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Food Security Through Increasing Technical Efficiency

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Abstract: Stochastic frontier production function was used to determine technical efficiency and its determinants in potato production. Cobb Douglas production function was adopted. Results indicated that age of the respondents, consulting extension staff and cost of plant protection measures were positively related with technical efficiency. However, cost of fertilizer was negatively affecting technical efficiency. The main reason was injudicious use of fertilizer especially nitrogenous fertilizer. The mean technical efficiency level was 76% indicating that there exist a large potential to increase potato production in Pakistani Punjab. Results of the study suggest that by improving technical efficiency, food security problem could be handled to a great extent with available technology and resources.

Key words: Efficiency, technical, stochastic, frontier, Pakistan

INTRODUCTION

Population of Pakistan has increased from 33 million at the time of its independence in 1947 to 152.53 million during 2004-05. Although the current population growth rate slowed to 1.9%, overall population has increased by 2.76 million people as compared to last year 2003-2004 (Government of Pakistan, 2005). Wheat is a staple food in Pakistan and fluctuations in its production substantially affect food security. Rice, pulses, fruits and vegetables are of prime important after wheat. Domestic production of wheat, rice and other food crops is not enough to fulfill the dietary demand of people of Pakistan. Mostly, people get nutrient ingredients from rice and wheat which are not sufficient totally to feed for long and also do not fulfill the dietary needs of population.

Integrating micronutrients-rich foods such as vegetables, fruits and livestock products into diets is the most practical and sustainable way to alleviate micronutrients deficiency prevailing in the country (Islam, 1996; Government of Pakistan, 1988). Vegetable growing in general and potato in particular comes as a first strategy to reduce poverty as well as to overcome food security problems. Despite a relatively minor contributor to the overall economy, potato has become an increasingly important sector in Pakistan in terms of its potential for contributing to food security, nutrition, employment and improvement in the socio-economic status of rural communities. Like other vegetables, potato production is labour intensive and thus generates higher employment at the farm level (Abedullah *et al*., 2002; Barron and Rello, 2000). In spite of all such facts, a number of problems still continue to hinder the development of this sector in Pakistan. These include an inadequate supply of quality seed, low output prices, lack of extension services and inadequate availability of financial resources (Ahmad *et al*., 2004, 2005).

Potato production is very low despite having surplus labour in the rural areas of the country. Now the question arises, how can we increase the potato production in our country? There are three possible ways to increase potato production a) by allocating more area, b) by developing and adopting new technologies and c) by utilizing the available resources more efficiently. The third option of using available resources more efficiently becomes viable in the current situation. This says that increased potato production lies in improvement of productivity i.e., yield per unit area. Since additional areas and development and adoption of new technology are not at hand, therefore, the ample scope exists for improving productivity. Productivity is vital for the future of mankind to meet its basic needs of food, fiber and shelter.

Potato growing farmers face two kinds of inefficiencies i.e., technical and allocative inefficiencies. Measuring technical efficiency at the farm level, identifying important factors associated with an efficient production system and assessing the potential for and sources of future improvements are essential for developing sustainable potato production. Instead of increasing the use of inputs to increase production, efforts should be made towards output growth through improved technical efficiency, i.e., producing more by

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using existing inputs more efficiently (Sharma and Leung, 2000). Moreover, the trend of increasing revenues from improving technical efficiency gives some indication that increased production may provide a revenue source to limited resource farmers (Kebede and Gan, 1999). Therefore, it is crucial to investigate technical efficiency and to provide information to the resource poor potato growers. This study has been designed to determine technical efficiency in potato production along with estimation of factors influencing technical efficiency.

MATERIALS AND METHODS

Stochastic frontier production function: Parametric (econometric) and non-parametric (mathematical) approaches have been widely used in estimating technical efficiency of various enterprises. Advantages and disadvantages of using these approaches have been discussed by Battese (1992), Bravo-Ureta and Pinheiro (1993), Coelli (1996b) and Coelli and Perelman (1999).

Stochastic frontier production function method has been adopted to estimate technical efficiency for the potato growers, since agricultural production in general and potato production in particular exhibits random shocks and there is a need to separate the influence of stochastic variables (random shocks and measurement errors) from resulting estimates of technical inefficiency. Several studies have used the stochastic production function approach to determine technical efficiency (Dawson *et al.*, 1991; Kalirajan, 1991; Bravo-Ureta and Rieger, 1991; Parikh *et al.*, 1995; Battese and Hassan, 1999; Hassan, 2004).

The stochastic frontier production function is as under:

$$\ln Y_i = \beta_0 + \sum_{i=1}^{7} \beta_i \ln \chi_i + \upsilon_i - \mu_i \quad i = 1, 2, \dots n \qquad (1)$$

where Y_i is the dependent variable in the production function showing the per acre yield (kg) for the i-th farm. ln represents natural logarithm and potato yield and input variables are expressed in logarithms. Six input categories and one variable for location are defined as explanatory variables in the production function. χ_i is a vector of k inputs used in the production of potato and χ_i are defined as under:

χ_{1i} shows number of tractor hours used for ploughing, planking, leveling and planting or simply we can say, tractor hours applied for land preparation on per acre basis. χ_{2i} represents the quantity of per acre seed (kg) used on the i-th farm growing the potato. χ_{3i} represents the cost incurred on plant protection measures (Pak Rupees and \$1 = Pak Rs 60) including cost of pesticide, fungicide and weedicide, etc. χ_{4i} represents number of hours required to irrigate one acre of land. χ_{5i} indicates labour input consisting of family and hired labour and it is calculated as the total number of labour hours required to perform various farming activities in potato production. χ_{6i} shows the NPK nutrients, (kg per acre). It was observed that a few vegetable growers used farmyard manure. It is, therefore more plausible to determine the quantity of nitrogen, phosphorus and potassium that are expected to be present in manure. These nutrients were calculated on the basis of chemical composition given by Brady (1990). Thus the NPK nutrients include both organic and inorganic nutrients. χ_{7i} shows dummy variable for location. It was taken as 1 if the district is Okara, otherwise zero.

β_0, β_i are unknown parameters to be estimated. V_1 is independent and identically distributed (i.i.d) normal variable with mean zero and constant variance, σ^2_v, independent of the μ_i. The μ_i shows the technical inefficiency effects and is associated with technical inefficiency of firm. The μ_i is assumed to be identically and independently distributed half normal random variable.

$u_i^{'s}$ are non-negative random variables, associated with technical inefficiency of production of the farmers, assumed to be independently distributed, such that the technical inefficiency effect for the i-th farmer is obtained by truncation (at zero) of the normal distribution with mean μ_i and variance σ^2, such that

$$\begin{aligned}\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \\ \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + \delta_9 Z_{9i} + \omega_i\end{aligned} \qquad (2)$$

where Z_{1i} represents the age of potato growing farmers in years, Z_{2i} represents schooling years of the potato growers, Z_{3i} represents family size (in number) of the farmers growing potato, Z_{4i} is a dummy variable indicating the tenancy status of the growers (if the farmer is cultivating his own land, then it has value of one, otherwise zero), Z_{5it} represents the total farm area operated by the potato growers in acres, Z_{6i} is a dummy variable showing the contact of potato growers with extension staff (if the farmers reported that they consulted with extension staff, then it has the value one, else zero), Z_{7i} is a dummy variable showing the contact of potato growers with input dealers (if the farmers reported that they consulted with input dealers, then it has the value one, else zero). The δs are unknown parameters to be estimated. w_i are unobservable random variables which are assumed to be independently distributed and obtained by truncation of the normal distribution with zero mean and constant variance (σ^2).

Two stage approach, estimating production function in first stage and then regressing technical efficiency on various farm and farmers specific variables in second stage to determine factors affecting technical efficiency contains serious problem concerning assumptions made for the μ_i. The second stage was criticized by Kumbhakar *et al.* (1991), Battese and Coelli (1995) and Wang and Schmidt (2002). Therefore, the above mentioned stochastic frontier production function and inefficiency effects model is estimated in one stage using the computer program, FRONTIER 4.1, written by Coelli (1996b). The parameters of the frontier model are estimated, such that the variance parameters are defined as

$$\sigma^2_s = \sigma^2_v + \sigma^2 \text{ and } \gamma = \sigma^2 / \sigma^2_s$$

where the γ has a value between zero and one.

A summary statistics of the variables included in stochastic frontier production function and technical inefficiency effects model defined above is given in Table 1.

Data sources: The data for this study came from the Department of Environmental and Resource Economics, University of Agriculture, Faisalabad, Pakistan. The cross section data were collected for potato during 2002-2003. Potato has been selected for this study due to the fact that potato is the most important vegetable in terms of area and production in the Punjab province of Pakistan. Two potato crops namely autumn and spring are cultivated during a year in Pakistan. However, more area is concentrated under autumn crop compared to spring crop. Because of this fact, data for autumn crop was collected.

As far as sampling is concerned, at first four districts i.e., Okara, Sahiwal, Pakpattan and Kasur being the most important in terms of area were selected. Out of these districts, two districts, namely Okara and Kasur, were chosen randomly. Share of Okara and Kasur in total potato area in the Punjab province was found to be 23.96 and 8.20%, respectively (Ahmad *et al.*, 2004). One tehsil of Okara and two tehsils of Kasur were taken for gathering information regarding potato cultivation. Four villages were selected from Okara tehsil whereas in case of Kasur and Chunian tehsils, four and one villages were taken respectively. A total of 100 farmers, 50 from each district were taken by using purposive sampling technique. A well structured and field pre-tested comprehensive interviewing schedule was used for the collection of detailed information on various aspects of potato crop of the year 2002-03.

Table 1: Descriptive statistics for variables in the model for potato growers

Variable	Sample mean	Standard deviation	Minimum value	Maximum value
Yield (kg ac^{-1})	8328.00	1689.69	4000.00	12000.00
Land preparation) (Tractor h ac^{-1})	6.67	1.39	4.00	10.00
Seed (kg ac^{-1})	1280.40	158.40	920.00	1800.00
Plant protection measures (Pak rupees/ac)	1613.54	526.24	455.00	3000.00
Irrigation (h ac^{-1})	16.48	5.01	6.50	24.00
Labour (h ac^{-1})	198.21	63.22	104.50	440.25
Fertilizer (kg ac^{-1})	245.78	55.40	121.00	408.01
Cost of fertilizer	4908.44	1189.70	2795.00	8280.00
Age (years)	44.31	13.74	24.00	85.00
Schooling years	7.33	3.78	0.00	16.00
Family size (No.)	6.91	2.51	2.00	12.00
Owners (No.)	47.00	-	-	-
Farm area (acres)	63.44	62.02	6.00	250.00
Farmers consulting extension staff (No.)	38	-	-	-
Farmers consulting input dealers (No.)	32	-	-	-

RESULTS AND DISCUSSION

The choice of functional form is an important issue in the stochastic frontier production. In most of the studies, Cobb Douglas functional form has been used to analyze farm efficiency despite its well-known limitations (Battese, 1992; Bravo-Ureta and Pinheiro, 1993; Thiam *et al.*, 2001; Battese and Hassan, 1999; Hassan, 2004) because it is easy to estimate and mathematically manipulate. Kopp and Smith (1980) indicated that functional form has a discernible but rather small impact on estimated efficiency. Ahmad and Bravo-Ureta (1996) rejected the Cobb Douglas functional form in favour of a simplified translog form, but concluded that technical efficiency measures do not appear to be affected by the choice of the functional form (Thiam *et al.*, 2001). On the other hand, translog functional form contains serious issue of multicollinearity. Therefore, Cobb Douglas stochastic production function is preferred for the present study.

The estimates of the parameters of the Ordinary Least Squares (OLS) and maximum likelihood (MLE) methods for potato growers are given in Table 2. It is evident from Table 2 that four of the maximum likelihood estimates of the coefficients associated with the production inputs for the data set of the potato growers are statistically different from zero. Coefficients of land preparation, seed, plant protection measures and labour are statistically different from zero when ML method is used. Only two variables i.e., irrigation and labour are statistically significant when parameters are estimated using OLS method. However, irrigation variable is not significantly different from zero using MLE method. Therefore, the MLE model is well representative of data set for the potato growers as compared to OLS method.

Table 2: Maximum likelihood estimates for parameters of CD stochastic frontier production function and inefficiency model for potato growers

Variable	Parameter estimates	
	OLS	MLE
Constant	6.989* (0.832)	6.647* (1.022)
ln (Land preparation)	0.046ns (0.091)	0.105*** (0.079)
ln (Seed)	0.166ns (0.171)	0.246** (0.163)
ln (PPM)	0.002ns (0.055)	-0.192*** (0.147)
ln (Irrigation)	0.097** (0.059)	0.064ns (0.059)
ln (Labour)	0.299* (0.069)	0.285* (0.062)
ln (NPK)	-0.089ns (0.083)	0.2446ns (0.229)
Inefficiency model		
Constant		0.327ns (0.369)
Age of the respondent		-0.003** (0.001)
Schooling year		0.001ns (0.008)
Family size		0.013ns (0.013)
Owners dummy		0.015ns (0.049)
Farm area		-0.0009ns (0.001)
Contact with extension staff		-0.148* (0.058)
Contact with input dealers		0.002ns (0.053)
Cost of PPM		-0.00018* (0.00008)
Cost of fertilizer		0.0008* (0.0003)
Variance parameters		
σ^2		0.023* (0.005)
γ		0.048ns (0.795)
Log likelihood function	27.307	45.806

Figures in parenthesis are standard errors, *, ** and *** indicate that estimates are significantly different from zero at 5, 10 and 20% level of significance respectively and ns stands for non-significant

Since Cobb Douglas production function is adopted in the present study, the estimates of the coefficients indicate elasticities of production. The production elasticity for labour variable is very high compared to other variables used in potato production. This result shows that one% increase in labour use would increase potato production by 0.285%. This elasticity is consistent with those of Battese *et al.* (1993), Hussain (1999) and Hassan (2004). Other important variable in term of magnitude is seed. This implies that increasing seed by one% would lead to an increase in yield of potato by 0.246%. This result is in full agreement with those of Ahmad *et al.* (1999) and Battese and Broca (1997). Elasticity of land preparation variable is also of vital important to increase potato yield. The unexpected elasticity estimate is found for plant protection measure variable. The negative sign indicates that more use of plant protection measures would decline potato yield by 0.192%. The primary reason of this negative elasticity estimate is that potato growers would be using plant protection measures at improper time. Lack of extension services could be other reason.

Using the specification of Eq. 1 and 2, the study makes an attempt to investigate determinants of technical inefficiency. The coefficients of the explanatory variables in the technical inefficiency model are of particular interest in terms of making policy options. Out of 9 variables explaining technical inefficiency, four variables are significantly different from zero, according to an asymptotic t-test.

Age of the head of the potato growers is included to assess the effects of age on the level of technical inefficiency. It is commonly believed that age can serve as a proxy for farming experience. Thus a farmer with the longer age has the greater farming experience. It is estimated that the age has a negative effect upon the technical inefficiency effects in potato production showing that as the age of the potato growers increases, technical inefficiency declines. This result is supported by Coelli (1996a) who concludes that the older farmers are likely to have had more farming experience and hence have less inefficiency.

The coefficient for contact with extension staff has the expected sign indicating that this variable is positively related with technical efficiency in potato cultivation. This result is in line with those of Bravo-Ureta and Evenson (1994), Parikh *et al.* (1995), Bravo-Ureta and Pinheiro (1997) and Ahmad *et al.* (1999). Giannakas *et al.* (2001) found a significant positive relationship between participating in Top Management Workshop (TMW) and farmer performance, underlying the merits of continuous extension services and training. The coefficient for contact with input dealers has sign according to our expectation. However, it is not significantly different from zero according to t-test. The major reason for this positive sign is that the input dealers lack technical expertise especially in potato production, therefore, they could not provide suitable guidelines to vegetable growers in general and potato growers in particular.

Cost of plant protection measures, proxy for environmental contamination has the negative coefficient and cost of fertilizer variable has a positive coefficient. The positive coefficient for cost of fertilizer variable is due to the fact that the potato growers were applying fertilizer above the recommended level especially nitrogenous fertilizer. Llewelyn and Williams (1996) find that inefficient farmers use excessive inputs especially nitrogenous fertilizer. The negative coefficient for cost of plant protection measures variable indicates that the more efficient farmers make use of more plant protection products. Hadri and Whittaker (1999) conclude that the farm size and environmental contaminants (fertilizer and chemicals) are positively related to technical efficiency. Similarly, Giannakas *et al.* (2001) identify a positive relationship between the level of technical efficiency and the use of seed and chemical inputs (pesticide and fertilizer).

Technical efficiencies in potato production: Frequency distribution of technical efficiency levels for potato growers is given in Table 3. The average predicted technical efficiency for potato growers ranges from 0.55 to 0.99 with a mean of 0.76 suggesting that there exist a great potential to increase per acre yield of potato. It is also

Table 3: Frequency distribution of technical efficiency estimates for potato growers

TE levels	No. of farms
<0.70	37.00
0.70-0.80	29.00
0.80-0.90	18.00
>0.90	16.00
Mean	0.76
Minimum	0.55
Maximum	0.99

evident from Table 3 that 37% potato growers are operating below 70% level of technical efficiency while only 16% potato growers operating above 90% technical efficiency level. This implies that a large number of potato farms in the sample faced severe technical inefficiency problems.

The mean level of technical efficiency for potato growers is less than that found by Amara *et al.* (1999) for potato farmers (80.27%) in Quebec, Canada. The level of technical efficiency for waterleaf vegetable (65%) in Nigeria investigated by Udoh (2005) is less than that found in the present study. But level of technical efficiency for potato growers is higher than the 58-59% efficiency of cotton and cassava farmers reported by Bravo-Ureta and Evenson (1994), the 63% efficiency for grain farmers in China reported by Yao and Liu (1998) and the 56.2% technical efficiency for rice farmers in Bangladesh by Coelli *et al.* (2002). For studies conducted in Pakistan, it is noted that the level of technical efficiency for potato growers is less than that found by Hassan (2004) for wheat crop (93.6%) in mixed farming system of Punjab, by Ahmad *et al.* (1999) for rice (85%) farmers and by Ali and Chaudhy (1990) for crops (84%). Shafiq and Rehman (2000) conclude that 38% of the farms have efficiency scores of less than 60% in cotton production in Pakistan. Parikh *et al.* (1995) measured the average level of cost inefficiency of 11.5% in Pakistan's agriculture.

Conclusions and suggestions: The results discussed earlier reveal that, in general, the potato growers have not been successful in employing best-practice production methods and achieving the maximum possible output from new and existing technologies. Mean technical efficiency over potato farms is 76%, indicating that a 24% increase in potato yield is feasible with the current technology and unchanged input quantities.

In view of the increased environmental problems associated with more intensive use of inputs, such as plant protection measures and fertilizer in vegetable cultivation, the potential for yield growth by increased intensification will be exhausted soon (Sharif and Dar, 1996). Therefore, in the long run, increase in yield must come from improvement in technical efficiency. However, this requires continuous government efforts in ensuring timely and adequate supply of required inputs, adequate provision of research, extension and credit facilities.

Utilizing available resources and technology efficiently, problem of food security could be handled in a better way without carrying out extra investment. So to achieve this end, the net of extension services should be expanded to reach each and every farmer and there is also need to modernize our extension department so that it can face new challenges and transfer the latest technology in an efficient way. The Government should allocate more funds in strengthening the extension department and expanding net of extension services to vegetable growers especially potato growers.

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