Research Article

# Technical Efficiency and Economic Analysis of Tomato Production in Khyber Pakhtunkhwa: A Stochastic Frontier Approach

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**Abstract** | This research investigated the technical efficiency of tomato production in the Mohamand district of Khyber Pakhtunkhwa, Pakistan. Data was collected from a sample of 119 tomato growers through a well-designed questionnaires and structured interviews. The research employed a multistage sampling technique to acquire primary research data, and the Cobb-Douglas type Stochastic Frontier Production model was utilized with maximum likelihood estimation. The outcomes unveiled a technical efficiency range of 0.73 to 0.76, with an average of 0.75. Notably, variables such as seedling, ploughing, labor, FYM, and pesticide demonstrated statistically significant, while urea, DAP, and irrigation were statistically insignificant. Moreover, the study identified experience as a significant contributor to inefficiency factors affecting farmers' technical efficiency. The research also shed light on the cost disparities between vertical and linear staking methods, with former incurring a production cost of Rs. 6,99,125/- compared to Rs. 1,84,000/- for the latter. Correspondingly, structured vertical staking led to higher profits, with Rs. 4,25,875/- compared to Rs. 1,92,000/- for linear staking, demonstrating the increased profitability of vertical staking practices. Based on the analysis, the study offers recommendations to foster the growth, promotion, and enhancement of vertically structured tomato production. Notably, labor costs constitute a substantial portion, approximately 50%, of tomato production expenses in the study area. To mitigate these costs, the adaptation of mechanized methods and the utilization of small machinery could hold the potential to reduce the production expenses. Furthermore, the application of a Cobb-Douglas production function regression unveiled a significant negative relationship between age and experience with inefficiency, suggesting the importance of both formal and informal education, such as Farmer Field School (FFS), and providing incentives to retain experience tomato growers in the production process. These measures have the potentials to further augment tomato production in the study area.

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## Introduction

Agriculture serves as a vital sector and a driving force within Pakistan's economy, employing approximately 37.4% of the labor force and contributing to 22.9% of the GDP. It holds immense potential as a catalyst for economic growth. However, the agricultural sector faces challenges such climate change, temperature fluctuations, water scarcity, varying rainfall patterns, and rising input costs. Despite these hurdles, agriculture plays a paramount role in sustaining livelihoods, driving rural development and ensuring food security (GoP, 2023).

In Pakistan, agricultural land occupies nearly 35 million hectares out of a total of 79.6 million hectares, with approximately 4.2 million hectares dedicated to forests. Among these, 22.93% is uncultivated land, 7.05 million hectares are arable, and 8.27 million hectares are used for cultivation. The majority of the rural population in Pakistan is engaged in agriculture, providing raw materials for industries and contributing significantly to export earnings. This sector encompasses four sub-sectors: livestock, crops, forestry, and fisheries, all of which make substantial contributions to the nation's economy (GoP, 2017).

The province of Khyber Pakhtunkhwa (PK) plays a pivotal role in fruit and vegetable production. Despite the potential for high yields, the newly merged districts of KP face challenges due to limited resources and poor socio-economic conditions of the farmers, resulting in lower actual yields compared to their potential. Districts, Mohmand and Bajaur demonstrate better yields for tomato and onions compared to other merged districts. Tomatoes, in particular, offer higher profitability to formers and generate employment opportunities for rural laborers. Tomatoes are versatile and widely used in various culinary preparations, making them a sought-after dietary staple. Given their high-income elasticity of demand, the demand for the vegetables remains consistently high with population and economics growth (Khan and Ali, 2013).

Globally, fresh tomato production stands at an estimated 182 million tonnes, with and average yield of 38 tonnes per hectare. China and India rank as the world's largest tomato producers, while Pakistan holding the 33rd position. Pakistan dedicates 61 thousand hectares to tomato cultivation, resulting in a total yield of 569 thousand tonnes and an average yield of 19.6 tonnes per hectare. Small-scale farmers in Pakistan dominate tomato production, influenced by the wide seasonality in production, tomato availability, and price fluctuation throughout the year. Pakistan experiences two tomato crop seasons annually, one in spring and another in autumn, although tomato cultivations is possible year-round in Sindh, the southern region of Pakistan. Tunnel farming practices are prevalent in remote areas of Baluchistan, Khyber Pakhtunkhwa, and Punjab (GoP, 2017).

Sindh emerges as the leading tomato producing province, with a tomato cultivation area of 27.9 thousands hectares, followed by Khyber Pakhtunkhwa, Baluchistan, and Punjab, in that order. The success of tomato farming in Sindh is attributed to the favorable soil and climatic conditions in the region. Sindh accounts for 43.6 % of the total tomato cultivation area and 24.5% of tomato production in the country in 2017. While, in Khyber Pakhtunkhwa 1.17 thousand hectares is dedicated to tomato cultivation, resulting in a total yield of 131.2 thousand tonnes with an average yield of 11.3 tonnes. Swat district stands out with the highest tomato production, totaling around 66.42 thousand tonnes, cultivated on 5.81 thousand hectares area. In swat valley, tomatoes from Cham Garhi Tehsil Bahrain typically hit the market in late August or early September, fetching excellent prices due to supply and demand dynamics. According to a 2008-2009 survey, Mohmand district encompasses 1,210.0 hectares of tomato cultivation, yielding a total production of 8,485.0 tonnes.

Tomatoes are garden crop and produced extensively worldwide and served as an essential element in many people's diets. Nutritionally, it provides vitamin C, potassium, folate, vitamin K and antioxidants like lycopene. It is a seasonal crop and can be used both in fresh and cooked form (Soytong *et al*., 2021). According to Qasim *et al*. (2018) tomato is an important vegetable in terms of area, yield and commercial use. FAOSTAT (2019) has reported that tomato production is two times higher compare to potato. Tomato is the most processed crop in the world, about 39 million tonnes are processed in factories that belong to the world's famous food brands.

Estimated annual tomato global production was 200 million tonnes with generated revenue of US$ 190 billion. Out of total production 7.3 million tons were exported. Mexico is the leading tomato exported while United States is the leading imported (Gatahi, 2020). In total global tomato production China contributes 52 percent, while Pakistan is the 33rd largest producer in world ranking (Tahir *et al*., 2012). Further, statistics shows that Pakistan accounts for 1.3 percent of global tomato area, 0.33 percent of global production, and 0.06 percent of global export. In the international tomato production, Pakistan ranks quite low in terms of per ha yield, export-production ratio, and export price. Its yield is only around a quarter of the global average. Pakistan is a net importer of fresh and processed tomatoes and the country is facing growing trade deficit. It grew from US$0.33 million in 2001 to US$114.9 million in 2016, before falling to US$32.4 million in 2017. During the period 2001-17, the country's tomato trade imbalance grew at a rate of 49 percent a year on average (TCFTS, 2020).

The justification for this study stems from its aim to access the factors influencing the technical efficiency of tomato farmers and identify opportunities for increased output. In the Mohmand districts, farmers engage in both off-season and regular season tomato cultivation. Despite the tomato crop being considered a lucrative crop, the producers fetch less marketing margin due to less yield, conventional crop management practices, and poor socioeconomic condition of the tomato growers. Keeping in mind the environmental condition of the Mohamand the tomato yield can be produced with a high yield if Farmers may focus on improved crop management practices. This research study will make an attempt to highlight the technical efficiency level of the farmers and to find out the factors which are responsible for the inefficiency of tomato growers. Furthermore, the study aims to provide recommendations to policymakers for promoting effective tomato production. To the best of our knowledge, no prior study has examined this subject in District Mohmand, Khyber Pakhtunkhwa.

The given objectives of the study are to compute the cost of production of the tomato crop in the study area. To estimate the technical efficiency of tomato production. To analyze factors affecting tomato producers' technical inefficiency and finally to present recommendations based on the study findings. These objectives aim to provide a comprehensive understanding of the tomato production economics, efficiency, and factors influencing performance, eventually influencing valuable insights and suggestions for improving efficiency and productivity in the tomato farming sector.

*Review of literature*

This research delves into the concept of technical efficiency, which evaluates the conversion of physical inputs such as land, labor and raw materials into outputs. Technical efficiency can be expressed as either output, representing the maximum output each input can generate, or input, signifying the minimum input required to produce a specific level of output; it provides insights into the current technological state of a specific industry (Hassan and Ahmad, 2005). Farell (1957) was a pioneer in applying technical efficiency, which encompasses both pricing proficiency and Production efficiency. Haile (2015) employed a similar approach. A previous study by Ali and Khan (2014) focused on estimating the technical efficiency of tomato, onion, and chili production. In the case of tomatoes, technical efficiency is accessed through the estimation of a production function using the Cobb-Douglas production function on a Stochastic Frontier.

Technical efficiency reflect the difference between what farmer is actually producing and what he can produce with the existing resources (Khan and Shoukat, 2013). Technical efficiency analysis helps to understand the potential improvement in farm production (Ogunniyi and Oladejo, 2011). It is vital to economist to deal increase of output with given inputs Battese and Coelli (1995). Productivity and efficiency related studies came into use from Koopmans (1951) later on formal base for current theory of efficiency analysis was laid down and prolonged by Farrell (1957). He further separated and use economic efficiency, allocative efficiency and technical efficiency. Both non-parametric and parametric approaches are used to measure efficiency. According to Bravo-Ureta and Pinheiro (1997) and Coelli and Perelman (1999) these both methods has its advantages and disadvantages. In non-parametric approach efficiency is measured in relation to the optimal production units. In this approach neither functional form nor distribution assumption of error term are imposed. While, in parametric approach functional form for production technology is specified along with making assumption about the distribution of error term. It also retain distinction between natural random error and farm specific technical inefficiency whereas non-paramatric has the random noise and technical inefficiency together (Uzundumlu *et al*., 2021).

Khan *et al*., (2020) observed technical, allocative, and economic efficiencies of tomato producer in Nowshera, Khyber Pakhtunkhwa. Technical efficiency score was noted 65 percent while allocative efficiency was 56 percent, respectively. Khan and Ghafar (2013) worked out technical efficiency of tomato growers in Peshawar, Khyber Pakhtunkhwa. They reported 92 percent score for technical efficiency. Age and experience were found main determinants of inefficiency in study area. Donkoh *et al*. (2018) conducted a study in Northern Ghana to assess tomato growers' technical efficiency. The average technical efficiency was 0.93, indicating the potential of enhancing tomato production by 7 percent at existing level of inputs. Tsoho *et al*. (2012) reported that farm location, cropping pattern, frequency of extension visits and irrigation are main determinants of technical and economic efficiency of vegetable farmers in Nigeria's Sokoto state.

Tabe-Ojong and Molua (2017) has reported that according to available literature most of the farmers have technical inefficiency issues irrespective of their land holding. Moreover, respondent age, education and agronomic practices has positive influence on technical efficiency. Zalkum *et al*. (2014) worked on tomato crop in Nigeria, 31.03 percent farmers were noted below frontier level, average estimated technical efficiency score was 69 percent. Khan and Shoukat (2013) employed stochastic frontier approach (SFA) to calculate technical efficiency of tomato grower in district Peshawar, Khyber Pakhtunkhwa, Pakistan. The estimated technical efficiency score was arrived 92 percent. Murthy *et al*. (2009) assessed technical efficiency of tomato growers in Karnataka, India. Their findings shows that small growers are cost effective and technical efficient. Innovative Farmers who adopt technologies get a higher return and output on investment.

## Materials and Methods

The study was conducted in Tehsil Prang Ghar, a predominantly tomato production region in district Mohmand. The tehsil is characterized by its frost free climate, limited water resources, and challenging agro-ecological conditions. Both vertical and horizontal tomato farming is practicing in district Mohmand. Tomato crops nursery raising and transplantation ends up to February and then the crop last up to November. Longevity of tomato fruit bearing time depends on its care, timely pesticide spray, irrigation and other management practices. The importance and challenges of tomato crop in study area, making it an apt setting to explore the technical efficiency. A cross-sectional survey design was employed to collect primary data from tomato growers in Tehsil Prang Ghar. A structured questionnaire was developed, validated, and pretested to ensure its reliability and appropriateness for the local context. The questionnaire encompassed multiple facets, including socio-demographic information, farming practices, resource utilization, and tomato production characteristics.

The sample was selected using a multistage random sampling technique. In the initial stage, villages were randomly chosen from Tehsil Pran Ghar, representing different agro ecological zones. In the subsequent stage, a list of tomato growers from each selected village was obtained from local agricultural extension offices at tehsil level. From this list, a proportional random sampling technique was employed to identify the final sample of tomato growers to be surveyed.

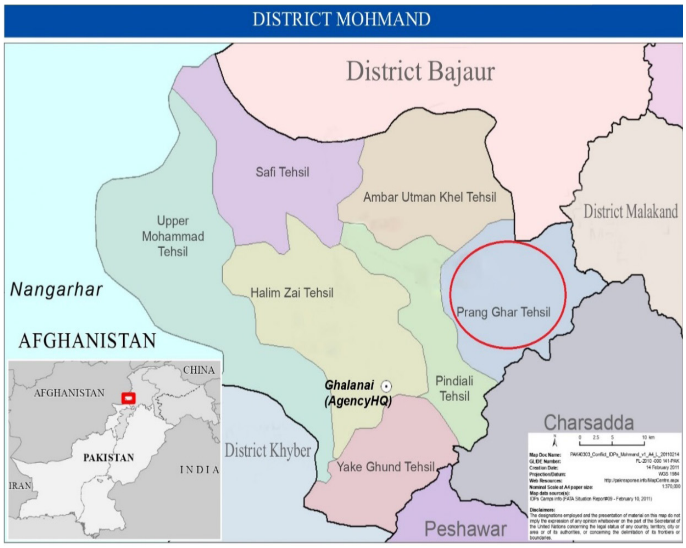


**Figure 1:** *District Mohmand map.*
**Source:** *Google Map, 2018.*

Figure 1 highlighted that district Momand has shared border with Afghanistan, district Peshawar, Charsadda and Bajour. There is no perennial water stream in district Momand. Solar tube wells are the only source of irrigation. Six Barani dams (Khurshad, J Dam, Yousaf Khal, Aqrab Dag, Motoshah and Michani dam) are also there to harvest rain water. But of because of low rain fall it remain dry most of the time. Continuously, year wise water table decrease 3 to 4 feet.

The soil and climatic conditions of the district is very conducive for producing other vegetable like potato, cauliflower, turnip, spinach, etc. as well.

Descriptive statistical techniques were employed to summarize the socio demographic characteristics (age of the sampled farmers, farming experience, education level, and membership of Farm Services Center (FSc) district Mohmand). Descriptive statistics were also estimated for yield obtained and inputs (seed, tractor hours, labor days, chemical fertilizer, farmyard manure and pesticides and weedicides) utilized during the tomato crop seasons 2022. Simple budgeting technique was employed to estimate net returns of horizontal and vertical tomato production in study area. The Cobb-Douglas production function was utilized to estimate the technical efficiency of tomato growers. The general form of the Cobb-Douglas production function is represented in Equation 1.

$$Yi = f(Xi, \beta) + \varepsilon i \ \ (i = 1,2 \dots n) \ \ \dots (1)$$

Where;

$Y_i$= Output; $X_i$= Inputs applied during the entire crop season by the tomato growers; β= Unknown parameters; $\varepsilon_i$= Error term for i[th] tomato grower's that is obtained by subtracting the predicted output from the observed output.

$$\varepsilon_i = V_i \varepsilon_i - \mu_i$$

The Cobb-Douglas production function was estimated using econometric software Stata. The estimated parameters (β and γ) were used to compute the technical efficiency of each respondent.

According to Saeed *et al.* (2023) Cobb-douglas production function has widespread application in agricultural economic research for technical efficiency analysis.

The coefficients of seed , tractor hours, labour days, chemical fertilizer, farmyard manure and pesticides/weedicides offers insights into performance of tomato production. The choice of employing the Cobb-Douglas function for analysis of technical efficiency is aligns with previous studies in agricultural contexts (Elyan *et al*., 2021). The multi-stage random sampling technique ensures and enhance the representation and generalizability of the study findings. Moreover, the validation and pretesting of the questionnaire contribute to the unbiased and robustness of the data collection procedures. The inclusion of socio-demographic information along with inputs use in the questionnaire facilitates a comprehensive insight of the factors influencing technical efficiency of tomato growers.

Methodology employed in this study encompasses a cross-sectional survey design, a multi-stage random sampling technique, simple budgeting technique and the application of the Cobb- Douglas production function. These methodological choices are based on established research practices and are in harmony with prior studies carried out in similar agricultural environment. Employing these approaches ensure the acquisition of unbiased, reliable and relevant data for exploring the technical efficiency of tomato growers in Tehsil Pran Gar, district Mohmand.

*Sample size and proportional allocation techniques for selection of respondents*

Employing Yamane (1967) techniques and Cochran (1977) proportional allocation technique, 119 respondents were selected as given in Table 1.

**Table 1:** *Sample respondents in study area.*

| District | Tehsil | Villages | No. of farmers | Sample size |
|---|---|---|---|---|
| Mohmand | Prang gar | Bakaro Dheri | 97 | 68 |
| | | Nawa Kalli | 73 | 51 |
| Total | | 02 | 170 | 119 |

**Source:** *Field survey (2022).*

## Results and Discussion

*Summary statistics of major variables considered in current study*

Study begins by presenting descriptive statistics in Table 2 of inputs applied during tomato crop season 2022 in Tehsil Prag Ghar. Tomato yield per acre was 15.46 tons/hectare, minimum yield realized was 15.22 tons/hectare and maximum was 15.53 tons/hectare. Ahmad *et al.* (2019) has reported 13.07 tons/hectare for district Mardan, which is adjacent to district Mohmand. Average land allocation to tomato crop was 1.74 acres up to maximum of 4 acres. The success and yield of any crop, including tomatoes, are influenced, among other factors, by the quality of the seeds.

**Table 2:** *Summary statistics of major variables used for per acre production.*

| Variables | Unit | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Yield | Kgs | 6185.32 | 51.827 | 6089 | 6292 |
| Land | Acres | 1.744 | 0.786 | 1 | 4 |
| Seed use (10 gm packet) | Pack | 34.591 | 18.706 | 1 | 8 |
| Manday's (all activities) | Days | 216.76 | 48.088 | 130 | 320 |
| Ploughing | Hrs. | 6.796 | 0.516 | 5 | 8 |
| Urea Bag (50kgs) | Bags | 115.82 | 28.704 | 1.2 | 3.3 |
| DAP Bag (50kgs) | Bags | 97.133 | 24.467 | 1 | 3 |
| FYM | Trolleys | 1.50 | 0.492 | 1 | 3 |
| Pesticide | Ml | 1150.3 | 48.897 | 1080 | 1250 |
| Irrigation | No's | 13.077 | 1.825 | 9 | 18 |
| | Total | 1637 | 172.43 | 141 | 2024.7 |

**Source:** *Primary data and experts (2021).*

The number of seedlings, considered a production unit, varies from farm to farm. In study area average seed used for nursery raising was 34.591 g/acre. Tomato cultivation is labor-intensive in nature. In study area, a total of 216.76man days, which encompassed tasks such as land preparation, applying farmyard manure (FYM), fertilizing, pesticide application, irrigation, and harvesting, were recorded. The range varied from a minimum of 130 man days to a maximum of 320 man days. The use of plowing also exhibited variability among farms, with an average value of 6.79 hours. The average urea usage during the study was 115.82 kgs, with a minimum of 55 kgs and a maximum of 175 kgs. Similarly, the application of Diammonium Phosphate (DAP) to enhance soil fertility and provide phosphorus for high-quality yield showed an average of 97.13 kgs, ranging from a minimum of 50 kgs to a maximum of 150 kgs.

Natural fertilizer in the form of farmyard manure (FYM) is crucial for maintaining soil fertility, and it is readily available in rural areas. The average FYM usage during the study was 1.50 tons, with a range from a minimum of 1 to a maximum of 3. Given the sensitivity of tomato crops, the use of pesticides is essential throughout the entire growing season. In the study area, farmer's exercised caution, regularly inspecting their tomato crops and applying chemicals as needed without hesitation. The average quantity of chemicals used per acre was 1150 ml, ranging from a minimum of 1080 ml to a maximum of 1250 ml. Irrigation is a fundamental requirement for optimal plant growth and yield. On average, the number of irrigations for tomato crops in the study was 13.077, with a minimum of 9 and a maximum of 18 irrigations.

**Table 3:** *Socioeconomic characteristics of respondents in study area.*

| | Characteristics | Frequencies | Percentages |
|---|---|---|---|
| Age | 20-30 | 19 | 15.97 |
| | 31-40 | 46 | 38.66 |
| | 41-50 | 40 | 33.61 |
| | 51 and Above | 14 | 11.76 |
| Education | Middle | 45 | 37.82 |
| | Matriculation | 39 | 32.78 |
| | Higher Secondary | 16 | 13.45 |
| | Bachelor | 11 | 9.24 |
| | Master | 8 | 6.72 |
| Experience | 0-15 | 31 | 26.05 |
| | 16-30 | 72 | 60.50 |
| | 31 and Above | 16 | 13.45 |
| Farm to market distance | 1 | 20 | 16.81 |
| | 2 | 38 | 31.93 |
| | 3 | 42 | 35.29 |
| | 4 | 19 | 15.97 |

**Source:** *Survey data crop year 2022.*

*Socioeconomic characteristics of Tehsil Prang Ghar*

Socioeconomic characteristics of respondents are given in Table 3. The age of a farmer plays a crucial role in the decision-making process, influencing their willingness to embrace or resist new technologies. It also contributes to an individual's learning attitudes and personal growth, ultimately impacting their overall performance as growers. It is anticipated that age can have both positive and negative effects on the technical efficiencies of farmers. Older farmers may possess more experience but tend to be more risk-averse, adhering to traditional and conservative practices while being reluctant to adopt new ones. Conversely, younger farmers are often more inclined to take risks, explore new initiatives, seize opportunities, and readily adopt advanced farming technologies, making them more technically efficient. In the current study, Table 3 reveals that a significant portion of the growers, 46 out of 119, fall within the age group of 31-40 years, which is considered the prime working age group in Pakistan. Providing targeted support and attention to this age group could potentially enhance their efficiency.

The persistent issue of neglecting education leading to adverse effects on agricultural productivity remains a concern in Pakistan. It is imperative to increase investments in order to broaden educational opportunities, including access to classes and training through agricultural extension services. Demonstrating the positive impact of education on agricultural output can significantly enhance the quality and yield of our agriculture. In other words, emphasizing the role of education underscores the importance of allocating more resources to its development, thereby promoting long-term economic and agricultural prosperity in the current study, Table 3 illustrates that the largest proportion of tomato growers, 45 out of 119 (37.82%), falls within the middle education category. Improved education equips growers with the knowledge to effectively follow instructions, such as the proper application of chemicals and other input operations. Engaging educated farmers in the agricultural sector and implementing tailored policies for them holds the potential for achieving higher yields and can be a valuable strategy for policymakers.

This article delves into the significance of experience among tomato growers, particularly in the context of agricultural technology adoption. Existing research has failed to definitively establish whether farming experience fosters or hinders the adoption of agricultural technologies (Knowler and Bradshaw, 2007). However, it is well-recognized that farming expertise can profoundly impact entrepreneurial decision-making. Moreover, the influence of this concept may vary across different age groups. In this regard, middle-aged groups are more likely to possess substantial farming experience, whereas youth groups often face financial constraints in acquiring land (Li *et al*., 2020). Consequently, the influence of agricultural experience on economic activities may be more pronounced in the middle-aged group compared to the younger demographic.

Furthermore, provincial capitals tend to be more economically developed than cities at other levels, characterized by larger populations and earlier urbanization (Zhou and Li, 2022). As highlighted in Table 3, the middle experience age group comprises a significant portion, with 72 out of 119 respondents having 16-30 years of experience, constituting 65.00 percent, in contrast to the experience category of 0-15 years, which accounts for 26.05 percent. Consequently, the impact of farming experience on economic activities is more pronounced within the middle-aged group than among the younger generation.

Individuals with a higher level of physical capital find it easier to achieve optimal income returns in the labor market since their prior experiences may exert a more substantial influence on current economic conditions (Shum and Faig, 2006). This, in turn, encourages the effective utilization of the advantages derived from their previous experiences and shapes their economic behavior.

When making production decisions, smallholder farmers in the Mohmand region of the Khyber Pakhtunkhwa province face significant challenges due to the state of the roads and the high costs associated with transportation. These farmers base their crop choices on considerations of technological efficiency, cost-effectiveness, and productivity. However, their choices are constrained by various factors, including labor availability, financial resources, concerns about food security, and access to both input and output markets. The proximity of farms to the market directly affects their accessibility, and as farm gate distance from the market increases, so do the costs of inputs, transportation, and the effective costs incurred by farmers for their outputs. To analyze this, the data were categorized into groups based on minimum and maximum distances in kilometers. Table 3 below presents the breakdown of farm gate distances from the market: Group 1: This group accounts for 20 cases (16.81%) and represents a cumulative percentage of 14.4%. Group 2: Comprising 38 cases (31.93%), this group represents a cumulative percentage of 48.9%. Group 3: With 42 cases (35.29%), this group constitutes a cumulative percentage of 87.8%. Group 4: This group includes 19 cases (15.97%) and has a cumulative percentage of 100%.

**Table 4:** *Total variable cost of vertical and conventional linear staking tomato production in district Mohmand.*

| Particulars | Vertical staking | | | Conventional linear staking | | |
|---|---|---|---|---|---|---|
| | Quantity | Price/Unit | Total (Rs/Acre) | Quantity | Price/Unit | Total (Rs/Acre) |
| Nursery Rising (land preperaton, watering, weeding, others) Man days | 12 | 600 | 7200 | 12 | 600 | 7200 |
| Seed (10 gram pack (No.)) | 6 | 9000 | 54000 | 5 | 2000 | 10000 |
| FYM (Hand cart) | 10 | 100 | 1000 | 10 | 100 | 1000 |
| NPK (Kg) | 10 | 80 | 800 | 10 | 80 | 800 |
| Total cost Nursury | | | 63000 | | | 19000 |
| **Crop production operation** | | | | | | |
| Land preparation (tractor hours) | 4 | 1500 | 6000 | 4 | 1500 | 6000 |
| FYM (Trolley) | 3 | 4000 | 12000 | 3 | 4000 | 12000 |
| Chemical fertilizer (Bags each of 50 kg) | 5 | 8000 | 40000 | 1 | 20000 | 20000 |
| Pesticides (weedicide, insectcide, fungicide) | 1 | 32000 | 32000 | 1 | 16000 | 16000 |
| Men days | 150 | 600 | 90000 | 85 | 600 | 51000 |
| structure (boomboos, labor) | 200 | 120 | 24000 | | | |
| Crop net | 60 | 400 | 24000 | | | |
| GI wire | 1 | 20000 | 20000 | | | |
| Sub total | | | 248000 | | | 105000 |
| **Marketeing cost** | | | | | | |
| Packing materials | 5625 | 7 | 39375 | 1875 | 10 | 18750 |
| Transportation cost to market | 5625 | 50 | 281250 | 1875 | 10 | 18750 |
| Market commission 6% | 1125000 | 6 | 67500 | 375000 | 6% | 22500 |
| Sub total | | | 388125 | | | 60000 |
| Total cost of production | | | 699125 | | | 184000 |
| Total Sales | 45000 | 25 | 1125000 | | | 375000 |
| Profit | | | 425875 | | | 191000 |

**Source:** *Primary data and experts (2022).*

*Variable costs of tomato production by using linear staking and vertical staking methods in study area*

The cost of production is derived from primary data collected from respondents, namely tomato farmers, and was further validated by agricultural experts. In District Mohmand, tomatoes are cultivated in open fields utilizing two methods: linear staking and vertical structures.

For standard open-field tomato production employing linear staking, the production cost stands at PKR 12.2 per kilogram. Based on expected yields, a farmer can target an average profit of PKR 191,000 per acre.

Conversely, the cost of production for structured tomato farming using vertical staking technology is PKR 14.9 per kilogram, which is slightly higher by 2 PKR compared to the cost associated with regular farming using horizontal staking. However, a farmer can potentially earn a profit of PKR 425,875 by adopting vertical structures for tomato cultivation, which is more than double the profit achievable through regular farming methods. Table 4 provides breakdown of the production expenses, operational costs, and marketing considerations for structured tomato farming, employing vertical staking, as well as for tomatoes cultivated with linear staking, all across one acre of land.

Tomato production encompasses both fixed and variable inputs. The subsequent information delineates the expenses associated with inputs in tomato production, marketing, and net return.

*Tomato production cost*

The cost associated with cultivating tomatoes, from land preparation to harvesting, is referred to as tomato production cost. The comprehensive summary of production costs provides insight into the cumulative contribution of all inputs employed in tomato cultivation and offers valuable data regarding yield's economic significance and profitability. In tomato production, costs include nursery raising, land preparation, seeds, farmyard manure, fertilizers (NPK, Urea, and DAP), weedicides, irrigation, and labor expenses. Table 4 presents an overview of tomato production costs.

*Nursery raising and transplanting*
Structured tomato farming with vertical staking involves planting nurseries in October and November, with saplings transplanted from February 15 to March 15. Harvesting takes place from May to July. To optimize yields, effective crop management practices are crucial. Tunnel farmers, on average, produce up to 2.000 bags of 10-11 kg (22 MTs per acre). Off-season (Kharif) tomato nurseries are planted in July-August, with saplings transplanted in August-September. Harvesting extends from November to February, and again, superior crop husbandry practices are essential. Tunnel farmers, on average, achieve production levels of up to 2,000 bags of 10-11 kg (22 MTS per acre).

When tomatoes need to be grown during unfavorable weather conditions, seedlings for open-field cultivation can be raised in plastic tunnels. A mixture of well-rotted farmyard manure, sand, and soil is commonly used as a medium for growing seedlings. Seedlings with a height of 15-25 cm and 3-5 true leaves are ideal for transplanting. Before transplanting, seedlings should be hardened by gradually reducing irrigation frequency and exposing them to strong sunlight. The nursery bed seedlings should be watered the day before transplanting. Transplanting should occur late in the afternoon to minimize seedling transpiration. The soil around the roots should be firmly pressed, ensuring good root contact, and the plants should be irrigated immediately. Transplanting is done on raised beds that are 1.5 meters wide, with a plant to plant distance of 50 cm and a row to row distance of 200 cm for optimal yield.

*Land preparation cost*
Land preparation is the foremost and crucial step in tomato cultivation. It involves plowing, leveling, and creating furrows, enhancing the soil's nutrient absorption and water retention capacity. In the study area, for structured tomato farming with linear staking, 4 tractor hours are employed per acre at a cost of Rs. 1500 per tractor hour. The average land preparation cost for tomatoes is Rs. 1500 per unit, representing 5.71% of the total production cost. Similarly, for vertical staking farming, 4 tractor hours are used per acre, with an average total cost of Rs. 1500 per unit. The average land preparation cost for tomatoes in this method is Rs. 6000 per acre, accounting for 2.41% of the total production cost.

*Crop production operations farm yard manure and fertilizer (NPK, Urea, DAP)*
Farmyard manure (FYM) is a natural fertilizer readily available to rural farmers. FYM is highly effective in improving soil fertility. In the study area, the use of FYM was widespread, with almost all sampled respondents employing it in varying quantities. For linear staking farming, FYM usage was measured at 3 trolleys per acre, with an average cost of Rs. 4000 per unit, representing 11.42% of the total cost. For vertical staking farming, the FYM amount was also 3 trolleys per acre, totaling 12000 PKR. The average cost of FYM for vertical staking was Rs. 4000 per unit, constituting 4.83% of the total cost.

Chemical fertilizers are used to boost crop productivity. Diammonium phosphate (DAP) is applied to the soil to enhance fertility and provide phosphorus for high-quality yields. Urea is applied to provide nitrogen for healthier crop growth, while NPK contains the essential nutrients nitrogen, phosphorus, and potassium. For linear staking farming, the average fertilizer cost was Rs. 20000/- per acre, accounting for 19.04% of the total cost. In vertical staking farming, the average fertilizer cost was Rs. 40000/- per acre, representing 16.1% of the total cost.

*Pesticide (Weedicide, Insecticide, Fungicide)*
Pesticides are substances used to control pests. In developing countries, expanding pesticide use is essential to maintain agricultural productivity and enable farmers to benefit from related investments. The average pesticide cost for vertical staking farming, including weedicide, insecticide, and fungicide, was Rs. 16000/- representing 15.23% of the total cost. For vertical staking farming, the average pesticide cost was Rs. 32000/- constituting 12.90% of the total cost.

*Man days (Labor cost)*
Labor plays a pivotal role in various crop production activities. Labor costs encompass the number of man-days involved in production, from land preparation to harvesting. Tomato cultivation is labor-intensive, with many farmers in the study area relying on

hired labor. Consequently, labor costs and labor days are higher than other variable costs. In the study area, labor costs include land preparation, planting, fertilizer application, harvesting, and collection. The average labor cost for linear staking tomatoes was Rs. 16000/- constituting 15.23% of the total cost. For vertical staking, the average labor cost was Rs. 90000/- representing 36.29% of the total cost. The majority of the total cost was allocated to wages.

*Marketing cost (packing material, transportation cost, market commission)*

The average marketing cost for linear tomato farming, including packing materials, transportation to the nearest market, and market commission, was Rs. 60000/- comprising 32.60% of the total production cost. For vertical staking farming, the average marketing cost, covering packaging, loading, transportation, and unloading, was 388125 PKR, representing 55.51% of the total cost.

Primary packing material cost is included in the production cost of a cost object. When both plain and fancy primary packing materials are used, the difference between them is categorized as secondary packing. For linear farming, the packing material cost was 18750 PKR, accounting for 31.25% of the total marketing cost. In structured farming with vertical staking, the average packing material cost was 39375 PKR, constituting 10.14% of the total cost.

Transport costs are calculated based on throughput, mode of transport, transport distance, and unit transport cost per ton throughput. For linear staking tomatoes, the average transportation cost from the farm to the market was 18750 PKR, representing 31.25% of the total marketing cost. In the case of vertical staking tomatoes, the average transportation cost was 281250 PKR, constituting 72.46% of the total. The commission paid to brokers (commission agents) for trading, 'based on the number of shares, options, and their monetary value, was also considered. For linear staking tomatoes, the commission amounted to 375000 PKR, with an average cost of 37.05% of the total marketing cost. Similarly, for vertical staking tomatoes, the commission amounted to 67500 PKR, with an average cost of 17.39% of the total cost.

Similarly the amount paid to the broker (commission agents) for vertical stacking tomatoes was 67500 PKR, the average cost of the commission was 17.39 percent of the total cost.

*Cobb-douglas type stochastic frontier production function estimates for tomato production in study area*

To estimate the Cobb-Douglas Stochastic Frontier Model, we employed the maximum likelihood estimation procedure. The study's outcomes aligned with our initial expectations, displaying the correct signs for all variables.

The results, as presented in Table 5 demonstrate that seedlings have a highly significant impact on production, with a p-value of 0.016. The coefficient for seedlings is 0.213, indicating that a one percent increase in seedling input leads to a corresponding 0.213 percent increase in output. This finding is consistent with the research of Khan and Ghaffar (2013).

**Table 5:** *Estimation of Cobb-Douglas type stochastic frontier production function for tomato growers (dependent variable = Ln yield).*

| Variables | Param-eters | Coeffi-cient | Std. Errors | T values | P values |
|---|---|---|---|---|---|
| Ln Seedling | $\beta_0$ | 0.213 | 0.088 | 2.42 | 0.016 |
| Ln Ploughing | $\beta_1$ | 0.055 | 0.078 | 7.10 | 0.000 |
| Ln labor | $\beta_2$ | 0.109 | 0.034 | 3.17 | 0.002 |
| Ln Urea | $\beta_3$ | 0.000 | 0.007 | 1.01 | 0.313 |
| Ln DAP | $\beta_4$ | 0.009 | 0.017 | 0.17 | 0.862 |
| Ln FYM | $\beta_5$ | 0.002 | 0.009 | 2.21 | 0.027 |
| Ln Pesticide | $\beta_6$ | 0.096 | 0.013 | 7.15 | 0.000 |
| Ln Irrigation | $\beta_7$ | 0.018 | 0.010 | 1.82 | 0.069 |
| **Inefficiency effect model** | | | | | |
| Constant | δ0 | -5.34 | 1.61 | -3.31 | 0.001 |
| Ln Age | δ1 | 3.11 | 1.39 | 2.27 | 2.23 |
| Ln Education | δ3 | -0.551 | .683 | -0.81 | 0.420 |
| Ln Experience | δ2 | -6.86 | 1.59 | -4.31 | 0.000 |
| Ln Distance | δ4 | -0.032 | 0.897 | -0.04 | 0.971 |
| **Variance parameters** | | | | | - |
| Sigma² u | α² u | 0.021 | - | - | - |
| Sigma² v | α² v | 0.033 | - | - | - |
| Sigma² | α² | 1.52 | - | - | - |
| Gamma (α² u/ α²) | Y | 0.56 | - | - | - |
| **Technical efficiency** | | | | | |
| Mean | $X_{mean}$ | 0.75 | - | - | - |
| Minimum | $X_{mini}$ | 0.73 | - | - | - |
| Maximum | $X_{mixi}$ | 0.76 | - | - | - |

**Source:** *Primary data and analysis (2022).*

The coefficient for plowing is positive (0.055) and statistically significant, signifying that plowing has a positive influence on tomato growers' output. This result is in line with the findings of Wasaya *et al.* (2012).

The labor coefficient is 0.109 and statistically significant, suggesting that expanding the labor force is likely to boost output. This discovery aligns with the research of Dipeolu and Akinbode (2008) and Sibiko *et al.* (2013). The coefficient for urea fertilizer is insignificant, with a value of 0.109, indicating that urea application negatively affects output. Since urea is banned in the merged districts, alternative inputs may need to be provided to farmers to enhance yields. This observation is in line with the findings of Dolisca and Jolly (2008) and Huq *et al.* (2010). The coefficient for DAP fertilizer is statistically insignificant, with a value of 0.002, implying that DAP does not significantly influence output. The coefficient for farmyard manure (FYM) is statistically significant, with a value of 0.002, indicating that a one percent increase in FYM application results in a 0.002 percent increase in output. This finding is consistent with the research of Khan *et al.* (2022).

The coefficient for chemical pesticides is also significant, with a value of 0.096, suggesting that increasing pesticide application by one percent leads to a 0.096 percent increase in output. This finding aligns with the results of Ahmad *et al.* (2005). The coefficient for irrigation is significant, with a value of 0.018, meaning that a one percent increase in the number of irrigation sessions leads to a 0.018 percent increase in output. This finding is in accordance with the research of Bakash *et al.* (2007) and Tsoho *et al.* (2012).

The results in Table 5 showed that seedling have highly significant effect on production having p-value of 0.016. The coefficient of seedling is 0.213 which suggests that by increasing one percent increase in seeding will benefit the farmers up to 0.213 percent rise in output. The finding of this study is accordance with the findings of Khan and Ghaffar (2013). The coefficient of the ploughing is positive (0.055) and significant which shows that ploughing has positive influence on the tomato growers output. This result is in conformity with the findings of Wasaya *et al.* (2012). The coefficient of the labor is 0.109 statistically significant which indicate that there are likely chances to increase the output by expanding the labors. This finding is similar to findings of Dipeolu and Akinbode (2008) and Sibiko *et al.* (2013). The coefficient of fertilizer (urea) is insignificant with the coefficient of 0.109 which indicates that urea application has negative effect on output. Urea is ban in the merged districts therefore an alternative inputs maybe provided to the farmers to enhance the yield. The study is similar with the finding of Dolisca and Jolly (2008). The coefficient of fertilizer (DAP) is statistically insignificant having coefficient of (0.002) which indicates that DAP does not influence the output. The coefficient of farm yard manure is statistically significant, having coefficient value of 0.002 which means that when there is one percent increase in the application of FYM there will be 0.002 percent increase in the output. This finding is in the coherence with the effects of Khan *et al.* (2022). The coefficient of the chemical (pesticide) is also significant, having coefficient value of 0.096, which suggests that the level of output will increase by 0.096 percent by the increase of one percent urea application. The finding of the study is in line with results of Ahmad *et al.* (2005). The coefficient of the irrigation is significant, having coefficient of 0.018 which means if the farmer increase the numbers of irrigation by one percent than there will 0.018 percent increase in output. The finding of the study is in accordance with Bakash *et al.* (2007) and Tsoho *et al.* (2012).

Efficiency factors such as age, education, experience, and farm gate distance were also examined. The results indicate that the T-ratios for education, experience, and distance (-0.81, -4.31, and -0.04) are negative and statistically significant. This implies that farmer education, experience, and proximity to the farm gate have substantial roles in reducing inefficiencies and increasing yield. The relationship between the age of tomato growers and technical efficiency is positive (2.27) but statistically insignificant, indicating that farmer age has no significant impact on yield. In the socioeconomic characteristics, the majority of respondents were in the age group of 26-30. The gamma value of 0.56 suggests that 56% of the variation in production is attributed to inefficiency, while the remaining 44% is due to unknown factors.

## Conclusions and Recommendations

This study focused on assessing the technical efficiency, production costs, and factors influencing the technical efficiency of tomato growers in District Mohmand, Khyber Pakhtunkhwa. Data from 90 respondents were collected through a multistage sampling technique, and a well-structured questionnaire was used for data collection. The collected data were analyzed using computer software such as STATA, SPSS, and MS Excel. The estimation of the Cobb-Douglas form of the Stochastic Production Function was carried out using the maximum likelihood estimation technique. The study found that the range of technical efficiency among tomato growers ranged from 0.73 to 0.76, with an average technical efficiency of 0.75.

Socioeconomic characteristics of the farmers revealed that the age of tomato growers ranged from 26 to 52 years, with a mean age of 39.211 years. Their experience in tomato cultivation ranged from 11 to 36 years, with a standard deviation of 5.77 and a mean experience of 20.76 years. The educational level of the growers ranged from 2 to 16 years, with an average of 7.97 years. The distance from the farms to the market ranged from 8 to 23 kilometers, with a mean distance of 15.31 kilometers.

For regular season tomato production using linear staking, the average total cost was 184.000 rupees. The highest cost component was the cost of inputs used in production operations at 105,000 rupees (57.6%), followed by marketing costs at 60,000 rupees (32.60%). Nursery costs included mendays cost at 7,200 rupees (37.89%), seed cost at 10,000 rupees (52.63%). farmyard manure (FYM) cost at 1,000 rupees (5.26%), NPK cost at 800 rupees (4.21%), and crop production operations cost, including land preparation, at 6,000 rupees (5.71%). Farmyard manure cost was 12,000 rupees (11.42%), fertilizer (NPK/Urea/DAP) cost was 20.000 rupees (19.04%), and pesticide (weedicide, insecticide, fungicide) cost was 16.000 rupees (15.23%). Mendays cost was 51,000 rupees (48.57%), followed by marketing costs, including packing material cost at 18,750 rupees (31.25%), transportation cost at 18.750 rupees (31.25%), and market commission (6%) cost at 22,500 rupees (37.05%).

For off-season tomato production using vertical staking, the average total cost was 699.125 rupees, with a total profit of 191,000 rupees. Nursery rising cost for one acre was 63.000 rupees (10.49 %), followed by crop production operation cost at 248,000 rupees (35.47%). Marketing costs were the highest at 388,125 rupees (55.52%). Nursery costs included mendays cost at 7.200 rupees (11.42%), seed cost at 54,000 rupees (85.71%), farmyard manure (FYM) cost at 1,000 rupees (1.58%), NPK cost at 800 rupees (1.26%), and crop production operations cost, including land preparation, at 6,000 rupees (2.41%). Farmyard manure cost was 12,000 rupees (4.83%). fertilizer (NPK/Urea/DAP) cost was 40,000 rupees (16.1%), and pesticide (weedicide, insecticide, fungicide) cost was 32,000 rupees (12.90%). Mendays cost was 90,000 rupees(36.29%), followed by marketing costs, including packing material cost at 39,375 rupees (10.14%), transportation cost at 281,250 rupees (72.46%), and market commission (6%) cost at 67,500 rupees (17.39%).

The study revealed that the technical efficiency of tomato growers in District Mohmand ranged from 0.73 to 0.76, with an average technical efficiency of 0.75, indicating that farmers in the study area efficiently utilize available resources. Factors such as age, experience, education, and farm-to-market distance were analyzed for their impact on inefficiency. Results indicated that age, education, and farm gate distance had an insignificant effect on technical efficiency, while experience had a significant impact.

The summary statistics of major variables used in the stochastic frontier analysis showed that the mean tomato yield was approximately 6,185.32 kgs per acre, with a minimum value of 6,089 kgs per acre and a maximum value of 6,292 kgs per acre. The cost of production analysis revealed that for regular season open-field linear staking, the cost was PKR 12.6/Kg, and a farmer could achieve an average profit of PKR 191,000 per acre. In contrast, structured tomato farming using vertical staking had a higher cost of PKR 14.9/Kg but yielded a profit of PKR 424,875 per acre, which was more than double in comparison with the profit of regular season farming.

Based on the study findings, it is recommended to promote vertical structure tomato production in the study area, as it has demonstrated higher profitability compared to linear staking. To reduce labor cost, mechanized methods and small machinery could be explored. The study also suggests that education, both formal and informal, such as Farmer Field School (FFS), and incentives to keep involve experienced growers in tomato production could further enhance tomato production in the study area.

## Novelty Statement

In this study, current position of horizontal and vertical tomato staking and potential gained through possible adjustment in practices and inputs use was pointed.

## Author's Contribution

**Hazrat Younas**: Principal author, conducted research, data collection and draft of the MS.
**Khuram Nawaz Sadozai**: Supervised data analysis and approved the MS.
**Amjad Ali**: Supervised and approved the MS.
**Rizwan Ahmad**: Helped in editing and technical assistance.

*Conflict of interest*
The authors have declared no conflict of interest.

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