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AN ESTIMATION OF TECHNICAL EFFICIENCY OF GARLIC PRODUCTION IN KHYBER PAKHTUNKHWA PAKISTAN

Nabeel Hussain
The University of Agriculture, Peshawar-Pakistan
Email:hussain_nabeel@yahoo.com

Shahid Ali
The University of Agriculture, Peshawar-Pakistan

Naveed Miraj
The University of Agriculture, Peshawar-Pakistan

Muhammad Sajjad
Agriculture Livestock & Cooperation Department, Khyber Pakhtunkhwa
Peshawar-Pakistan

Abstract

This study was conducted to estimate the technical efficiency of farmers in garlic production in Khyber Pakhtunkhwa province, Pakistan. Data was randomly collected from 110 farmers using multistage sampling technique. Maximum likelihood estimation technique was used to estimate Cob-Douglas frontier production function. The analysis revealed that the estimated mean technical efficiency was 77 percent indicating that total output can be further increased with efficient use of resources and technology. The estimated gamma value was found to be 0.93 which shows 93% variation in garlic output due to inefficiency factors. The analysis further revealed that seed rate, tractor hours, fertilizer, FYM and weedicides were positive and statistically significant production factors. The results also show that age and education were statistically significant inefficiency factors, age having positive and education having negative relationship with the output of garlic. This study suggests that in order to increase the production of garlic by taking advantage of their high efficiency level, the government should invest in the research and development aspects for introducing good quality seeds to increase garlic productivity and should organize training programs to educate farmers about garlic production.

Key words*:* *Cobb Douglas, garlic, Khyber Pakhtunkhwa, MLE, stochastic frontier, technical efficiency*

1. Introduction

Garlic (Allium sativum, Linn.) is a perennial herb belonging to the family Alliaceae and is widely used around the world as a condiment or for seasoning in different cuisines. It is grown throughout Pakistan and consumed by most of the people because of its pungent, spicy flavor that mellows and sweetens considerably with cooking. Research shows that garlic may help guard against heart diseases and cancer. In addition, garlic reduces cholesterol and blood pressure levels due to the presence of certain antioxidants.

Tissue culture techniques have an extremely important role to play in the conservation of certain plants of economic importance. Of particular significance are those crops which are normally vegetative propagated: garlic falls into this category (Gizawy & Lloyd, 1986). If Pakistan can boost the cultivation of garlic, the country can also export it with other condiments and spices (Ahmad, 2010). The rice, garlic, and mint; rice, potato, onion, and mint; and a rice, chamomile, and mint cropping sequences increased the total equivalent yield of oil by 276.3, 284.8, and 230 percent, respectively, as compared with a rice and wheat cropping sequence. The rice, garlic, and mint cropping sequence increased net return, production efficiency, and benefit as compared with other cropping sequences (Ram & Kumar, 1996).

According to the United Nation's Food and Agriculture Organization (FAO) estimates world production of garlic is 22.23 million metric ton (MMT) approximately. Asia is the largest garlic producing continent in the world and it contributes more than 80% to the total world garlic production. China is the leading garlic producing country in 2010, which produced 18.56 MMT of garlic accounting for over 77% of world output followed by India, South Korea, Egypt, Russia, Myanmar, Ethiopia, USA, Bangladesh and Ukraine respectively (FAO, 2010).

According to commodity wise imports garlic is the 19th most important import commodity of Pakistan after palm oil, rapeseed, sugar refined, cotton lint, cake of soybeans, chick peas, sunflower seed, dry onion, dry peas, jute, tea, wheat, arecanuts, flour of wheat, tomatoes, residuals of fatty subs, lentils and fatty acids (FAO, 2010).

Pakistan ranked among the top 10 garlic importing countries of the world from 2001-2010 with the exception of year 2001 and 2002 in which Pakistan is ranked as 13th and 14th largest importer of garlic. From 2001-2010 Pakistan ranked only twice among the top 20 garlic exporting countries of the world, in the year 2003 and 2008. In the year 2003 and 2008 Pakistan was net importer as well as net exporter of garlic (FAO, 2010).

Forty four percent (44%) of the total garlic production of Pakistan is contributed by Punjab followed by Khyber Pakhtunkhwa, Balochistan and Sindh with thirty five per cent (35%) twelve per cent (13%) and eight per cent (8%) contribution, respectively. Concerning the increase in area and production of garlic it has progressed well (GoP, 2010-11).

Increase in domestic production of garlic can be achieved by enhancing productivity of garlic crop. Productivity can be accelerated by introducing new technology or by improvement in efficiency or both. In Pakistan the adoption rate of new technology in Pakistan is very slow, therefore improvement in efficiency is an appropriate option to increase the agriculture productivity in short run (Javed et al. 2008). Measurement of the efficiency of agricultural production is an important issue in developing countries.

Efficiency was introduced by Farrell (1957), who proposed that the two components, technical and allocative efficiencies, combine together to give a measure of economic efficiency. The term technical efficiency of a farm is its ability to produce the largest possible potential output from existing set of inputs and existing technology while allocative efficiency refers to the ability of a firm to produce at a given level of output using the least cost combination of inputs. An effective economic development strategy depends on enhancing productivity and output growth in agricultural sector (Bravo-Ureta & Pinheiro, 1997). Enhanced productivity increases return to the producers as well as to labor and enables larger consumption of goods and services per person (Productivity Commission, 2013).

This study will provide help to farmers to identify factors that affect garlic growers's technical efficiency and determining the opportunity for increasing output. The findings of this study will also be beneficial for policy makers to form sound programs related to expand garlic production potential more effectively. This study, therefore, is an attempt to assess technical efficiency of various resources used in the production process of garlic in Khyber Pakhtunkhwa.

2. Materials and Methods

2.1 Data Collection and Sample Size

This study was carried out in district Swabi of Khyber Pakhtunkhwa, Pakistan. Multistage sampling technique was used for the sample selection. In the first stage of this sampling technique district Swabi was purposively selected. In the second stage out of 17 villages 03 major garlic producing villages namely Jalbai, Jalsai and ToorDheer were randomly selected. Based on the information taken from the local patwari of the three villages there were 422 farmers in Jalbai, 476 in Jalsai and 510 in ToorDher. In the third and final stage of multistage sampling technique, 110 garlic producers were selected through proportional allocation sampling technique from each randomly selected village.

For measuring relationship between output and input relationship, mean technical efficiency and technical inefficiency in garlic production data was analyzed by using the ML estimates of the stochastic frontier model.

2.2 Model Specification

Stochastic frontier production model was developed by Aigner et al. (1977). Meeusen and Broeck (1977) composed the error model. Their work was based upon the measure of technical efficiency of Farrell in 1957.

Following Bravo-Ureta and Rieger(1991) the stochastic production function is defined as:

$$Yi = f(X_i; \beta) + \epsilon_i \qquad i = 1, 2, 3,..., n \qquad (1)$$

Where; Y_i represents output of garlic for the *ith* farmer in Kgs/ha, f(X; ß) is a suitable function such as Cobb-Douglas production function, X_i are the inputs used in production of onion in units/ha, β_i are the coefficients to be estimated, ϵ_i is a composed error term that captures the error term and inefficiency component (v_i,u_i).The v_i are random errors associated with measurement errors in the yields of garlic reported or the combined effects of input variables not included in the production function. The u_i is assuming independent and is obtaining by truncation (at zero) of the normal distribution with mean μ, and variance σ2u. So, the specified empirical model of the Cobb-Douglas production function for the garlic growers was given as follows:

$$lnYield = \beta0 + \beta_1 lnSeed + \beta_2 lnTrctrHrs + \beta_3 lnLabor + \beta_4 lnFert + \beta_5 lnFYM + \beta_6 lnIrrig + \beta_7 lnWeed + \epsilon_i \qquad (2)$$

Where;
Yield = Yield of garlic in kg per hectare
Seed = Seed rate used in kg per hectare
TrctrHrs = Total tractor hours used per hectare
Fert = Chemical fertilizers (Urea and DAP) in kg per hectare
Labor = Total labor man days per hectare
FYM= Farm yard manure used in kg per hectare
Irrig = Number of irrigations per season
Weed= Volume of weedicides used for one hectare
β_I = Coefficients to be estimated
ϵ_i = Composed error term

ϵ_i = $v_i + u_i$
v_i = Natural error term
u_i =Technical inefficiency error term
ln = Natural logarithm

The explanatory variables (seed rate, tractor hours, labor, chemical fertilizers (Urea, DAP), farm yard manure, number of irrigations and volume of weedicides) have been incorporated for estimation of elasticities of production function and technical efficiency/inefficiency factors in the model. These explanatory variables have the major contribution to the cost of production therefore these were incorporated in the production function.

This research work is being followed by keeping in view the research work done by (Adewumi & Adebayo, 2008) and Wakili (2006) who applied the seed rate, Kibaara (2005) applied the labors and farm yard manure, Obwona (2006), Balbalola et al (2009) and Maganga (2012) applied the fertilizers.

The inefficiency model based on Battese and Coelli (1995) was specified as follows:

$$\mu_i = g(Z_i : \sigma_i) \quad (3)$$

$$\mu_i = \sigma_o + \sigma_1 AGE + \sigma_2 EXP + \sigma_3 EDU + \sigma_4 FARM\ SIZE + \omega_i \quad (4)$$

Where;
μ_i =Technical inefficiency error term
σ_i = Coefficients to be estimated
AGE = Age of the garlic growers in years
EXP = Farming experience of the garlic growers in years
EDU = Education of the garlic growers in years
FARM SIZE = Area under garlic for the farmers in hectare
ω_i = Random error term

Technical efficiency for individual farmer can be defined as the ratio between observed output and corresponding frontier output, which can be expressed as follows:

$$TE_i = Y_{0b} / Y_{fr} = f(\beta, X) + (v_i + u_i) / f(\beta, X) + (v_i) \quad (5)$$

Where Y_{0b} is the observed output produced by the individual farmer and Y_{fr} is the frontier output, the maximum output that a farmer can produced from the given resources. TE takes the value between 0 and 1.

2.3 Model Adequacy Tests

2.3.1 Tests for Detection of Heteroscedasticity Problem

The important assumption of the homoscedasticity of the classical linear regression model is that, the variance of each disturbance term μ_i, appearing in the population regression function are homoscedastic and symbolically it can be written as:

$$E(\mu_i^2) = \sigma^2 \quad i = 1,2,3\ldots..,n \quad (6)$$

If the above mentioned assumption is seriously violated then a problem of heteroscedasticity will appear, which means that variance of the error term will no more remain same and may result in overestimating the goodness of fit. Heteroscedasticity can cause ordinary least square estimates of the variance of the coefficients to be biased, leading to type I or type II error which means that OLS is not BLUE (Best Linear Unbiased Estimator). Heteroscedasticity mostly occurs in cross sectional data as ours, as compared to the time series data (Gujarati & Porter, 2009).

The presence of heteroscedasticity can be tested by several methods but we use Breusch-Pagan-Godfrey test and Goldfeld-Quandt test to find the heteroscedasticity in our data as follows:

2.3.2 Goldfeld-Quandt Test

Procedure of Goldfeld-Quandt test is given as follows:
1. Arrange the data in ascending order according to the values of X_i, beginning with the lowest value of X.
2. After omitting central observation 'c' the remaining data was divided into two groups each of $(n – c)/2$ observations.
3. Run separate OLS regressions for each $(n – c)/2$ observations and obtain the residual sum of squares (RSS) for each regression i.e. RSS_1 for smaller values (the small variance group) and RSS_2 for larger values (the large variance group). Each RSS has $(n – c – 2k)/2$ df, where k is the number of parameters including the intercept term.
4. Compute the ratio: λ = RSS2/df ÷ RSS1/df, If we take μi to be normally distributed and if there is a valid assumption for homoscedasticity then "λ" of the above equation follow the F-distribution with numerator and denominator df each of $(n – c – 2k)/2$ respectively. If the computed value of λ (=F) is greater than the F-tabulated value at the chosen level of significance, then we will reject the hypothesis of homoscedasticity other wise not (Gujarati & Porter, 2009).

2.3.3. Breusch-Pagan-Godfrey (BPG) Test

Procedure of Breusch-Pagan-Godfrey test is given as follows:
1. Run the regression of model (2) by OLS and obtain the error terms μ1, μ2, μ3,……………., μn.
2. Obtain $\sigma^2 = \Sigma\, \mu i^2/n$. (7)
3. Construct "*pi*" variable by the following equation.

$$pi = \mu i^2/\sigma^2 \quad (8)$$

4. Run the regression "*pi*" on the Z's as fallows.

$$pi = \alpha 0 + \alpha 1Z1 + \alpha 2Z2 + \alpha 3Z3 + \ldots\ldots\ldots\ldots + \alpha nZn + vi \quad (9)$$

Where, *vi* is the error term for the above regression.
5. Obtain the explained sum of squares (ESS) from the regression eq. (9) and compute Θ, as Θ = 1/2(ESS). Consider the normal distribution of μi that if there is homoscedasticity and if the sample size *n* increases, then $\Theta \sim X^2 m\text{-}1$, which shows that Θ follows the chi-square distribution with (m-1) degrees of freedom. Therefore if the computed value of Θ $(=X^2)$ exceeds the critical chi-square value at the chosen level of significance, then one can reject the hypothesis of homoscedasticity otherwise accept it (Gujarati & Porter, 2009).

2.4 Test for Multicollinearity Problem

The basic assumption of our study is that explanatory variables should not be correlated with each other and if this assumption is violated then it means there is a problem of multicollenearity. Multicollinearity naturally occurs in time series data by showing "perfect" or exact linear relationship among some or all the explanatory variables of the regression model. Multicollinearity problem can be detected by performing the correlation matrix test (Gujarati & Porter, 2009).

3. Results and Discussion

3.1 Result of Goldfeld Quandt Test for Heteroscedasticity

The estimate value of λ is 1.66 which follows F distribution (Gujarati & Porter, 2009). The critical $F_{0.05\,(45,\,45)}$ value is 1.69. Since the estimated value does not exceed the critical value, therefore, we accept the null hypothesis of homoscedasticity.

3.2 Result of Breusch-Pagan-Godfrey Test for Heteroscedasticity

The estimated value of Θ is 0.874 which follows chi-square distribution. Tabulated $\chi^2_{0.05\,(7)}$ value is 14.0671. As our estimated value does not fall in the critical region, so we can not reject the null hypothesis of homoscedasticity. This result reinforces that the model (2) is not plagued with the problem of heteroscedsticity.

3.3 Result of Correlation Matrix

The above correlation matrix between explanatory variables shows that there is no linear relationship among all the explanatory variables because none of the value is greater than 0.80 which suggests that the basic assumption of multicollinearity has not been violated so multicollinearity problem does not exist in the model (Table1).

Table 1. Result of Correlation Matrix

Variables	lnSeed	lnTracthrs	lnLAB	lnFERT	lnFYM	lnIRRI	lnWEED
lnSEED	1.000						
lnTRAC	0.489	1.000					
lnLAB	0.220	-0.129	1.000				
lnFERT	0.678	0.569	0.210	1.000			
lnFYM	0.509	0.406	0.076	0.464	1.000		
lnIRRI	-0.071	0.004	0.147	-0.069	0.093	1.000	
lnWEED	0.175	0.470	-0.102	0.406	0.269	0.071	1.000

Note: Yield= Yield of garlic in kg per hectare

3.4 Major Determinants of Garlic Yield

To achieve higher and impressive level of garlic production, it is important to adopt better practices of crop management. Seed rate, tractor hours, labor days, fertilizers, farmyard manure, number of irrigations, weedicides and age, education, experience and farm size under garlic of the respondents were the different factors which affect the garlic yield.

3.5 Factors of Technical Efficiency

The effect of regressors on garlic production is discussed below in detail:

The coefficient for the seed rate is positive which indicates a positive relationship between seed rate and garlic production by implying that one percent change in seed rate will increase garlic yield by 0.22 percent and is statistically significant showing the same results as estimated by (Adewumi & Adebayo, 2008) and Wakili (2006). The positive coefficient for tractor hours shows that one percent increase in tractor hours will increase the garlic production by 0.24 percent and is statistically significant. The coefficient for labors is negative and statistically insignificant, which shows a negative impact on the production of garlic and these results are the same as the results of Kibaara (2005). The coefficient of fertilizers is positive and statistically significant which indicates that one percent change in fertilizers will increase garlic production by 0.29 percent and the results are in accordance with the results of Obwona (2006), Balbalola et al (2009) and Maganga (2012). The coefficient of farm yard manure is also positive and statistically significant which implies that one percent change in farm yard manure will increase yield of garlic by 0.09 percent and the same results were estimated by Kibaara (2005). Irrigation is insignificant and its coefficient is also negative. Weedicide is statistically significant and its coefficient is also positive which shows that one percent change in weedicide will increase garlic production by 0.02 percent. It was concluded from maximum likelihood estimates of Frontier 4.1 that seed rate, tractor hours, fertilizers, farm yard manure and weedicides are statistically significant 1%, 5% and 10% level of significance with a positive coefficients. Labors and irrigation are statistically insignificant and shows negative relationship with garlic yield. The mean technical efficiency is found to be 0.78 indicating that there is a considerable room to improve the garlic production in the study area through the efficient use of available resources and technology.

3.6 The factors of technical inefficiency

The technical inefficiency factors are those factors which show their expected influence on the technical efficiency of the garlic growers. The inefficiency factors were estimated by using the estimated (σ) coefficients of the inefficiency effects. The inefficiency effects were specified as those related to age, education, farm size and farming experience under garlic.

Age: The coefficient of age is positive and significant, which shows a significant positive relationship with technical inefficiency. This result is the same as that found by Msuya and Ashimogo (2005).

Farming experience: The coefficient of farming experience is negative as well as insignificant showing that the relationship between farming experience and technical inefficiency is negative. Msuya and Ashimogo (2005) also found the same result.

Education: Education plays an important role in adoption of better technology and achieving high output. The coefficient for education is negative and significant which shows negative relationship with technical inefficiency and positive effect on garlic yield.

Farm size: The coefficient of farm size is statistically insignificant and the negative coefficient of farm size implies that farm size of farmers has positive but insignificant impact on yield of garlic.

So only age and education were statistically significant and age coefficients were positive while coefficients of education were negative. Farming experience and farm size is statistically insignificant and their coefficients were negative.

3.7 Variance Parameters

Maximum likelihood estimates was used to estimate the gamma value with the estimation of mean technical efficiency and the value of parameter estimates for the inefficiency effects model.

The theory says that the true value of gamma should be greater than zero but less than one and its value can be calculated through the estimated values of variance parameters δ^2 and δ_u. The maximum likelihood estimates (MLE) of the stochastic frontier production function estimates a positive coefficient of variance parameter (σ^2) which is significant at 10% level and shows goodness of the distributional assumption of the composite error term. The value of gamma (γ) was calculated by the formula σ^2_u/σ^2, which is 0.9355 and significant at 1% level indicating 93.55% variation in garlic yield due to inefficiency factors.

Table 2. Maximum Likelihood Estimates of the Stochastic Frontier Production Function for Garlic in District Swabi (Dependent variable = Yield of garlic in kg/ha)

Variables	Parameters	Coefficients	Standard error	T ratios
Constant	B_0	5.5744	0.6518	8.5515
Seed rate	B_1	0.2249*	0.0693	3.2409
Tractor Hours	B_2	0.2423*	0.0637	3.8048
Labor	B_3	-0.0327	0.0518	-0.6307
Fertilizer	B_4	0.2876*	0.0610	4.7130
FYM	B_5	0.0961**	0.0464	2.0687
Irrigation	B_6	-0.0694	0.0909	-0.7631
Weedicide	B_7	0.0211***	0.0132	1.5987
Inefficiency Effect Model				
Constant	σ_0	0.6936	0.4532	1.5301
Age	σ_1	0.0116***	0.0069	1.6812
Experience	σ_2	-0.0335	0.0278	-1.2050
Education	σ_3	-0.0392***	0.0214	-1.8318
Farm Size	σ_4	-2.7184	2.6322	-1.0327
Variance Parameters				
Sigma square	σ^2	0.3642	0.4208	
Gamma	Γ	0.9355	0.0725	12.9038
Mean efficiency	X	0.7752		

Note:*, ******, ******* are significant 1%, 5% and 10% level respectively.

It was concluded from the ML estimations of stochastic frontier Cobb-Douglas production function, that seed rate, tractor hours, fertilizers, FYM and weedicides were statistically significant at 1%, 5% and 10% level of significance with positive coefficients.

The inefficiency model shows that area and education under garlic crop are statistically significant at 10% level of significance respectively, with age having positive and education having negative coefficient.

The ML estimations of Frontier 4.1 estimates, the value of gamma (γ) is 0.9355and significant at 1% level of significance, respectively. It shows that 93.55% variation is due to inefficiency factors, respectively in the yield garlic. So, it indicates that the random error component of inefficiency, significantly contribute to the analysis (Table 2).

Table 3. Frequency Distribution of Technical Efficiency of Garlic Growers

Technical efficiency	Frequency	Percentage
<0.50	5	5
0.51 - 0.60	11	10
0.61 - 0.70	14	13
0.71 - 0.80	19	17
0.81 - 0.90	34	31
>0.90	27	25
Sample size	110	
Minimum	0.21	
Maximum	0.95	
Mean	0.77	

3.8 Frequency Distribution of Technical Efficiency of Garlic Growers

Table 3 shows the estimated technical efficiency's frequency distribution for the garlic growers. The minimum and maximum values for estimated technical efficiencies are 0.2109 and 0.9563 with a mean efficiency 0.7752 respectively. So these results indicate that by using the available inputs the yield of garlic can be improved.

4. Conclusion and Recommendations

Present study applied Cobb Douglas stochastic frontier production function for the estimation of technical efficiency of garlic production in Khyber Pakhtunkhwa province of Pakistan. The result shows that the mean technical efficiency was 93.55 percent which shows that farmers in the study area were highly efficient. The results of socio economic characters such as age, education, farm size and experience shows that education is the only factor which significantly affect farm technical inefficiency. Based upon these findings it is recommended that government should introduce latest mechanical technology to reduce/replace number of labors used in garlic production. Due to high prices of oil and shortage of electricity in the country the farmers were facing problems to irrigate the farms, so development of canal irrigation system to solve the irrigation problem of the famers will boost up garlic production.

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