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MEASURING TECHNICAL EFFICIENCY OF ONION (*Allium cepa* L.) FARMS IN BANGLADESH

M. A. BAREE[1]

Abstract

An attempt was made to determine the overall farm-specific technical efficiency or inefficiency of onion farms of Bangladesh. Farm-level data were used for the estimation of the parameters of Cobb-Douglas stochastic frontier production function. The model for technical inefficiency effects in the stochastic frontier included age, experience, education, and farm size. The elasticity of output with respect to land, labour, and capital cost was estimated to be positive values of 0.3026, 0.0718, and 0.0442, respectively, and also significant. With respect to seed and irrigation, it was found to be insignificant with negative values of 0.0045 and 0.0007. It indicates that per hectare yield of onion decreases if the amount of seed and irrigation hour increase. The coefficients of age, experience, and farm size were significant with expected negative signs, which means that the inefficiency effects in onion production decreases with increase in age, experience, and farm size. The technical efficiency of onion farms varied from 58% to 99% with mean value of 83%. It denotes that there is a scope to increase output per hectare of onion farm by 17% through the efficient use of production technology without incurring any additional costs.

Keywords: Technical efficiency, onion in Bangladesh.

Introduction

Onion is the most important herbaceous bulb and spice crop in Bangladesh as well as in the world. It ranks first and second among other spices and condiment crops grown in respect of production and area in Bangladesh, respectively (BBS, 2004). Onion is grown in all districts of Bangladesh and widely cultivated in commercial scale in the greater districts of Faridpur, Pabna, Rajshahi, Dhaka, Dinajpur, Jessore, Kushtia, and Rangpur. The area under onion production is 86235 hectares with production of 589 thousand metric tons and 6.83 metric tons per hectare in Bangladesh (BBS, 2005). As a minor crop, onion plays an important role in the economy of Bangladesh. It offers a considerable promise in terms of generating increased rural employment opportunities because its production is more labour intensive than other crops. The demand for onion is world wide for its multipurpose uses as spices, vegetables, salad, dressing, etc. It is used to prepare almost every food item by all classes of people. It also relieves head sensation and insect bites due to its medicinal properties. Onion contains vitamin B and a trace of vitamin C and also trace of iron, calcium, and volatile oil

[1]Associate Professor, Department of Crop Science and Technology, University of Rajshahi, Bangladesh.

known as allylpropyl-disulphide (Yawalkar, 1985). Approximately a shortage of 323 thousand tons of onion per year is existed. To meet up the increasing demand, Bangladesh has to import onion from India and Pakistan every year at the cost of hard earned foreign currency.

It is difficult to increase onion production by increasing the area of land under cultivation due to the limitation of land. But, there is an opportunity to increase production of onion by improving the existing production technology. Farmers may be relatively inefficient due to land fragmentation, less experience, illiteracy, etc. If farmers are found to be technically inefficient, production can be increased to a large extent using the existing level of agricultural inputs, the agricultural extension services and the available technology. In the past, so far, the author's knowledge is concerned, there was no study on technical efficiency of onion producers. This study was undertaken to find out the overall farm-specific technical efficiency or inefficiency of onion farms. The study may be helpful for policy makers in this field to draw a strategic planning for increasing production of onion farm.

Materials and Method

Data source, sampling

The field survey was conducted covering the 15 villages of Santhia Upazila of Pabna district of Bangladesh during the period from January 2004 to July 2004. A total of 225 sample farmers were selected from all farm groups by using stratified random sampling technique. Face to face interviewing respondents' method was followed for data collection. The collected data ware scrutinized, edited, tabulated, and analyzed carefully to achieve the meaningful interpretation. The marginal analysis of variables was the basis of analysis for this study. The variables were measured functionally using stochastic frontiers production function. The parameters of respective variables were estimated using the statistical package FRONTIER 4.1 (Coelli, 1996).

Model specification

The Cobb-Douglas stochastic frontier production function model has been specified to estimate the level of overall technical efficiency of onion farms. The Cobb-Douglas production function specification provides an adequate representation of the production technology. The specification of the Cobb-Douglas stochastic frontier production function model can be written as:

$$\text{InYi} = \beta_0 + \sum_{i=1}^{5} \beta_i INx_i + V_i - U_i$$

$$\text{InYi} = \beta_0 + \beta_1 In(X_1) + \beta_2 In(X_2) + \beta_3 In(X_3) + \beta_4 In(X_4) + \beta_5 In(X_5) + V_i - U_i \quad (1)$$

Where the subscript i refers to the i-th farmer, In represents the natural logarithm, Y represents the per hectare output (kg), X_1 is the land use cost per hectare (Tk.), X_2, X_3, X_4, and X_5 represent the total quantity of labour/ha (man-days), amount of seed/ha (kg), irrigation hour/ha (hour), and capital cost/ha (Tk.), respectively. The V_i are assumed to be independently and identically distributed random errors, having $N(0, \sigma v^2)$ distribution, and the U_i are non-negative random variables, called technical inefficiency effects, associated with the technical inefficiency of onion producers involved.

It is assumed that the inefficiency effects are independently distributed and U_i arise truncation (at zero) of the normal distribution with mean, μ_i, and variance, σ^2, where μ_i can be specified and defined as:

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4$$

Where Z_1 denotes the age of farm operator, Z_2 represents the experience of farm operator, Z_3 is the year of schooling of farmer and Z_4 represents the farm size of onion. The β and δ are unknown parameters to be estimated together with the variance parameters, which are expressed in terms of:

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2 \text{ and } \gamma = \sigma_u^2 / \sigma_s^2$$

Where the y-parameter has the value between zero and one.

The parameters of the stochastic frontier production function model are estimated by the method of maximum likelihood, using the computer program, FRONTIER Version 4.1 (Coelli, 1996).

The technical inefficiency model for the inefficiency effects (2) can only be estimated if the inefficiency effects are stochastic. Hence, there is an interest in testing the null hypotheses that the inefficiency effects are not present;

$H_0 : \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$; and

The coefficients of the variables in the model for the inefficiency effects are zero,

$H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$.

These null hypotheses are tested by using the generalized likelihood-ratio statistics γ that is defined by

$$\gamma = - 2\text{In } [L(H_0)/ L(H_1)]= - 2 [\text{In}\{L(H_0)\} – \text{In } \{L(H_1)\}] \quad (3)$$

Where L (H_0) and L (H_1) are the values of the likelihood function under the specifications of the null and alternative hypotheses H_0 and H_1, respectively. If the null hypothesis is true, then γ has approximately a Chi-square (or a mixed Chi-square) distribution (Coelli, 1995). Given the specifications of the stochastic frontier model (1) and (2), the technical efficiency of i-th farmer can be shown to be equal to:

$TE_i = \exp(-U_i)$

Thus, the technical efficiency of a farmer is between zero and one and is inversely related to the inefficiency effect. The efficiencies are predicted using the predictor that is based on the conditional expectation of exp(Uj) (Battese and Coelli, 1993).

Results and Discussion

The stochastic frontier model involves input variables like land, labour, seed, irrigation, and capital cost, and socio-economic variables like age, experience, education and farm size are considered in the inefficiency model. The maximum likelihood estimates of the coefficients of parameters in the Cobb-Douglas stochastic frontier and inefficiency model, defined by equations (1) and (2), is presented in Table 1. The comparative significance of inputs of production is predicted by the elasticity estimates from the stochastic frontier production function. The coefficients of land, labour, and capital cost were found to be positive and also significant. The elasticity of output with respect to land, labour, and capital cost was estimated to be positive values of 0.3026, 0.0718, and 0.0442, respectively. Thereby we can say that if the land areas, number of labourers, and capital cost are increased by one per cent, per hectare yield of onion will be increased by 0.3026 percent, 0.0718 percent, and 0.0442 percent, respectively. The coefficients of seed and irrigation are found to be negative and also insignificant which indicates that per hectare yield of onion decreases if the amount of seed and irrigation hour increase. From the results of stochastic frontier model, we see that if the inputs of which coefficients have positive sign are increased by one percent, the total yield per hectare of onion is estimated to increase 0.4186 percent.

Land occupied the highest elasticity of output that indicates the most dominant factor of production. But land is scarce to the farmers in Bangladesh. Land is not a single factor that influences the output, but other influencing factors like labour and capital cost of which marginal productivity are diminishing have positive effect on production. The marginal productivity of seed and irrigation is negative, which have negative effect on production. The return to scale of onion production 0.4134 (summation of all input coefficients) indicates the decreasing returns, which means that farmers produce their production on the non-optimal level of operation.

Table 1. Maximum likelihood estimates for parameters of Cobb-Douglas stochastic frontier production function and technical inefficiency model for onion farms.

Variables	Parameter	Coefficients	T-ratio
Stochastic Frontier:			
Constant (x_0)	β_0	2.3621**	6.2461
Land (x_1)	β_1	0.3026**	4.5598
Labour (x_2)	β_2	0.0718*	1.5906
Seed (x_3)	β_3	-0.0045	-0.2844
Irrigation (x_4)	β_4	-0.0007	-0.1664
Capital cost (x_5)	β_5	0.0442*	1.8081
Inefficiency Model:			
Constant	δ_0	-0.5869**	-2.7028
Age (Z_1)	δ_1	-0.0090*	-1.7626
Experience (Z_2)	δ_2	-0.0006*	-1.6019
Education (Z_3)	δ_3	0.0027	1.3249
Farm size (Z_4)	δ_4	-0.0007**	-3.9489
Variance Parameters:			
$\sigma^2_s = \sigma^2_v + \sigma^2_u$		0.2549**	3.9469
$\gamma = \sigma^2_u / \sigma^2_s$		0.7265*	1.6956
Log-likelihood Function:		101.82	

**Significant at 5%; *Significant at 10%

Inefficiency effects

The estimated δ-coefficients associated with the explanatory variables in the stochastic frontier model for technical inefficiency effects had to be analyzed due to the effect of these variables on the capability of farmers. The signs on the δ-parameter in the inefficiency effect model are expected to be negative. The coefficients of age, experience, and farm size are estimated to be negative sign and significant. The estimated results indicate that the technical inefficiency of onion producers decreases if the age, experience, and farm size of farmer increase. The coefficient of education is insignificant with positive sign, which means that the technical inefficiency effect increases with the increase in education of farmer. It is unexpected but not entirely surprising since most of the educated farmers have alternative income sources and they do not completely rely on agriculture for their livelihoods. If the farmers with more formal education have alternative income sources, or they are not attentive with farming practices and rely more on fixed labourer those are not educated, may have positive effect upon the inefficiency effects.

The γ-parameter associated with the variance in the stochastic frontier model is to be estimated at 0.7265, which is significantly different from zero. It indicates that inefficiency effects have a significant contribution in determining the level and variability of output of onion farms. The tests of null hypotheses are that the technical inefficiency effects are not present and the coefficients of the variables in the model for the inefficiency effects are zero. Formal tests of null hypotheses are tested by using the generalized likelihood-ratio test statistic. The estimated LR statistics are 36.82 and 22.12, which are greater than the critical values of 11.07 and 9.49 at 5 percent level of significance. Thus both the null hypotheses are strongly rejected.

Farm-specific technical efficiency

It is more useful for policy makers to measure the individual farm-specific technical efficiency than the average technical efficiency estimates. Individual farm-specific efficiency measures facilitate identification of the determinants of efficiency rating among farms. Then appropriate policies can be formulated to decrease efficiency differences of farms, which is important to accelerate the overall growth of farms. Table 2 displays the frequency distribution of farm-specific technical efficiency estimates of onion farms from the Cobb-Douglas stochastic frontiers.

Table 2. Distribution of technical efficiency of onion farms.

Efficiency (%)	No. of farms	Percentage of farms
0-55	0	0
55-60	10	4.44
60-65	13	5.78
65-70	20	8.89
70-75	24	10.67
75-80	31	13.78
80-85	46	20.44
85-90	40	17.78
90-95	23	10.22
95-100	18	8.00
Total number of farms	225	100
Minimum	58	
Maximum	99	
Mean	83	
Standard Deviation	11	

The study reveals that only 18.22 percent of total sample farmers were found to have received outputs which were very close to the maximum frontier outputs maintaining the efficiency level 90 percent to 100 percent and 38.22 percent of total sample farmers were observed to produce output lying on the efficiency level 80 percent to 90 percent, while 43.56 percent of total sample farmers produced outputs following the efficiency level 0 percent to 80 percent. The maximum and minimum technical efficiencies were observed to be 99 percent and 58 percent, respectively, where standard deviation was maintained at 11. The mean of technical efficiency was found to be 83 percent. From the result, it can be interpreted that on average, there appears to be 17 percent (= 1-0.83) technical inefficiencies among the sample farmers of onion farms. This implies that the output per hectare of onion farm can be increased, on average, by 17 percent through the efficient use of existing production technology without incurring any additional production costs.

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Appendix

Table 1. Summery statistics of the variables used in the model.

Variables	Mean value	Minimum value	Maximum value	Standard Deviation
Return (Tk./ha)	10113.17	8002.80	16302.00	1430.53
Land (rental value, Tk./ha)	15042.85	9880.00	22230.00	2937.22
Labour (man-days/ha)	323.94	274.17	372.97	19.41
Seed (kg/ha)	5.77	3.71	7.41	0.71
Irrigation (hour/ha)	15.56	11.12	18.53	2.01
Capital cost (Tk./ha)	6062.59	4438.59	9077.25	969.21
Age of farmer (years)	42.79	25.00	58.00	6.41
Experience (years)	14.90	7.00	30.00	4.84
Education (years)	3.80	0.00	14.00	4.14
Farm size (ha)	0.190	0.033	0.709	0.162

Source: Field survey, 2004