_i + \sum_{m=1}^m \omega \ln Y_{mi} + (V_i + \mu_i) \quad \dots(4)$$

In Equation 4, V_i represents approximation errors, statistical noise and uncontrolled disturbance. While the term μ_i depicts the allocative inefficiency. According to Fatima *et al.* (2017) in production function inefficient growers operate below the production possibility frontier, which mean the frontier is convex to the origin, while in cost frontier the inefficient producers operate above the minimum cost frontier. Cost frontier is concave to the origin, so the tem $\omega = V_i + \mu_i$ will be change to $\omega = V_i - \mu_i$. Where, V_i represent factors like flood, climate change, pandemic etc that are not under control of the growers, while μ_i represents inefficiency on part of growers like not following proper rate and time of inputs application etc.

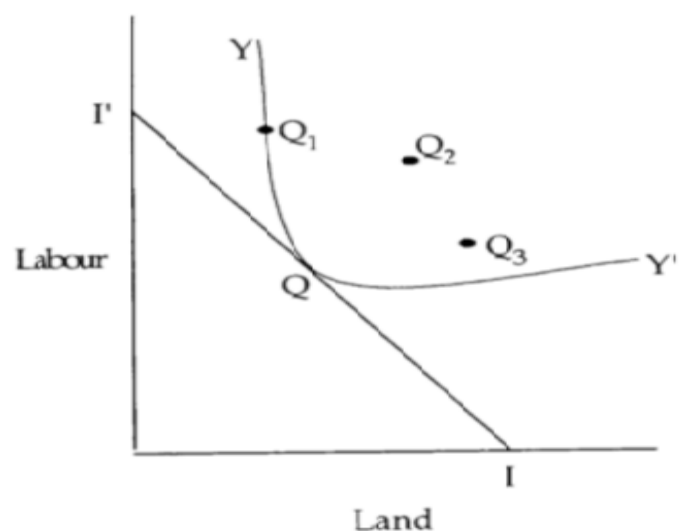


Figure 1: Diagrammatic representation of allocative efficiency: Adopted from Farrell (1957). The point of tangency (Q) for both the isoquant YY' and iso-cost II' that forms the optimal point. The point Q represent best combinations of inputs considering the prevailing market prices. The point also illustrates minimum expenditure that a profit maximizing producer should embrace.

Model for estimation of allocative efficiency in current study
Allocative efficiency can be interpreted in context of both cost minimization and profit maximization

approach. Farrell (1957) considered inability of a farmer to equate marginal factor cost to marginal product price as allocative in-efficiency. Other researchers like Lau and Yotopolous (1971), Schmidt and Lovell (1979) and Kopp and Diewert (1982) has also considered allocative inefficiency as inability of growers to equate marginal value product of inputs to its prices. According to Bashir and Khan (2005) allocative efficiency generally for cross sectional data can be estimated by equalizing Marginal value product (MVP) and Marginal Factor Cost (MFC).

In current study self-dual property of Cobb-Douglas type production function was applied to arrive the cost frontier, being a base to estimate allocative efficiency of sample respondents. Self-dual property of Cobb-Douglas type production function was preferred because it relates to optimization of model subject to certain constraints. According to Debertin (2012) in optimization either maximization or minimization represent the primal. In dual relationship, solution to the primal can be obtain from the corresponding dual. In current study cost frontier is the corresponding dual of production frontier. This method has applied by researchers like Bravo-Ureta and Pinheiro (1997) and Sajjad (2012). The specific functional form was as follow:

$$\ln C_j = \alpha_0 + \sum_{i=1}^{n=i} \alpha_j \ln p_j + \alpha_j \ln Y^* + \varepsilon_j \dots (5)$$

Where; C_j = total cost incurred on inputs (Rs/acre), Y^* = tomato Yield for year under study in kg acre⁻¹, ρ_1 = land rent per acre of ith farmer (Rs acre⁻¹), ρ_1 = cost of labor for all activities (Rs acre⁻¹), ρ_1 = seed cost (Rs acre⁻¹), ρ_1 = tractor hours cost for land preparation (Rs acre⁻¹), ρ_1 = Irrigation cost for entire season (Rs acre⁻¹), ρ_1 = urea fertilizer cost (Rs acre⁻¹), ρ_1 = DAP cost per acre (Rs acre⁻¹), ρ_1 = Fym cost (Rs acre⁻¹), ρ_1 = pesticides cost till harvesting (Rs acre⁻¹), ε_i = error term ($\mu i - \mu i$); α_0 = intercept of model; α_i = model parameters.

In above equation $\ln$, α_0 and α_i represents natural log, intercept and model parameters that need to be estimated. Inputs cost and tomato yield in study area was considered in log form as explanatory variables in the cost function.

Allocative efficiency of individual grower

For individual grower estimates of allocative efficiency of ratio of minimum cost to observed cost was considered. This method has also been applied by

Ali and Jan (2017) in their studies:

$$AE_j = \frac{C_i^*}{C_j} \dots (6)$$

Where; AE_j = Allocative efficiency of individual tomato growers in study area, C_i^* = minimum possible cost of ith tomato producer, C_j = Observed cost for jth tomato producer.

While individual tomato producer allocative inefficiency level was calculated by using the following formula.

$$\text{Allocative inefficiency} = 1 - \text{Allocative efficiency} = 1 - [\text{minimum cost } (C_i^*) / [\text{observed cost } (C_j)]$$

For allocative inefficiency model uncontrolled error term ($v_i \sim N(0, \sigma_v^2)$) normal distribution and inefficiency term ($\mu_i \sim N(0, \sigma_u^2)$) half distribution was assumed. Determinants were expressed as follows:

$$\mu_j = \delta_0 + \delta_1 Z_{1j} + \delta_2 Z_{2j} + \delta_3 Z_{3j} + \delta_4 Z_{4j} + \omega_i \dots (7)$$

Where; μ_j = Dependent variable for allocative inefficiency, Z_{1j} = Tomato grower's age (Years), Z_{2j} = Formal schooling years of respondent, Z_{3j} = Family size of tomato grower (No.), Z_{4j} = Extension contacts of tomato growers in entire season 2024 (No.), ω_i = Random error term having normal distribution with 0 mean and constant σ^2 , δ_0 represents constant for inefficiency model under consideration and δ_j are parameters to be estimated.

Results and Discussion

Principle findings followed by its discussion are presented in following section. Study area, respondent's socio-economic characteristics, inputs cost, gross revenue, net returns of tomato production along with allocative efficiency analysis were in following sections.

Universe of the study

District Bajaur geographically bounded by districts of Dir Lower, Mohmand, and Malakand to the east, south, and by Afghanistan to the west. District Bajaur divided into multiple tehsils, each with unique agricultural characteristics, the district has a total size of 1,220 square kilometers. Notable for their noteworthy contributions to the district's agricultural, tehsils Utman Khel is famous for high

production of tomato, which borders Malakand and is located in eastern Bajaur. It is an important region for the production of other vegetables and fruit orchards as well. District Bajaur plays a vital role in the region's food supply chain because of the tehsils' excellent geography and climate, which foster a robust agriculture sector. District Extension Office has declared this region as a tomato valley as given in Figure 2. Keeping in view the above facts Tehsil Utman Khel was selected for conducting the study.

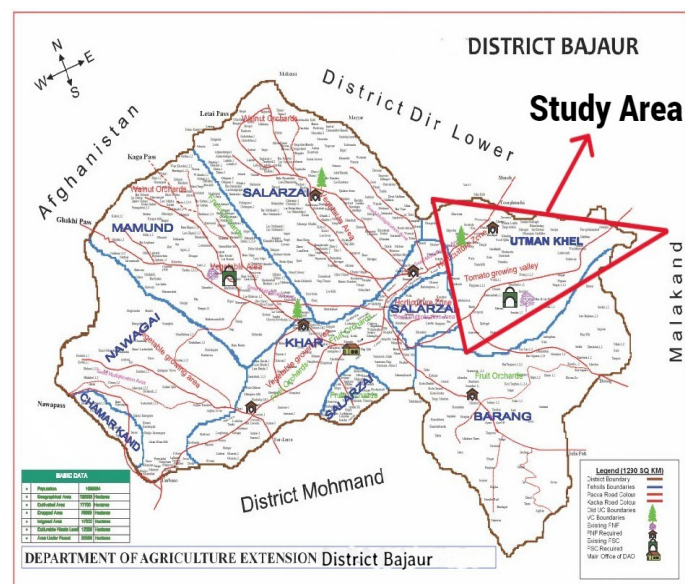


Figure 2: District Bajaur map.

Source: District director agriculture extension, Bajaur.

Respondents socio-economic characteristics

Prominent socioeconomic characteristics i.e., age, education, family size, access to extension services etc. influence grower's livelihood choices, technology adoption, contacts with trainers and decisions making process (Ali, 2018). In current study these characteristics are given in Table 2. Average age of respondents was noted 41.61 years, from minimum 19 to maximum 66. Average age shows that respondents are in working age group. Age was considered as proxy for experience. According to Collie (1996) age contribute in learning, personality growth, behavior and attitude development. Both positive and negative relations of age and inefficiency could be expected. Older farmers are experience but possible risk averse and traditional. On other hand younger farmers could be risk takers, willing to adopt new techniques and hence efficient.

Education has role in timely decision making, rational resources use etc. According to Niazi and Khan (2012) maximum economic and social issues are to low level

of education achievement. Farmers with higher level of education are expected to have good managerial skill and less inefficiency. According to Abdullah *et al.* (2007) both education and experience are important to deal rapid changing in farming system. Table shows that in study area respondents are literate up to primary level on average, while maximum education level was noted intermediate.

Table 2: Descriptive statistics of socio-economic variables.

Variable	Observation	Mean	Std. Dev	Minimum	Maximum
Age (Year)	214	41.61	13.16	19	66
Education (Year)	214	5.67	3.75	1	12
Family Size (No.)	214	10.54	5.96	4	13
Ext.Contact (No.)	214	8.52	3.64	3	16

Source: Primary data and experts (2024).

Family size represents all members dwelling under the same roof. According to Ali and Jan (2017) large family size has the advantage of labor force at peak cultivation, harvesting and picking times. Family members are motivated because of direct benefits from farms. However, excessive family labor also cause inefficiency due to hidden unemployment, therefore, both positive as well as negative signs are expected for estimated coefficient of family size in relation to inefficiency. In current study average family size was noted 10.54 numbers, which shows joint family culture in study area.

It is commonly argued that farmers access to more extension services both in literature and contact forms improved efficiency. Because of extension contacts growers have access to market information, best available practices and new inputs. Due to short shelf life of tomato, extension contacts serve best to avoid and decrease economic losses to growers. Average extension contacts were noted 8.52 up to maximum 16 for entire period. An increase extension contacts reflect importance of crop and interest of the growers.

Cost of inputs per acre and net returns analysis

Inputs unit, quantity used per acre, unit price and total value estimates are given in Table 3. Table 3 shows that land rent value is high followed by labor, irrigation, seed, DAP and others. Land rent vary according to crop grown, its profit and availability. Because of transformation trend to vertical tomato production and use of high yielding hybrid varieties growers were of the view that land rent will further

increase. Seed type and rate, pesticides and fertilizer application could yield lucrative results in its optimal mix. Incorporation of green manure technique, regular contacts from seed to harvesting and avoiding blind practices of fellow farmers could reduce resource wastage and cost of production. Table 3 shows that per acre total cost of production is Rs. 4,92,786.69. The value of output is about Rs. 14,88,241.13/-. The difference of total cost and total revenue gives profit of Rs. 9, 95,454.44/-.

Table 3: Per acre cost and net returns analysis in study area.

Inputs	Unit	Quantity/acre	Price/unit	Value
Land rent	Acre	1	112557.04	112557.04
Tractor Cost	Hour	5.115	1404.31	7183.06
Seed Cost	Gram	99.083	385.61	38207.40
Labor Cost	Day	236.187	891.60	210585.31
Urea Cost	Kg	164.084	103.57	16994.86
Dap Cost	Kg	115.89	275.58	31937.16
Fym Cost	Trolley	2.18	7597.31	16562.14
Pesticides	Milliliter	1846.29	10.01	18483.29
Irrigation	No.	20.187	1995.17	40276.43
Total Cost (TC)	RS.			492786.69
Total Revenue (TR)				
Yield	Kg	19539.27	76.17	1488241.13
Net Revenue (TR-TC)	RS/Acre.			995454.44

Source: Author's calculation from primary data (2024).

Estimates of cost function, allocative inefficiency and variance parameters

For data analysis maximum likelihood estimation technique was applied to find major factors that influence cost of production and allocative efficiency in study area. Results of the cost function are presented in Table 4. A total of fourteen parameters were estimated under cost function and inefficiency model. Table 4 shows that yield co-efficient is negative and significant at 5% significance level. Its estimated elasticity illustrates that one percent increase in production can decrease cost by 0.0695%. Result is according to the findings reported by Fatima et al. (2017). They highlighted that negative relationship between output and cost of production is realizing the economics of size. In economies of size increase in output resulted decrease in corresponding cost of production.

Results shows that in tomato production seed, labor, urea, DAP, organic fertilizer (FYM), pesticides, irrigation and land rent are major cost factors that carry positive sign and are significant at specified 5% level. The estimated elasticities shows that one percent increase in quantity of inputs could increase total cost by 0.453 % for seed, 0.248 by labor, 0.0077 by tractor hours, urea by 0.0194, DAP by 0.0329, 0.0211 by Fym, 0.0241 by pesticides, 0.0675 by irrigation and 0.1529 for land rent, respectively. Tractor hours coefficient is positive but non-significant which means that its contribution in total cost compare to other inputs is less.

Table 4: Regression model, allocative inefficiency estimates and variance parameters.

Variables	Parameter	Co-efficient	Std. deviation	T Value	P Value
Constant	α_0	1.312	0.293	4.480	0.000
Ln (Yield)	α_1	-0.069	0.012	-0.580	0.566
Ln (seed cost)	α_2	0.453	0.005	96.300	0.000
Ln (Labor cost)	α_3	0.248	0.008	29.020	0.000
Ln (tractor cost)	α_4	0.008	0.005	1.530	0.134
Ln (Urea Cost)	α_5	0.019	0.003	5.840	0.000
Ln (DAP cost)	α_6	0.033	0.003	9.440	0.000
Ln (Fym cost)	α_7	0.021	0.004	5.930	0.000
Ln (Pesticides)	α_8	0.0241	0.002	9.990	0.000
Ln (Irrigation)	α_9	0.067	0.021	3.240	0.003
Ln (land rent)	α_{10}	0.153	0.011	14.420	0.000
Allocative inefficiency model estimates					
Constant	δ_0	0.000879	0.0029121	0.30	0.764
Age (Year)	δ_1	-0.00021	0.0000723	-2.904	0.001
Education (Year)	δ_2	0.0002171	0.0001682	1.29	0.204
Family size (No.)	δ_3	0.0000612	0.0001078	0.57	0.573
Ext. contact (No.)	δ_4	-0.000229	0.0001102	-2.075	0.002
Variance parameters					
Sigma V	σ_v			0.049	
Sigma U	σ_μ			0.061	
Lambda (σ_μ/σ_v)	Λ			1.244	
Gamma ($\sigma_\mu^2/(\sigma_\mu^2 + \sigma_v^2)$)	Γ			0.61	

Source: Own calculation from survey data, 2024.

In inefficiency model farm manager age, formal education, family size and consultative contacts with extension workers were considered independent variables. In current study tomato grower was considered farm manager and his age was taken as a proxy for relevant experience. Results shows that

age and extension contacts are negatively co-related with allocative inefficiency. Extension services is an important policy instrument but capacity of extension workers, interest of growers and bureaucratic hurdles matter for its success. Increase in farm manager age or experience and paying extra consultative contacts with extension department could decrease inefficiency in production process.

Formal education and increase in family size has exhibited positive association with allocative inefficiency. Possible reason of direct association between inefficiency and formal education may be focus of educated youth on quick returns job, fitty business in different cities of the country and wage labor. During survey this trend was realized in study area. According to Ali (2018) educated people try to finds off-farm earning opportunities and give less attention to farming. On other hand education is less effective in areas where growers use traditional methods in farming. Musaba and Bwacha (2014) have also reported positive association between formal education and inefficiency. Khan and Ali (2013) have noted negative association for formal education and inefficiency, while Azhar (1991) argued little or no association between efficiency and formal education. The estimated gamma (γ) value is 0.61 which shows that 61 % variation in tomato cost of production among growers is associated with growers' allocative inefficiency. Gamma value represents factors which can be managed by growers like inputs adjustment, resources re allocation and application time etc.

Analysis of allocative efficiency

Frequency distribution for allocative efficiency of sample respondents is given in Table 5. Minimum level of allocative efficiency is about 69% and maximum is around 90%. About 29% farm managers allocative efficiency range between 71-80 %, followed by 22.43% which lies in 81-90% level and 14.48% respondents were found in 50-60% range. It was noticed that only 18.22 % out of total have gained above 90% allocative efficiency level. Positive association of family size and formal education with inefficiency level may be possible factors in detaining growers to achieve above 90 % allocative efficiency.

The estimated results given in Table 6 demonstrates that respondent on average realize allocative efficiency of about 78%. Results also revealed that 22% overall allocative inefficiency (OAI) exist in tomato

production of sample respondents. Hence, growers can decrease their cost of production by removing this inefficiency in their production process. Khan and Ali (2013) have conducted study on tomato efficiency in Peshawar, they reported average allocative efficiency score of 56 %. None of the grower's performance was to 100% allocative efficiency index. Resources allocation to next best alternative uses on part of farm managers were recommended. Similarly, Ahmad *et al.* (2019) have worked out allocative efficiency in district Mardan, they found that Urea, DAP and labor are underutilized, its readjustment could improve performance level of growers.

Table 5: Frequency distribution of sample respondents based on efficiency level.

Efficiency level	Frequency	Percentage out of total
50-60	31	14.485
61-70	35	16.355
71-80	61	28.504
81-90	48	22.429
> 90	39	18.224
Total	214	100

Source: Authors calculation from survey data, 2024.

Table 6: Allocative efficiency descriptive.

Estimates	Level
Mean	0.78
Std. Dev	0.051
Minimum	0.69
Maximum	0.90

Source: Authors calculation from survey data, 2024.

Conclusions and Recommendations

Being a country multiple on-going challenges like, climate change, raising external debt, inflation, political instability and dependence on agriculture sector necessitate to attain high level of efficiency in agriculture production. In present study total cost of production was dependent variable, while tomato yield, and cost of factors i.e seed, labor, tractor hours, urea, DAP, farmyard manure, pesticides, irrigation and land rent were independent variables. Self- dual property of Cobb-Douglas type production function was employed to arrive stochastic frontier cost function. Model results illustrate that yield is negatively correlated with cost of production, while other factors i.e., seed, labor tractor hours, urea, DAP, farmyard manure, pesticides, and irrigation have positive and

significant contribution in overall estimated cost. In socio-economic characteristics grower's age and extension contacts exhibit negative relationship with allocative inefficiency, while education and family size have positive but non-significant association with inefficiency. Results illustrate that mean allocative efficiency score is 78%, overall allocative inefficiency is 22 % in tomato production of study area. Inefficiency has harmful impact on farm income. To ensure food security and fulfill the growing market demand for fresh tomato, being a major vegetable, farm specific inefficiency factors need to be focused via national policies. Frequency distribution table shows that maximum respondents lines in the range of 70-80 % allocative efficiency. Above 90 % score was noted for only 18.22 % growers out of total in study area. Technological and technical assistance through extension department and policies to keep involved experienced growers in tomato production could contribute to highest allocative efficiency score in study area.

Future research need

Various crops (wheat, maize, rice), vegetables (tomato, onion, okra) and fruits are grown in district Bajaur. In future researchers need to focus on profitability and efficiency of single as well as complete cropping pattern in entire district. Cross sectional and panel data analysis pertaining to various aspects of these crops need to be considered.

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Novelty Statement

Tomato is an important livelihood source of respondents in study area and Up to knowledge of the researchers its first study conducted in newly merged district of Khyber Pakhtunkhwa.

Author's Contribution

Khuram Nawaz Sadozai: Developed main idea for conducting study and then reviewed the final draft of the paper.

Amjad Ali: Worked on primary data collection, tabulation, analysis and write-up.

Munawar Raza Kazmi: Review of final draft.

Rizwan Ahmad: Technically support and supervise the entire process.

Hazrat Younas: Work on initial draft of the paper along with cross checking for references in discussion.

Conflict of interest

The authors have declared no conflict of interest.

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