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A COMPREHENSIVE FARM EFFICIENCY ANALYSIS OF APPLE GROWERS IN NEWLEY MERGED DISTRICT SOUTH WAZIRISTAN

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ABSTRACT

In the apple-producing land of South Waziristan's three tehsils, Wana, Bermal, and Tiarza, this research paper is designed to analyze farmers' efficiencies, e.g., production, allocative and technical dimensions. Through a Data Envelopment Analysis (DEA) framework, the study evaluates the performance trajectories of 304 apple growers. A multistage sampling technique was used for the farmer's interview. To the researcher's knowledge, there is no detailed efficiency analysis of South Waziristan's apple growers in existing literature, so there is a need to investigate the factors affecting efficiencies in the targeted area. The researcher is therefore encouraged to conduct a study of the farm efficiency of apple growers in South Waziristan. Apple growers' efficiencies were categorized as technical, allocative, and economic efficiency using the DEA approach. Results of the study show that there were tremendous inefficiencies of apple growers, which need to be reduced. This study sheds light on optimal resource allocation, productivity dynamics, and efficiency frontiers within apple cultivation in South Waziristan. The research offers an understanding of agricultural practices, resource utilization patterns, and efficiency benchmarks. The empirical insights derived from this comprehensive analysis facilitate informed decision-making among farmers and provide policymakers, agricultural stakeholders, and development practitioners with actionable recommendations to enhance agricultural productivity, sustainability, and socio-economic well-being in the region. Through empirical evidence and contextual relevance, this paper contributes significantly to the evolving discourse on agricultural efficiency analysis and underscores the imperative of tailored interventions for optimizing apple cultivation practices in South Waziristan.

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INTRODUCTION

In many developing nations, including Pakistan, the agricultural sector plays a pivotal role, contributing 18.9% to the national GDP and engaging 42.3% of the workforce (GOP, 2019b). Given its substantial reliance by a majority of the population, bolstering agricultural growth is crucial for ensuring food security and poverty alleviation. The research underscores the interconnected benefits of agricultural expansion, such as reduced food prices and increased employment opportunities, both within the agricultural sector and beyond (Irz et al., 2001; Janvry and Sadoulet, 2010; Schneider and Gugerty, 2011; Thirtle et al., 2003; Pingali, 2007).

Agricultural growth proves more effective in poverty reduction than its industrial counterpart, extending beyond mere farm income. As domestic incomes rise, so does consumer demand for both urban and rural goods and services (Dorosh et al., 2003). Pakistan's government is dedicated to enhancing agricultural production, bolstering marketing, and fostering trade competitiveness. Creating an enabling environment is pivotal for realizing these policy objectives, as increased agricultural income yields multifaceted benefits (Hayat et al., 2019). Agricultural advancements not only elevate household incomes surpassing other sectors but also disproportionately benefit impoverished households, as highlighted by the World Bank's estimation favoring the economically disadvantaged (Christiaensen et al., 2011). Concurrently, heightened crop production drives down real food prices, alleviating urban poverty pressures (Chengappa, 2018). Furthermore, agricultural progress catalyzes non-farm revenue growth, enhancing intersectoral synergies and value addition within Pakistan's economy (Henneberry et al., 2000).

Pakistan's agricultural productivity faces stagnation due to various challenges: sluggish technical progress, limited adoption of contemporary farming techniques, inconsistent input quality and timing, insufficient infrastructure investment and maintenance, trade barriers, disease outbreaks, and constrained access to credit (GOP, 2018a). Dominating the agricultural landscape, Punjab leads in productivity, followed by Sindh, Khyber Pakhtunkhwa, and Baluchistan in succession.

Producers in integrated modern supply chains reap benefits from heightened awareness, as highlighted by (Badar et al., 2019). Nonetheless, operational constraints in marketing and production often challenge the capacities of smallholders, disproportionately affecting the disadvantaged, as noted in studies by (Gereffi and Frederick, 2010; Kwon and Suh, 2005; Abebe et al., 2013). Contrarily, recent research underscores that modern value/supply chains fortify buyer-producer relationships, particularly benefiting stallholders in developing nations (Singh and Datta, 2010; Singh et al., 2011; Swinnen and Vandeplas, 2012; Gómez and Ricketts, 2013; Masamha et al., 2018).

Due to the importance of agriculture in income generation and its role in other sectors' development, this sector has been given high priority in governmental policies and strategies (GOP, 2019b). The agriculture sector provides food and income for the general population on a large scale. Although major and cash crops are important, the horticulture sector has emerged as vital due to the export potential. Apple holds a prominent place among other horticultural crops due to high domestic demand and potential for economic growth attributes (Khan, 2011; Sheikh and Tripathi , 2013). South Waziristan, where this study is proposed, is the second highest producer of apples after Baluchistan, fulfilling the home consumption and market demand. Statistics show that apple farmers in the targeted area are not substantially the recipients of benefits (GOP, 2019a). With this context, the author decided to address some of the issues related to the efficiency of agricultural commodities (apple). The role of different factors affecting the efficiency of apple growers in South Waziristan is addressed in detail.

Rational of the Research

The agriculture sector remains integral to Pakistan's socio-economic fabric despite its GDP contribution declining from 50% to 18.9% since independence (GOP, 2019a). Employing 42.3% of the national labor force, it continues to be the linchpin of Pakistan's economy, driving growth and poverty alleviation efforts. Recognizing its significance, governmental policies prioritize agricultural development (GOP, 2019a). While staple and cash crops are crucial, the horticulture sector, particularly apple cultivation, gains prominence due to its export potential and economic growth prospects (Khan, 2011; Sheikh and Tripathi, 2013). South Waziristan is home to a variety of fruits. This area could produce fruits for home consumption and market demand. South Waziristan is selected where this study is proposed due to its potential for fruit (apple) production. Statistics show that apple farmers in the targeted area are not substantially the recipients of benefits (GOP, 2019a). A question arises: How can the farmers' performance be improved? How can the apple industry be developed in Pakistan? To the researcher's knowledge, there is no detailed study that provides information about the constraints faced by apple farmers in South Waziristan, so there is a need to investigate the constraints in the targeted area. The researcher is therefore encouraged to conduct a study of the efficiency of apple growers in South Waziristan. The scope and scale of the problem must be investigated to define effective solutions for public and private stakeholders. Keeping in view the significance of the study, this study aims to estimate the technical, allocative, and economic efficiency of apple farms and the associated factors.

METHODOLOGY

Description of the Study Area

South Waziristan is the largest district in the newly merged areas of Khyber Pakhtunkhwa, having 6619 square kilometers and comprising 24.3 percent of the total FATA area (CMDO, 2021). The key source of livelihood within the district is agriculture (fruit and vegetable farming). The weather conditions of South Waziristan are pleasant in the summers, while in winter, the climate is cold, with snowfall in some places. South Waziristan district is composed of three subdivisions (Wana, Laddha, and Sarwakai) and eight tehsils (Wana, Tiarza, Serwaklai, Makeen, Laddha, Sararogha, Bermal, and ToiKhulla). Among the eight tehsils, Wana is the largest, while Tiarza is the smallest tehsil according to population (CMDO, 2021; GOP, 2018b). The study area map is shown in Figure 1.

Figure 1. Map of FATA and South Waziristan

Apple farmers from tehsils (Wana, Bermal, and Tiarza) were investigated as sampling units. The sampling frame is based on lists that identify the distribution of apple farms, villages, areas under cultivation, places, and areas under apple cultivation prepared under the informal survey in South Waziristan. The information received during the informal survey was used to decide the sample size. A total of 304 farmers were surveyed in South Waziristan. For better representation of the study area, the sample size was further used with a multistage sampling technique. In the first stage, the South Waziristan district was purposely selected as it is the most significant area in apple production. In the second stage, tehsil Bermal, Wana, and Tiarza were selected due to the concentration of the apple farming population. In the third stage, apple producers were selected randomly. Poate and Daplyn (1993) suggested a minimum of 60 respondents for a large population to bring certainty to decision-making. This research study used a sample size of 304 apple farmers for data collection. The survey sample for apple growers in South Waziristan contains 153 interviews from tehsil Wana, 121 interviews from tehsil Bermal, and 30 interviews from tehsil Tiarza representing their apple grower's population.

Apple Farmer's Efficiency Analysis

In developing countries, farmers cannot completely exploit the potential of available technologies and cannot efficiently distribute resources, so farmers cannot achieve profitability in agricultural farming (Abatania et al., 2012; Piya et al., 2012; Umanath and Rajasekar, 2013). In South Waziristan, there is little support for apple farming by the government departments. The farmers' managerial skills need to be improved with organizational support to achieve profitability and efficiency in farming (Murtaza and Thapa, 2017). South Waziristan is known for apple quality and taste. The demand for apple produce is increasing in Pakistan. However, the production of apples per acre is very low compared to the developed nations. There are wide variations in the yields and efficiencies of apple production in apple-producing districts of Pakistan (Murtaza and Thapa, 2017). Variations at the farm level are also experienced in apple-producing areas. Keeping in view the potential of apple production in South Waziristan, there is a need for efficiency analysis. This research estimates the technical, allocative, and economic efficiency of apple production in South Waziristan using Data Envelopment Analysis (DEA), assuming that some farms are more efficient than others. The modern efficiency concept begins with Farrell (1957), following the work of Debreu (1951) to define the measure of firm efficiency using multiple inputs. He proposed that the efficiency of a firm is of two types, i.e., technical and allocative. Technical efficiency is the capability of a firm (unit) to achieve maximum output from a given set of inputs. Allocative efficiency is the ability of a firm (unit) to use the same inputs in optimal proportions, given the respective prices. These two efficiencies combined give a measure of economic efficiency. Efficiencies are compared between farm sizes and tehsils of the selected district.

Data Envelopment Analysis (DEA)

DEA is a linear programming method to construct a non-parametric piecewise frontier over the data. This enables the researcher to calculate efficiencies relative to this surface. This program considers a variety of models, such as Standard Constant Return to Scale (CRS) and Variable Return to Scale (VRS). DEA models involve the calculations of technical, allocative and economic efficiencies. The modern efficiency concept begins with Farrell (1957), following the work of Debreu (1951) to define the measure of firm efficiency using multiple inputs. He proposed that the efficiency of a firm is of two types, i.e., technical and allocative. Technical efficiency is the capability of a firm (unit) to achieve maximum output from a given set of inputs. Allocative efficiency is the ability of a firm (unit) to use the same inputs in optimal proportions, given the respective prices. These two efficiencies combine to give the measure of economic efficiency.

To analyze the factors affecting the efficiencies, this study follows the two-step approach suggested by Coelli et al. (2005), where efficiency scores are regressed against a set of independent variables of a non-discretionary nature. DEA literature expressed that the efficiency scores attained in the first stage are correlated with the independent variables used in the second stage, which makes the second-stage estimates inconsistent and biased. Therefore, the use of Simar and Wilson (2007) truncated regression analysis is necessary to overcome this challenge. Specification of the estimated regression is expressed as:

$$\theta_i = \beta_0 + \beta_1 Age + \beta_1 Edu + \beta_1 FS + \beta_1 OFY + \beta_1 ExtS + \beta_1 SubF + \beta_1 SmlF + \beta_1 DistMM + \beta_1 FL + \varepsilon_i \quad (1)$$

Where θ_i is the bootstrapped biased-corrected efficiencies score. Age refers to the age of farmers. Edu refers to the education of the farmer. FS is the family size of household, OFY is the off-farm income of household, ExtS refers to the access of the farmer to the agriculture extension services, SubF is the farm size where farmer hold subsistence landholding, SmlF refers to small landholders, DistMM is the distance of orchard from the main market, and FL is the farm labor employed in apple farming. Medium/large landholders are omitted in the regression function. Six separate truncated models are estimated for CRS and VRS assumptions (three for each category), where the dependent variables were Technical Efficiency, Allocative Efficiency, and Economic Efficiency.

Description of independent variables used in DEA model

Factors influencing efficiency are believed to be important in the Data Envelopment Approach because obtaining scores of TE, AE, and EE using CRS and VRS assumptions simply have an incomplete use for policy management. The question arises: What reasons seem to be linked to inefficiency? In literature, a variety of studies i.e., Wadud and White (2000), Coelli et al. (2002), Kamruzzaman and Ahmed (2006), Kalirajan and Shand (1989), Begum et al. (2010), Bravo-Ureta and Evenson (1994), and Parikh et al. (1995) used variables of age, education, farming experience, farm size, training, and access to extension services to identify variability of farm efficiency. In this study, to identify the variability in the efficiency of farms, the variables used are the farmer's age (in years), farmer's education (years), family size (number of persons per household), off-farm income (yes or no off-farm income), extension services role (yes or no access to service), farm size (subsistence, small and medium/large), distance from main market (distance of orchard from main market), and farm labor hired (weather hired labor or not) for regression. These ten variables are used for regression having the importance of these variables in determining the level of efficiency of farms.

RESULTS AND DISCUSSIONS

Agricultural productivity in Pakistan is relatively low (Ahmad et al., 2002). Although many efforts have been made to develop new seed varieties, the agriculture production in Pakistan is not fulfilling demand, and thus, imports are the only option to fill the gap. There are considerable inefficiencies in apple farms in Pakistan. These inefficiencies are calculated using DEA in this study. Both the interpretation and projection of the results require care, having the technical nature of the agricultural production process.

The study sample size is divided into three tehsils according to the apple grower's population. Wana Tehsil has the highest number of apple orchards, while Tehsils Bermal and Tiarza are in second and third place, respectively. Landholding in the study area is very low; 177 out of 304 apple growers have less than two acres for apple farming, while 34 farmers hold more than five acres of land dedicated to apple farming. Orchards' average age was around 15 years, while people above 44 years of age were connected to apple farming in the study area. The education status is very low in the study area as the mean schooling years were below 10 in all the tehsils. There is no canal available for irrigation; all the farms are either irrigated from tubewells or kariz (the underground water channel).

Constant and Variable Returns to Scale Efficiencies in Apple Farms

The three efficiency measures, i.e., technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE)were calculated with respect to CRS and VRS.

Frequency distribution of CRS efficiency estimates

In DEA model using the CRS, the mean values for TE, AE, EE were 65%, 67%, and 44%, respectively. These figures indicate that there are significant inefficiencies in apple production in South Waziristan when applying the CRS assumption. Efficiency scores for farms were categorized into five clusters ranging from 0.00 to 1.00. Specifically, two farms scored below 20% in technical efficiency, while 49 farms achieved scores between 81% to 100%. The results in Table 1 segmented farms into different clusters based on their technical, allocative and economic efficiencies. For Technical efficiency, cluster 1 has 2 farms, cluster 2 has 11 farms, while cluster 3, 4, and 5 has 112, 130 and 49 farms, respectively. For allocative efficiency, clusters ranged from 0 farms in Cluster 1, 172 farms in Cluster 4, and 51 farms in Cluster 5. In terms of economic efficiency, the breakdown is as follows: cluster 1 includes nine farms, clusters 2 and 3 each encompass 127 farms, and Clusters 4 and 5 consist of 37 and 4 farms, respectively. To optimize efficiencies, there is a need to enhance allocative efficiency by 33%, technical efficiency by 35%, and economic efficiency by 56% to achieve optimal levels in apple farming within South Waziristan. In essence, the findings underscore the imperative to address inefficiencies across these dimensions to enhance apple farming productivity and performance in South Waziristan.

Table 1. Frequency distribution of CRS efficiency estimates from DEA models.

Index (%)	Technical Efficiency	Allocative Efficiency	Economic Efficiency
0-20	2 (0.7)	0 (0)	9 (3)
21-40	11 (3.6)	12 (3.9)	127 (41.8)
41-60	112 (36.8)	69 (22.7)	127 (41.8)
61-80	130 (42.2)	172 (56.6)	37 (12.2)
81-100	49 (16.1)	51 (16.8)	4 (1.3)
Mean	0.657	0.675	0.442
S.D.	0.158	0.140	0.138
Min	0.161	0.232	0.075
Max	1.000	1.000	1.000

Figures in parentheses are percentages.

Frequency distribution of VRS efficiency estimates

In DEA model using VRS approach, the mean scores for TE, AE, EE were determined to be 88%, 64%, and 63%, respectively. These findings in Table 2 highlight existing inefficiencies within South Waziristan's apple farms. These efficiency scores were categorized into five clusters, with all farms demonstrating technical efficiency above 60%; notably, 302 farms achieved scores between 81% and 100%. Regarding VRS allocative efficiencies, clusters ranged from zero farms in cluster 1 to 129, 111, and 57 farms in clusters 3, 4, and 5, respectively. Similarly, for VRS economic efficiencies, clusters spanned from zero farms in cluster 1 to 136, 107, and 54 farms in clusters 3, 4, and 5, respectively. Overall, the mean efficiency scores for the 304 surveyed farms in 2018 were 0.88, 0.64, and 0.63 for TE, AE, and EE, respectively, meaning that these inefficiencies can be decreased by 12, 36, and 37 percent, respectively. Improving management practices and input utilization is imperative to elevate farm efficiency levels fully. By optimizing these aspects within the VRS framework, there is potential to elevate technical efficiency by 12%, allocative efficiency by 36%, and economic efficiency by 37%. In essence, the DEA analysis underscores substantial opportunities for South Waziristan's apple growers to bolster efficiency and profitability.

Comparison of CRS and VRS efficiencies according to farm size

In this study, a comparison has been made between CRS according to farm size using the DEA model as shown in Table 3. First, the results of CRS are presented in this section. Farms are categorized as subsistence, small and medium & large farms based on the orchard size in the study area. Starting with the subsistence farmers of apple the scores are 0.66, 0.68, and 0.45 for technical, allocative, and economic efficiency respectively, meaning that subsistence farmers are behind thirty-four percent to the maximum technical efficient level, thirty-two percent from the allocative efficiency level, and fifty-five percent from the economic efficient level in the study area according to the constant returns to scale scenario, indicating that there is need to improve the efficiency by 34, 34 and 56 percent, respectively. While medium & large farms are lagging 41, 37, and 63 percent in TE, AE, and EE under CRS assumption, respectively.

Table 2. Frequency distribution of VRS efficiency estimates from DEA models.

Index (%)	Technical Efficiency	Allocative Efficiency	Economic Efficiency
0-20	0(0)	0(0)	0(0)
21-40	0(0)	7 (2.3)	7 (2.3)
41-60	0 (0)	129 (42.4)	136 (44.7)
61-80	2 (0.7)	111 (36.5)	107 (35.2)
81-100	302 (99.3)	57 (18.8)	54 (17.8)
Mean	0.889	0.641	0.633
S.D.	0.038	0.152	0.153
Min	0.787	0.248	0.248
Max	1.000	1.000	1.000

Figures in parentheses are percentages.

Table 3. CRS estimates – Farm size.

Farm Size	Statistics	Constant Return to Scale		
		Technical Efficiency	Allocative Efficiency	Economic Efficiency
Medium& Large Farmers	Mean	0.593	0.639	0.375
	S.D.	0.148	0.130	0.124
Small Farmers	Mean	0.664	0.665	0.440
	S.D.	0.166	0.144	0.138
Subsistence Farmers	Mean	0.665	0.687	0.456
	S.D.	0.154	0.139	0.138

Source: DEAP output.

Results for VRS comparison in shown in Table 4. Starting with the subsistence farmers of apples, the scores are 98 percent for each farm size, meaning that subsistence, small, and medium & large farms are behind two percent to the maximum level in TE, AE, and EE, in the study area according to the variable returns to scale scenario. Scores of small farms in VRS assumption are 0.99 for all TE, AE, and EE, indicating that there is a need to improve the efficiency by one percent in each category. The DEA model estimated using the VRS, that the medium & large farms are lagging one percent in technical, allocative, and economic efficiency, meaning that very little efforts are needed, i.e., one or two percent increase in TE, AE and EE can lead to the maximum level of efficiency in South Waziristan.

Constant and variable return to scale efficiency according to Tehsil

Results of the DEA model, assuming a CRS in the three tehsils Bermal, Tiarza, and Wana of South Waziristan, are presented in Table 5. The results indicated that tehsil Bermal is far behind in the full efficiency level production of apples in all three categories: TE, AE, and EE. Bermal tehsil needs to improve by 35, 32, and 56 percent for TE, AE, and EE, respectively to reach its potential efficient level. Tiarza tehsil is also not performing well because there is a need to put tremendous effort into reaching the efficient level. The mean statistics of Wana tehsil are also not satisfactory as more than thirty percent efficiencies are required to improve.

Results of the DEA model, assuming a VRS in the study area, are presented in Table 6. Starting with tehsil Bermal results indicated that its scores for TE, AE, and EE are 99, 66, and 66 percent, meaning that this tehsil can improve technical efficiency by one percent, allocative efficiency by thirty-four percent, and economic efficiency by thirty-four percent. Using the assumption of a variable return to scale tehsil Tiarza has a score of 0.98, 0.60, and 0.59 for TE, AE, and EE, respectively. The Tiarza tehsil is close to the efficient level in TE. This tehsil is lagging in efficiency for AE and EE. The mean statistics of Wana tehsil are also not satisfactory as the allocative and economic efficiency scores are 0.65 and 0.64, respectively. Only the technical efficiency score is close to one hundred percent, meaning that litter efforts can bring the farms to an efficient level in Wana tehsil.

Table 4: VRS estimates – Farm size

Farm Size	Statistics	Variable Return to Scale		
		Technical Efficiency	Technical Efficiency	Technical Efficiency
Medium& Large Farmers	Mean	0.995	0.995	0.995
	S.D.	0.028	0.028	0.028
Small Farmers	Mean	0.990	0.990	0.990
	S.D.	0.037	0.037	0.037
Subsistence Farmers	Mean	0.987	0.987	0.987
	S.D.	0.040	0.040	0.040

Source: DEAP output.

Table 5. CRS estimates – Tehsil wise.

Tehsil	Statistics	Constant Return to Scale		
		Technical Efficiency	Allocative Efficiency	Economic Efficiency
Bermal	Mean	0.651	0.681	0.442
	S.D.	0.150	0.138	0.135
Tiarza	Mean	0.696	0.663	0.461
	S.D.	0.156	0.139	0.158
Wana	Mean	0.653	0.673	0.438
	S.D.	0.165	0.142	0.138

Source: DEAP output.

Table 6. VRS estimates – Tehsil wise.

Tehsil	Statistics	Variable Return to Scale		
		Technical Efficiency	Allocative Efficiency	Economic Efficiency
Bermal	Mean	0.992	0.637	0.631
	S.D.	0.031	0.144	0.145
Tiarza	Mean	0.986	0.607	0.599
	S.D.	0.043	0.136	0.140
Wana	Mean	0.987	0.650	0.641
	S.D.	0.042	0.160	0.161

Source: DEAP output.

Optimality of Apple orchards using CRS and VRS in South Waziristan

Farms using the same technology are expected to have increasing returns to scale with a relatively low output and decreasing returns to scale for farms with relatively high output. The CRS is expected to have an output level equal to the mean output (Begum et al., 2010). The mean output level for CRS and VRS is 52757 kg apple per acre. In this study, farms having greater yields than the average value of output are considered optimal, while those farms having less output than the average value are considered suboptimal. Using the CRS assumption, 133 farms were optimal, and 171 farms were suboptimal in the study area. Meaning that 133 farms were producing apples above the average per-acre yield. At the same time, 171 farms were performing below the average yield. Table 7 shows that using the VRS assumption, 147 farms were optimal, and 157 farms were suboptimal in the study area. This means that 147 farms were producing apples above the average per-acre yield. Meanwhile, 157 farms were performing below the average yield.

Factors Affecting Efficiencies

To understand the effects of different variables on efficiency, truncated regression is performed using the assumptions of CRS and VRS. The truncated regression model was employed because "efficiency" is a censored variable with an upper bound of 1 and a lower bound of 0. Truncated regression was employed with the help of the statistical software "DEAP". The dependent variable "efficiency" is calculated using the CRS and VRS DEA model.

Distance of farms to main markets is crucial in efficiency analysis because access to the main markets helps farmers deliver their produce to markets and brings farm inputs easily. The results indicated that with the increase in distance, TE, AE, and EE decrease, implying that distance's role inefficiencies cannot be ignored. However, the coefficient of the distance of the farm from the main market is insignificant in TE, AE, and EE of the model used in this study. This research checks whether permanent labor plays any role in determining efficiency. The results show that farm labor positively correlates with the efficiency in TE, AE, and EE, indicating that permanent labor hired at farms contributes to increasing farm efficiency levels. The coefficient of farm labor is significant in Allocative efficiency, while for the other two categories (TE and EE) it is non-significant. The reason may be that there is no familiar trend of hiring farm labor (permanent) by the Apple producer in South Waziristan.

Factors Affecting CRS Efficiency

The factors affecting CRS efficiency of apple farmers in the study are using truncated regression are shown in Table 8. The age of the respondent is used as a proxy for experience input. Aged farmers may lead to better decisions on the farm, resulting in efficient production of apple fruit. The coefficient of age is positive in TE, AE, and EE, implying that older farmers are comparatively more efficient than younger. However, the parameter of age was not significant for TE in the CRS scenario. In this research, the proxy for managerial experience is used as the farmer's education. The higher the level of education the better the assessment of farm-related problems, which leads to better decisions on farms as used by Begum et al. (2010). In view of the present literature, farmers engaged in apple farming in Pakistan, have a low level of education. Therefore, it is a major constraint which hampers the efficiency of farms. Less education is one of the constraints for the adaptation of new technologies at farms. As expected, in this study, the education variable is positively related to the farm's TE and EE. The reason for this positive relation could be that educated farmers have better access to improved skills, updated information, and farm planning. The negative coefficient of education in AE is surprising. However, this parameter is not significantly different from zero in TE, AE, and EE. The potential negative effects of education on allocative efficiency in specific contexts, such as apple farming in South Waziristan, it is essential to consider that the lack of localized agricultural knowledge, influence of external agricultural practices, limited practical experience and exposure, economic and market dynamics, and cultural and social factors.

Family size is considered an important factor in farm efficiency. It is believed that family members provide labor for apple farms. The result of the regressed model indicates that family size is positively related to efficiency in all the categories of TE, AE, and EE. The results are as expected: family size contributes to the farm efficiency. This may be due to the labor offered to farms by family members within the time frame whenever needed. The parameter is significant in all the cases of categories of TE, AE, and EE. It is evident from the rural livelihood literature that households in developing countries participate in non-farm employment to supplement their household income (Mondal et al., 2020). In the last few decades, there has been an increase in non-farm income among farmer households in Pakistan. The role of non-farm income in agricultural societies for expenditures and efficiencies is worth knowing, as suggested by (Takahashi and Otsuka, 2009). The results show that non-farm income affects the TE, AE, and EE using the CRS assumption, meaning that if non-farm income is increased, then the farm efficiency will increase in the study area. Non-farm income parameter is significant for TE and EE, while for AE it is insignificant.

Table 7. Efficiency analysis and the optimal apple orchard.

Scale	Statistics	Optimal (> Mean EE)	Sub Optimal (< Mean EE)	Total Farmers
Constant Return to Scale	Frequency	133	171	304
	Percentage	44	56	100
	Yield (kg/Acre)	58,082	48,615	52,757
Variable Return to Scale	Frequency	147	157	304
	Percentage	48	52	100
	Yield (kg/Acre)	53,779	51,800	52,757

Table 8. Factor affecting CRS efficiency – truncated regression model.

Factors	Dep. Variable = TE	Dep. Variable = AE	Dep. Variable = EE
Age	0.0008	0.0022***	0.0019***
Education	0.0026	-0.0018	0.0005
Family size	0.0031***	0.0024*	0.0038***
Non-farm income	0.0527**	0.0204	0.0509***
Extension services	0.0294	-0.0660***	-0.0233
Subsistence farmers	0.1011***	0.0418*	0.0992***
Small farmers	0.1004***	0.0281	0.0883***
Medium/large farmers	*Omitted Dummy*		
Distance from the main market	-0.0004	-0.0004	-0.0005
Farm labor	0.0307	0.0742***	0.0121
Constant	0.4317***	0.5397***	0.2005***
Sigma	0.1535***	0.1307***	0.1317***
Wald chi2(9) = 18.22 Prob>chi2 = 0.0327 Loglikelihood=138.432		Wald chi2(9)= 43.25 Prob>chi2= 0.0000 Loglikelihood=187.175	Wald chi2(9) = 32.75 Prob>chi2= 0.0001 Loglikelihood=186.260

Note: ***, **, * indicate 1, 5, and 10 percent level of significance, respectively.

Farm efficiency and the role of extension services are interlinked in agriculture production. The role of extension services cannot be neglected, as the most relevant information about the farm activities is provided by the extension department. The production variability among the farms is dependent on the farmers' visits to and from extension services departments. This study attempts to investigate the integration between farm production efficiency and extension services. The empirical results of the study indicate that extension services were positively correlated with TE, while surprisingly, the coefficient negatively affects AE and EE. Implying that the farmer who was visiting the extension services centers was comparatively technically efficient. The results are similar to the study of Dinar et al. (2007), where extension services played a role in the production function, and were complementary to the technical inefficiency effect function. The coefficient is significant in the case of AE, while in other cases it is insignificant.

This study also investigated the role of farm size in determining efficiency levels. The parameter is significant in all the efficiency estimates. Small farms were also positive for all the categories of efficiency. For AE, the parameter is non-significant, while for TE and EE, it is significant. The results of the model highlight the role of farm size in determining the level of efficiency. As the farm size decreases the efficiency increases for the study area. Subsistence farms were comparatively playing a greater role in determining the level of efficiency. Small Apple farms also play a greater role compared to medium & large in determining TE, AE, and economic efficiency in the study area of South Waziristan.

Factors Affecting VRS Efficiency

The factors affecting VRS efficiency of apple farmers in the study using truncated regression are shown in Table 9. The estimated variable affecting the efficiency of farms had good explanatory power. Farmer's age is used for experience proxy. The coefficient of farmer's age is positive in explaining TE, AE, and EE, implying that older farmers are more efficient than younger ones. Older farmers may have better experience regarding the technicalities of apple production. However, this parameter was not significant for TE, AE, and EE in the VRS scenario.

A proxy of farmer's education is used for managerial experience in this study. One can see the literacy rate of the population in South Waziristan, which is very low (GOP, 2018b). Therefore, it is considered one of the major agricultural sector constraints hindering farm productivity. Study results show that the level of farmers' education positively explained the farms' TE, AE, and EE. This positive explanation may be due to the farmer's skills, access to information, and farm planning. The parameter of education is significant for EE, while for TE, and AE this parameter is not significant in VRS assumption. It is believed that family members provide labor for farms, and different tasks are completed at farms without any additional expense. The result of the regressed model indicates that family size is positively related to efficiency in all the categories of TE, AE, and EE. The results are as expected: family size contributes to farm efficiency, and this may be due to the labor offered to farm by family members within the time whenever needed. The parameter is significant in all the cases of categories of TE, AE, and EE.

Farmers in the farming communities usually do not solely rely on farm income. Farmers also depend on off-farm income for household expenditures. There has been an increase in non-farm income among farm households in Pakistan in the last few decades. The role of non-farm income in agricultural expenditures and efficiencies is worth knowing, as suggested by (Takahashi and Otsuka, 2009). This raises the question of whether off-farm income complements agriculture production due to a possible shift in inefficiencies of the fruit (Apple) industry of Pakistan. This study tries to identify the effects of non-farm income on TE, AE, and EE of apple farms in South Waziristan, using the VRS DEA model. The study results indicated that non-farm income influences TE, AE, and EE, using the VRS assumption, meaning that with an increase in non-farm income, farm efficiency will also increase. Non-farm income parameter is not significant for TE and EE, while for EE it is significant.

The production variability among the farms is dependent on the farmers' visits to the extension service center. Agriculture production/yield is also dependent on collecting information from extension services departments. This study attempts to investigate the integration between farm efficiency and extension services. By extension service center, we mean governmental centers for agricultural information. The study results indicated that the coefficient was positively correlated with TE and EE. Surprisingly, the coefficient of extension services was affecting AE negatively. This implies that farmers who were visiting the extension services centers had improved technical and economic efficiency. The results of this model are consistent with Dinar et al. (2007). Extension services played a role in explaining the TE and EE of farms in the study area.

Table 9. Factor affecting VRS efficiency – truncated regression model.

Factors	Dep. Variable = TE	Dep. Variable = AE	Dep. Variable = EE
Age	0.002	0.0005	0.0007
Education	0.0015	0.0018	0.0028**
Family size	0.0006**	0.0030**	0.0034*
Non-farm income	0.0112	0.0206	0.0281**
Extension services	0.0009	-0.0262	0.0248
Subsistence farmers	-0.0046***	0.1059***	0.104
Small farmers	-0.0009***	0.0834***	0.0832
Medium/large farmers	Omitted Dummy		
Distance from the main market	-0.0004	-0.0007	-0.0009
Farm labor	0.0027	-0.0172	-0.0141
Constant	0.9583***	0.4812***	0.4517***
Sigma	0.0372***	0.1461***	0.1470***
Wald chi2(9) = 14.07 Prob>chi2 = 0.1199 Loglikelihood= 568.94556		Wald chi2(9)= 22.12 Prob>chi2= 0.0085 Loglikelihood = 153.3996	Wald chi2(9)= 23.10 Prob>chi2= 0.0060 Loglikelihood = 151.576

Note: ***, **, and * indicate 1, 5, and 10 percent level of significance, respectively.

The extent of farm size in explaining efficiencies is investigated in this research. Farms were categorized as subsistence, small, and medium/large landholders for comparison. Medium/large farms were omitted in the VRS DEA model estimates. Subsistence land farmers were positively affecting the AE and EE, and negative in TE in VRS assumption. The parameter is significant for TE and EE but not significant for EE in the model. Small farms also had positive signs for AE and EE. For TE, the coefficient has a negative sign, meaning that as the farm decreases in area the in-efficiency increases. The parameter is significant for TE and AE, and it is non-significant for Economic Efficiency. The results of the model highlight the role of farm size in determining the level of efficiency. As the farm size decreases, the allocation and economic efficiency increase for the study area. Subsistence farms were comparatively playing a greater role in determining the level of efficiency. Small apple farms also play a greater role compared to medium/large farms in determining TE, AE, and EE in the study area of South Waziristan.

Distance of farms from main markets is crucial for farm productivity and efficiency because access to the main markets means that farmers can deliver their produce to main markets and bring farm inputs easily. The results of this model indicate that as the distance from the main market increases, the TE, AE, and EE decrease. Implying that distance from the main market is responsible for inefficiencies in the study area. However, the coefficient of the distance of the farm from the main market is insignificant for TE, AE, and EE using the VRS assumption in the DEA model.

The results show that farm labor positively correlates with the TE, while this coefficient has a negative sign for AE and EE, indicating that permanent labor hired at farms contributes to increasing farm TE levels, and decreases the AE and EE using the VRS DEA model. The parameter of farm labor is insignificant for TE, AE, and EE in the model. The reason may be that there is no familiar trend of hiring farm labor (permanent) by the apple producer in South Waziristan.

CONCLUSIONS

The impacts of apple farming in South Waziristan are very deep due to the dependence of a large proportion of the population on the cultivation of fruits. Apple is the major fruit of South Waziristan, which is supplied to the national markets for consumer demand. Apple is a perishable fruit, and due to the poor infrastructure in the study area, farmers are unable to receive maximum returns. Appropriate agricultural policies are required to lead the farmers to higher agricultural production. For policy formulation, the efficiency measurements in the agriculture production system are important to investigate. In this research the technical, allocative, and economic efficiencies of apple farmers were measured. Results show that under CRS specification, technical, allocative, and economic efficiencies were 65, 67, and 44 percent, respectively, whereas under VRS specification, technical, allocative, and economic efficiencies were 88, 64, and 63 percent, respectively. These results indicate that there is a substantial inefficiency that needs to be improved. Furthermore, truncated regression models were estimated to identify the factors affecting efficiencies. Based on the study results, it is recommended that the level of education and training of farmers in Pakistan, particularly in South Waziristan, needs to be improved meaningfully to elevate efficiency levels in the apple industry.

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