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Technical Efficiency of Okra (*Abelmoschus esculentus* L Moench) Growing Farms: An Opportunity to Stabilize Agriculture Economy

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Abstract

Vegetables are essential for food and nutrition security and affordable sources of important vitamins and minerals, indicating their nutritional potential for exploitation in world agriculture. Okra (*Abelmoschus esculentus* L. Moench) is an economically important vegetable crop with the potential to increase the incomes of the farmers not only in open fields but also in greenhouses in Oman as it is Okra is popular among the customers and valuable with higher retail prices than other vegetables. Hence, a survey study investigated the technical efficiency of okra-growing farms in Oman. Our research estimated and examined the technical efficiency of okra-growing farms in different governorates of Oman. A sample of 115 okra-growing farms was selected, adapting the multistage sampling method. The interview schedules were followed for data collection in 2016 and 2017. The maximum likelihood method was used, adapting the Cobb-Douglas stochastic frontier production model for the data collected. the output of the Frontier 4.1 was found to be a good fit as evidenced by significant sigma squared value ($p<0.05$). The results indicated that the mean technical efficiency for okra farms in Oman was estimated to be 70%, with a wide range from as low as 8% to as high as 88%. There was considerable possibility of increasing Okra output by 30% with the current level of inputs employed by Okra farmers. Among the inefficiency factors, the experience of the farmers significantly contributed to the technical efficiency of the farms. Okra-growing farms had an enormous scope to improve their efficiency and increase the productivity of Okra by following regular extension programs related to Good Agriculture Practice (GAP) involving farmers interested in the cultivation of Okra.

***Key words*: Technical efficiency, Maximum likelihood method, Stochastic production frontier, Okra

Vegetables are essential for food and nutrition among customers, while they are economic crops for farmers' livelihoods [1]. Besides, their cultivation brings not only employment opportunities but also alleviation of rural poverty [2]. Vegetables are the most essential and affordable sources of vitamins and minerals that reflect their nutritional potential to be regarded as quality foods among customers. Regarding their annual economic output, FAO data could estimate their farmgate value to be about $1 trillion per year compared to that of all food grains together (US$ 837 billion) [3]. In the Arabian Peninsula, vegetables are grown under open fields and greenhouse conditions. The investigations of ICARDA's APRP (Arabian Peninsula Research Program) have shown that growing vegetables adapting protected agriculture has proved very successful in raising their livelihoods and economic stability among the farmers in the Arabian Peninsula in general [4-11] but also in Oman in particular [12-15]. By adopting protected agriculture techniques like greenhouses, farmers can increase crop yields, improve water use efficiency, and reduce pest and disease issues, leading to higher.

The total estimated cultivated area in the Sultanate of Oman by the end of 2022 increased by 3.9 percent to reach 276,000 acres, compared to 266,000 acres by the end of 2021, with total agricultural production of 3.501 million tons, according to the statistics of the National Centre for Statistics and Information of which vegetables with a total area of 69,074 acres produced 1.137655 million tons [16]. Increasing vegetable production in Oman is expected to contribute to government efforts to diversify the national economy [17-18]. In Oman, the open-field production of vegetables still exists, with a simultaneous increase in the area under protected agriculture throughout all the governorates [1]. The area and production of vegetables have been significantly increasing, backed by local demand [1]. As for Okra, production was found to have increased from 415 metric tons in 2009 to 1916 metric tons in 2018, nearly an increase of 362% [1]. This increase in production is considered a very positive development and indicative of the potential opportunities ahead for Okra in particular and vegetables in general, not only in Oman but also in other countries [19-21].

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In the present study, the Stochastic Production Frontier (SPF) was applied to assess the efficiency of the production of Okra. Earlier, several scientists used frontier applications in the field of production in general [22-28]. Subsequently, SPF was employed in agriculture [29], horticulture [30], vegetable production [31-33], and dairy sciences [34]. Recently, SPF was used in the estimation of the technical efficiency of production in individual crops, viz. hybrid maize [35], black cumin [36], sweet melon [37], tomato [38], and Okra [39-40]. All these studies in agriculture have suggested effective measures for increasing vegetable production to increase efficiency. In light of the above, the present study evaluated the production efficiency of okra-growing farms in Oman.

MATERIALS AND METHODS

Data and variables

In this study, primary data were collected by means of a survey administered through questionnaires. Huge data were collected from 115 farmers growing Okra from selected farmers across four governorates: North Al Batinah, South Al Batinah, North Al Sharqiya, and Al Dakhiliya of Oman.

The variables were chosen according to previous efficiency studies [41-42]. The dependent variable was the total amount of output in kilograms. The input variables in the efficiency model include the following factors: farm size, fertilizer, labor, seeds, irrigation facility, electricity, and chemicals. The units for inputs were: i. farm size, which is the size of the farm planted by the farmer in hectares; ii. Fertilizer is the quantity of fertilizer applied in kilograms per hectare. iii. labor as the term given to the number of person-hours, iv. seeds, the number of seeds used in kilograms per farm; v. irrigation facility, the amount of water applied in cubic meters per day; vi. electricity, the amount consumed in OMR per month, vii. Chemicals, applied in kilogram per hectare.

The study included three farm-specific variables used for the inefficiency model: farmer's age, farmer's experience, and farmer's level of education. Farmer's age refers to just the chronological age of the farmer in years and his experience over a number of years. In contrast, his level of education was given numerical values of 0 and 1 to reflect the level of education in each category. Three category levels were surveyed: illiteracy (no school), educated farmers till year twelve (Year 1-12) and educated farmers beyond year 12. The numerical value of 1 stands for positive in a category, and 0 stands for negative.

Technical inefficiency model adapted

Like many other agricultural commodities, the production of crops such as capsicum, cabbage, Okra, eggplant, and tomato is naturally stochastic. Therefore, the SFP approach is preferred to assess the technical efficiency of these farms in Oman. The present study adapted the technical inefficiency effects model of Battese and Coelli [43].

Resources and data analysis

Data were analysed to estimate efficiency, and this was accomplished by using both SHAZAM econometric software and the Coelli (1996) "FRONTIER 4.1" computer program [44]. The software referred to as SHAZAM is a very comprehensive tool for measuring econometrics, statistics, and analytics. It is quite popular worldwide as it offers a variety of computations to build models, check hypotheses, and explain the variation among different factors. The Coelli "FRONTIER 4.1" computer program [44] is a stand-alone software package for Stochastic Frontier Analysis. Both together complement each other.

RESULTS AND DISCUSSION

In recent years, Battese and Coelli's technical inefficiency effects model has been popular for application as it has computational simplicity and the ability to examine the effects of different farm-specific variables concerning technical efficiency in an econometrically consistent manner as compared to the previous two-step procedure, which is inconsistent with the assumption of independence and identically distributed technical inefficiency effects in the stochastic frontier. Further, Battese and Coelli's method is superior to the previous two-step technique in that it incorporates farm-specific factors in estimating the production frontier, which directly impacts efficiency and is necessary for policy purposes [43]. In the present study, the okra crop was econometrically estimated. The coefficients were elastic as all the variables were in log form.

Table 1 Maximum likelihood estimates of the common stochastic production frontier for okra with yield (Y) as dependent variable

Variable Name	Parameter	Coefficient	Standard Error	T-Ratio
Stochastic \ Frontier Models				
Constant (Intercept)	B_0	-12.32	7.26	-1.70
In(X_1) (Farm size)	β_1	10.56	1.33	7.93
In(X_2) (Fertilizer)	β_2	9.29*	1.18	7.89
In (X_3) (Labor)	β_3	-2.06	1.04	-1.98
In (X_4) (Seeds)	β_4	-1.35	1.06	-1.27
In (X_5) (Water)	B_5	4.06*	1.04	3.91
In(X_6) (Electricity)	B_6	5.51*	1.06	5.20
In(X_7) (Chemicals)	B_7	10.00	2.65	3.77
In (X_1) *In (X_1)	B_8	-0.25	0.26	-0.94
In (X_2) *In (X_2)	B_9	-0.34	0.08	-3.99
In (X_3) *In (X_3)	B_{10}	-0.47	0.30	-1.57
In (X_4) *In (X_4)	B_{11}	-0.17	0.06	-2.72
In (X_5) *In (X_5)	B_{12}	-0.23	0.07	-3.16
In (X_6) *In (X_6)	B_{13}	-0.23	0.10	-2.40
In (X_7) *In (X_7)	B_{14}	1.61	0.28	5.82
In (X_1) *In (X_2)	B_{15}	0.59	0.17	3.54
In (X_1) *In (X_3)	B_{16}	-0.16	0.42	-0.38
In (X_1) *In (X_4)	B_{17}	0.04	0.13	0.29
In (X_1) *In (X_5)	B_{18}	0.24	0.15	1.55

In (X_1) *In (X_6)	B_{19}	0.28	0.23	1.21
In (X_1) *In (X_7)	B_{20}	0.93	0.26	3.56
In (X_2) *In (X_3)	B_{21}	0.55	0.20	2.74
In (X_2) *In (X_4)	B_{22}	-0.06	0.08	-0.75
In (X_2) *In (X_5)	B_{23}	-0.13	0.13	-1.03
In (X_2) *In (X_6)	B_{24}	-0.12	0.15	-0.80
In (X_2) *In (X_7)	B_{25}	-0.94	0.18	-5.31
In (X_3) *In (X_4)	B_{26}	-0.39	0.17	-2.28
In (X_3) *In (X_5)	B_{27}	0.08	0.18	0.43
In (X_3) *In (X_6)	B_{28}	0.22	0.28	0.80
In (X_3) *In (X_7)	B_{29}	-0.17	0.36	-0.47
In (X_4) *In (X_5)	B_{30}	0.15	0.08	1.86
In (X_4) *In (X_6)	B_{31}	0.22	0.09	2.38
In (X_4) *In (X_7)	B_{32}	0.05	0.18	0.25
In (X_5) *In (X_6)	B_{33}	-0.09	0.13	-0.67
In (X_5) *In (X_7)	B_{34}	0.02	0.17	0.14
In (X_6) *In (X_7)	B_{35}	-0.55	0.25	-2.17

Technical efficiency of okra production

The maximum likelihood estimates for Okra are presented in (Table 1). The result indicated that variables such as water, electricity, and fertilizer were all favourable to okra production, with a substantial significance of 5%. This means that these parameters lead to an increase in output. The coefficient of fertilizer had the highest value (elasticity), followed by electricity and water. The estimate of output elasticity of Okra production for fertilizer was positive (9.29) and significant ($p<0.05$). This means that a 1 unit increase in input (fertilizer kg/fed) would lead to a rise in output of 9.29 kg. On the other hand, farm size, chemicals, and labour were negative to Okra production but insignificant ($p>.05$). The coefficient of fertilizer had the highest value (elasticity), followed by electricity and water.

Table 2 MLE Results of Inefficiency effect model

Inefficiency Model				
Variable Name	Parameter	Coef.	Standard Error	T-Ratio
Constant ($\delta 0$)	δ_0	-16.04**	7.14	-2.25
Farmer's Age (Z_1)	$\delta 1$	-0.08	0.06	-1.43
Farmer's Experience (Z_2)	$\delta 2$	0.36*	0.18	2.04
Education Dummy (Z_3)	$\delta 3$	-1.47	1.12	-1.31
Sigma Square	$\sigma 2$	7.33**	3.01	2.43
Gamma	Γ	0.96*	0.02	45.19

In an inefficiency effect model, the parameters of variance viz. sigma squared was highly significant ($p<0.01$), indicating goodness of fit of the Translog production model, while the gamma value was significant at the 5% level indicated the normal distribution of error term (Table 2). The inefficiency model considered the parameters viz. farmer's age, farmer's experience, and education (Table 2). Farmer's experience was found to be positive and significant at 5%, which showed that older and much more experienced farmers tend to be much less efficient. The farmer's experience coefficient was positive (0.36) by a priori expectations, indicating that experience increases inefficiency and reduces efficiency. Further, the older, more experienced farmers tended to be much more technically inefficient than their relatively younger counterparts, as was also observed by Srinivasulu et al. (2015) [45]. The other two factors about farmers, such as age and education level, were negative but insignificant ($p>0.05$).

Data depicted in (Table 3) presents the distribution of the technical efficiency over the number of okra farms. Based on this table, the mean technical efficiency for okra farms in Oman is estimated to be 70%, with a range from as low as 8% to as high as 88%. Therefore, with the current level of inputs employed by Okra farmers, it is very possible to increase okra output by 30% (Fig 1).

Table 3 Range and frequency distribution of efficiency index for okra farm samples studied

Efficiency index (%)	Study Samples	
	Number of farms	Percentage (%)
Less than 60	15	13.04
Between 60–70	29	25.22
Between 70–80	48	41.74
Between 80–90	23	20.00
Between 90–100	0	
Mean Efficiency	70%	
Median	72%	
Maximum	88%	
Minimum	8%	
Standard deviation	1.31	
Sample size	115	100

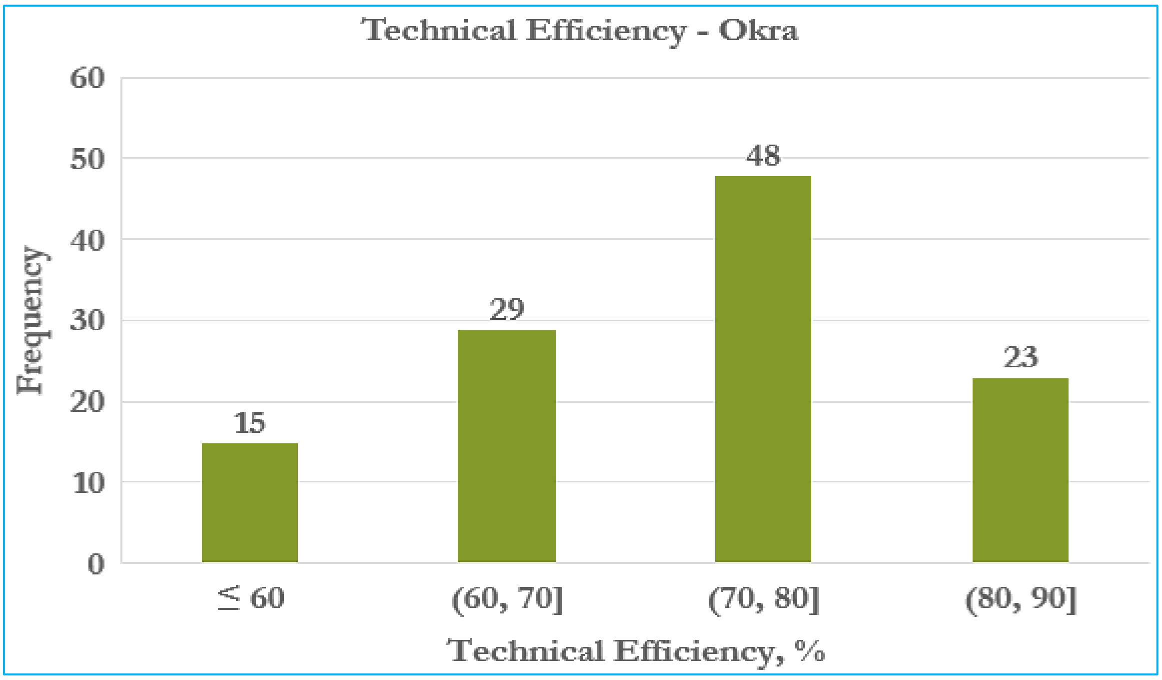

Fig 1 The distribution of technical efficiency scores over number of farms of okra

Most okra farms (92) hold less than 80% technical efficiency. The remaining 23 farms have 90% technical efficiency. This indicates a significant opportunity to increase the efficient production of Okra farms at the current levels of inputs. Similarly, the studies of Ume et al. towards understanding the use of resources and technical efficiency of okra production among female-headed households in Nigeria found that the determinants of technical efficiency of production of Okra viz. level of education and extension service, were positive and significantly related to technical efficiency whereas the credit access and age had inverse relationship with technical efficiency. The mean technical efficiency was observed to be 0.56, with a range from 0.23 to 0.95. However, the farmers could not achieve optimum allocative efficiency in using any of the resources [39]. In contrast to these observations, in the investigations of Alabi *et al*. (2023) on the technical efficiency and return to scale of Okra production among smallholder rural women farmers In Kaduna State, Nigeria, it was observed that mean technical efficiency was 46.5%, providing 53.5% scope for improvement. In this study, the first component of the stochastic frontier production model was labor, followed by fertilizer, chemical, seed, and farm size, which were the statistically significant influencing output of okra production among smallholder rural women farmers. However, in the technical inefficiency component, factors like age, educational level, gender, marital status, household size, and farming experience were statistically significant, decreasing technical inefficiency among smallholder rural women okra producers [40]. Interestingly, in the studies of Ayeni *et al*. (2023), the mean technical efficiency value of vegetable farmers was about 0.73 with technical inefficiency coefficient of farming experience (−0.420), adjusted household size (−0.193), and extension contacts (−0.162) that increased technical efficiency of okra production [46]. Further, based on the data collected from 222 okra farming households in two provinces of Thailand, Katepan *et al*. [47] showed that the average technical efficiency of okra production among the samples in Suphan Buri and Nakhon Pathom Provinces was 81.45% and that okra growers' gender, age, formal years of schooling, number of family members involved in okra production had a positive impact with efficiency scores [47].

Our study had been more comprehensive, covering a larger sample of 115 farmers/farms spread across four prominent vegetable-growing wilayat's of North Al Batinah, South Al Batinah, North Al Sharqiya, and Al Dakhiliya governorates of Oman. The study was mainly related to okra production, one of the lead crops in Oman in terms of land and water consumption based on the FAO report, which incorporated technical and social variables in evaluating technical efficiency. The growth and development towards self-sufficiency of the agricultural sector is the key to sustainability economically not only in Oman, as highlighted in the FAO-MAF SARDS 2040 strategy of Oman [17], but also in any country of the Arabian Peninsula and the world as vegetables have great potential in elevating economy and employment opportunity [2], [10].

CONCLUSION

The study's results indicated that the mean efficiency level of Okra was about 70 %, indicating that there is 30 % scope to raise the efficiency to 100% with the same level of inputs considered in the study. Intensifying extension activities on okra cultivation among the farmers and arranging training programs concerning Good Agriculture Practice (GAP) for improving their skills to increase okra productivity.

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