The Lahore Journal of Economics
11 : 2 (Winter 2006) pp. 1-22

Technical Efficiency and its Determinants in Potato Production, Evidence from Punjab, Pakistan

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Abstract

Potato cultivation accounts for 5.71 percent in total cropped area of the Punjab province and it supplements the diet of the growing population at lower prices as compared to grains, meat and chicken. Data from 100 farmers, 50 each from the districts of Okara and Kasur during the year 2002-2003 (the autumn crop) has been collected. The study estimates the technical efficiency in potato production by employing the Cobb-Douglas stochastic production frontier approach. The null hypothesis of no technical inefficiency in the data is rejected. Our results indicate that potato farmers are 84 percent technically efficient, implying significant potential in potato production that can be developed. By shifting the average farmer to the production frontier, the average yield would increase from 8.33 tons per acre to 9.92 tons per acre using the available resources. The additional quantity of potatoes gathered through efficiency improvements would generate Rs. 990.81 ($16.51) million of revenue each year. Consultation with extension workers significantly contributes to the improvement of technical efficiency and implies that the extension department should be one of the major targeted variables from the policy point of view in order to improve technical efficiency in potato production.

Key Words: *Potato, stochastic production frontier, technical efficiency*

Jel Classification: *QR*

Introduction

The population of Pakistan is growing at the rate of 2.1 percent per annum, with the addition of 3.1 million persons every year (Government of Pakistan, 2003). However, the supply of food crops is not keeping pace with

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population growth. To fill the gap between supply and demand, Pakistan invests its scarce resources to import grains and other food items. Wheat is a dominant crop while other labor intensive and more remunerative enterprises are ignored due to social taboos or other reasons. Vegetable cultivation is not only a cheap source of essential nutrients but it also creates more employment opportunities than that of growing other crops such as cereals (AVRDC, 2001). However, vegetable cultivation is limited to the vicinity of cities and comprises only one and two percent of the total cropped area in Pakistan and the Punjab, respectively (Government of Punjab, 2002) as compared to fifteen percent in Taiwan (Ali, 2000). This indicates a low availability of vegetables to consumers. Annual per capita consumption of vegetables is extremely low, 35.6 kg/capita/annum in Pakistan compared to 155 kg in Korea while the minimum recommended level is 73 kg/capita/annum (Ali and Abedullah, 2002).

Vegetable cultivation is inadequately addressed and given low priority by researchers and research institutes, and as a result the growth of vegetable production in the past decades remained low compared to other crops. Now policy makers are realizing the importance of vegetables and research budgets are being allocated to this neglected food frontier. The potato is one of the major vegetable crops in Pakistan in terms of area and output volume.

Potato production plays an important role in the economy of Pakistan in general and that of the Punjab in particular. On the one hand, it accounts for 5.71 percent in total vegetable cropped area of the Punjab providing economic benefits and creating employment opportunities for the rural poor. On the other hand, it supplements the food consumption of the growing population at lower prices as compared to grains, meat and chicken. The data from developed countries indicate that potatoes have 75 percent more food energy per unit area than wheat and 58 percent more than rice. Also, potatoes have 54 percent more protein per unit area than wheat and 78 percent higher than rice. Therefore, potato consumption is the best alternative to grains to maintain calorie intake.

It is generally believed that resources in the agricultural sector, especially in under-developed countries are being utilized inefficiently. According to our knowledge there exists very little literature dealing with technical inefficiency in vegetable production. A large body of literature exists dealing with technical efficiency in major crops, such as cereals (rice, wheat and maize) and cash crops (cotton and sugarcane) and some extended their research to estimate allocative efficiency as well. Bravo-Ureta and Pinheiro (1997), Taylor and Shonkwiler (1986), and Shapiro (1983) estimated technical inefficiency between 30-34 percent in the Dominican Republic, Brazilian and Tanzanian agriculture. Hussain (1989) estimated 30 and 57 percent technical and allocative efficiency, respectively in Pakistan's agriculture. Ali and Flinn (1989) concluded that the profit of the rice farmers in Pakistan could be increased by 28 percent through improved efficiency. Bravo-Ureta and Evenson (1994) found technical and allocative inefficiency to be 40 and 30 percent, respectively in cotton production in Paraguay. In spite of the vast literature concentrating on cereals, we did not find much literature exploring efficiency in vegetable production except Wilson *et al.* (1998) and Amara *et al* (1999) who estimated technical efficiency in potato production in the UK and Canada, respectively. The present study will help fill this gap in Pakistan where no such study exists that explores efficiency in vegetable production. The main objective of the present study is to estimate technical inefficiency in potato production in Pakistan's Punjab province, by employing the stochastic production frontier approach and to determine the sources of inefficiency in order to develop policy parameters to improve the existing situation.

The organization of the paper is as follows. In the next section, a brief review on technical efficiency is summarized. In the second section, a conceptual and analytical framework explaining technical efficiency is discussed. The third section explains the study area and data collection procedure and delineates the empirical model with variable specification. Empirical results are presented in section 4 and conclusions are derived in the subsequent section.

2.1. Analytical Framework

When firms operate under uncertainty, fluctuations in output are mainly due to fluctuations in inputs, technical inefficiency and random shocks. The fluctuation due to variation in inputs can be captured through a production function specification. The variation in output due to technical inefficiency and random shocks can be captured and decomposed through the stochastic production frontier approach (parametric approach). The existence of inefficiency in production comes from inefficient use of scarce resources. The present study deals with the technical inefficiency in potato production. Technical efficiency (TE) can be estimated by employing different approaches, including the stochastic production frontier and data envelopment analysis (DEA), also called the non-parametric approach. These two methods have a range of strengths and weaknesses which may influence the choice of methods in a particular application and the constraints, advantages and disadvantages of each approach have been discussed by Coelli (1996) and Coelli and Perelman (1999). However, it is well documented that the DEA approach works under the assumption of absence of random shocks in the data set. Since farmers always operate under uncertainty, the present study employs a stochastic production frontier approach introduced by Aigner *et al.* (1977); and Meeusen and van den Broeck (1977). Following their specification, the stochastic production frontier can be written as:

$$y_i = F(x_i, \beta) e^{\varepsilon_i} \qquad i = 1,2,\ldots\ldots\ldots\ldots N \qquad (1)$$

where y_i is the yield of potatoes for the i-th farm, x_i is a vector of k inputs (or cost of inputs), β is a vector of k unknown parameters, ε_i is an error term. The stochastic production frontier is also called "composed error" model, because it postulates that the error term ε_i is decomposed into two components: a stochastic random error component (random shocks) and a technical inefficiency component as follows:

$$\varepsilon_i = v_i - u_i \qquad (2)$$

where v_i is a symmetrical two sided normally distributed random error that captures the stochastic effects outside the farmer's control (e.g. weather, natural disaster, and luck), measurement errors, and other statistical noise. It is assumed to be independently and identically distributed $N(0, \sigma_v^2)$. Thus, v_i allows the production frontier to vary across farms, or over time for the same farm, and therefore the production frontier is stochastic. The term u_i, is a one sided (u_i>0) efficiency component that captures the technical efficiency of the i-th farmer. This one sided error term can follow different distributions such as truncated-normal, half-normal, exponential, or gamma [Stevenson, (1980); Aigner *et al.*, (1977); Green, (2000, 1990); Meeusen and Von den Broeck, (1977)]. In this paper it is assumed u_i follows a half normal distribution $N(0, \sigma_u^2)$ as typically done in the applied stochastic frontier literature.[1] The truncated-normal distribution is a generalization of the half-normal distribution. It is obtained by the truncation at zero of the normal distribution with mean μ, and variance, σ_u^2. If μ is pre-assigned to be zero, then the distribution is half-normal. Only two types of distributions are considered in FRONTIER 4.1 i.e. half-normal and truncated-normal

[1] On the basis of generalized likelihood ratio test, half-normal distribution is selected for the present study. The distribution of u_i would not affect the efficiency calculations and therefore this paper does not include gamma and exponential modeling of the error term [also see Kebede (2001) and Wadud (1999)].

distributions[2]. The two error components (v and u) are also assumed to be independent of each other. The variance parameters of the model are parameterized as:

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2 ; \qquad \gamma = \frac{\sigma_u^2}{\sigma_s^2} \quad and \ \ 0 \le \gamma \le 1 \tag{3}$$

The parameter γ must lie between 0 and 1. The maximum likelihood estimation of equation (1) provides consistent estimators for the β, γ, and σ_s^2 parameter, where, σ_s^2 explains the total variation in the dependent variable due to technical inefficiency (σ_u^2) and random shocks (σ_v^2) together. Hence, equation (1) and (2) provide estimates for v_i and u_i after replacing ε_i, σ_s^2 and γ by their estimates. Multiplying both sides of equation (1) by e^{-v_i} and replacing the β's with maximum likelihood estimates yields the stochastic production frontier as:

$$y_i^{\bullet} = F\left(x_i, \beta^{\otimes}\right)e^{-u_i} = y_i\, e^{-v_i} \tag{4}$$

where y^*_i is the yield of potato of the i-th farm adjusted for the statistical random noise captured by v_i (Bravo-Ureta and Rieger, 1991). All other variables are as explained earlier and $\beta^{\otimes}$ is the vector of parameters estimated by maximum likelihood estimation. The technical efficiency (TE) relative to the stochastic production frontier is captured by the one-sided error components u_i>0, i.e.

$$e^{-u_i} = \left[\frac{y_i}{F\left(x_i, \beta^{\otimes}\right)e^{v_i}}\right] \tag{5}$$

The function determining the technical inefficiency effect is defined in its general form as a linear function of socio economic and management factors,

$$IE_i = F\left(Z_i\right) \tag{6}$$

More detail about dependent and independent variables is given in the empirical model.

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[2] The distribution of u_i would not affect the efficiency calculations and therefore this paper does not include gamma and exponential modeling of the error term [also see Kebede (2001) and Wadud (1999)].

3. Data Collection Procedure

For the purpose of this study, four districts were initially selected (Okara, Sahiwal, Pakpattan and Kasur) because they have the highest area allocated to potato cultivation. Of these, two districts, (Okara and Kasur) were selected by using the simple random sampling technique. The share of Okara and Kasur in total potato area in the Punjab province was found to be 24.24 and 9.11 percent, respectively. Two potato crops, namely autumn and spring, are cultivated each year in all districts of the Punjab province. However, more land is cultivated under the autumn crop compared to the spring crop. Because of this fact, data for the autumn crop was collected from Okara and Kasur districts of the Punjab.

The Okara district has cultivated, uncultivated and cropped areas of 237,000 acres, 848,000 acres, and 1.44 million acres respectively and the area sown more than once is 618,000 acres. With suitable climatic conditions, the intensity of potato cultivation is higher in this district than all other districts in the Punjab province.

In terms of climate, district Kasur is similar to the Okara district. District Kasur has cultivated, uncultivated, and cropped areas of 835,000 acres, 146,000 acres, and 1.21 million acres, respectively and the area sown more than once is 395,000 acres. After the Okara and Sahiwal districts, the intensity of potato cultivation is the highest in this district.

3.1. Sampling

Major potato growing villages were selected with the consultation of the Department of Agricultural Extension (Agriculture Officer) in the Okara and Kasur districts. A total of 100 farmers, 50 from each district were chosen by using a random sampling technique among the potato growers. A well structured and field pre-tested comprehensive interviewing schedule was used for the collection of detailed information on various aspects of the potato crop for the year 2002-03. Survey data had information on socio-economic characteristics of the farmers, input-output quantities, and management practices. Marketing data, collected from the farmers as part of the production survey includes information about the output disposal pattern, packing material and marketing cost. Data on the production constraints of potato production were also gathered. The mean value of household related variables (age, years of education, and frequency distribution of ownership and tenure status) and economic variables (input-output quantities and cultivated area) for two districts are reported and compared in Table-1. The quantity of seed, labor and area allocated to vegetables is significantly higher in Okara district compared to Kasur district. However, cost of plant protection measures, farmyard manure, irrigation hours and yield is significantly higher in Okara compared to Kasur.

3.2. Empirical Model

The empirical strategy will comprises three steps. In the first step, we will estimate the Cobb-Douglas and translog production functions for potato cultivation, and select the best functional form using the likelihood ratio test. The estimation of the production function will help us to select the variables that will be used in the estimation of technical efficiency in Step 2. In Step 2, the stochastic frontier is estimated using the variables that had statistically significant coefficients for the production function in Step 1. Finally, in Step 3, the estimated technical efficiency from Step 2 is utilized in a regression to discover the sources of technical inefficiency.

Step 1: Selecting the Functional Form of the Production Function

Cobb-Douglas is a special form of the translog production function where the coefficients of the squared and interaction terms of input variables are assumed to be zero. In order to select the best specification for the production function (Cobb-Douglas or translog) for the given data set, we conducted hypothesis tests for the parameters of the stochastic production frontier model using the generalized likelihood-ratio statistic "LR" defined by

$$LR = -2 \ln \left[L(H_0) \big/ L(H_1) \right] \tag{7}$$

where, $L(H_0)$ is value of the likelihood function of the Cobb-Douglas stochastic production frontier model, in which the parameter restrictions specified by the null hypothesis, $H_0 = \beta_{ji} = 0$, (i.e. the coefficient on the squared and interaction terms of input variables are zero) are imposed; $L(H_1)$ is the value of the likelihood function for the full translog stochastic production frontier model (where the coefficient of the squared and interaction terms of input variables are not zero). If the null hypothesis is true, then "LR" has approximately a chi-square (or mixed chi-square) distribution with degrees of freedom equal to the difference between the number of parameters estimated under H_1 and H_0, respectively. We use the Cobb-Douglas (CD) and translog production functions and on the basis of the test statistic we discovered that the CD is the best fit to our data set.

On the basis of this test statistic we selected the Cobb-Douglas production function.

In addition to the above evidence, the Cobb-Douglas (CD) functional form (in spite of its restrictive properties) is used because its coefficients directly represent the elasticity of production. It provides an adequate representation of the production process, since we are interested in an efficiency measurement and not an analysis of the production structure (Taylor and Shonkwiler, 1986). Further, the CD functional form has been widely used in farm efficiency analyses.[3]

Step 2: Estimating the Stochastic Frontier

The stochastic production frontier (as given below) for potatoes, is empirically estimated by employing maximum likelihood estimation technique:

$$\ln y_i = \ln \beta_0 + \sum_{j=1}^{7} \beta_j \ln x_{ij} + v_i - u_i \quad (8)$$

where,

y_i = yield of vegetables of the *i*-th farm in ton/acreage

β_o is intercept and β_i's are response parameters or elasticity corresponding to each input

x_1 = tractor hour/ acreage

x_2 = seed in kg/ acreage

x_3 = family and hired labor used for all activities (except for harvest) in days/acreage

x_4 = Plant protection cost (Rs./acres)

x_5 = Farm yard manure in trolleys/ acreage

[3] The statement can be supported by the empirical literature reviewed in Battese (1992), and in Bravo-Ureta and Pinheiro (1993). Kebede (2001) and Bravo-Ureta and Pinheiro (1997) also employed a similar functional form. Moreover, different studies concluded that choice of functional form might not have a significant impact on measured efficiency levels (Wadud, 1999; Ahmed and Bravo-Ureta, 1996; Good *et al.*, 1993; Villano, 2005).

x_6 = fertilizer in kg of NPK nutrients/acreage

x_7 = hour of irrigation/ acreage

v_i = a disturbance term with normal properties as explained above

u_i = farm specific error term as defined in equation (2)

The model is estimated on per acreage basis by employing the Frontier Version 4.1 program developed by Coelli (1994). There are two reasons to estimate on a per acreage basis: first, it is intuitively simpler to directly interpret efficiency on a per unit area as opposed to per plot basis; second, farm size is collinear with other variables included in the model.

The error terms v_i and u_i are then found from the stochastic production frontier model and technical efficiency is predicted by replacing parameters with their maximum likelihood estimates. Subtracting v_i from both sides of equation (8) and by replacing *β's* with maximum likelihood estimates ($\beta^{\otimes}$s) yields:

$$\ln y_i^{\bullet} = \ln y_i - v_i = \ln\beta_0^{\otimes} + \sum_{j=1}^{7} \beta_j^{\otimes} \ln x_{ij} - u_i \tag{9}$$

where, $y_i^{\bullet}$ now represents the farm's observed yield for the stochastic random noise captured by v_i (as explained in equation 5). The farm specific technical efficiency is estimated by using the relation as discussed in equation 6 and for our specific empirical model it is given below;

$$TE_i = \exp(-u_i) = \left[\frac{y_i}{\left(\beta_0^{\otimes} \prod_{j=1}^{7} x_{ij}^{\beta_j^{\otimes}} \right) e^{v_i}} \right] \tag{10}$$

The literature indicates that a range of socio-economic and demographic factors determine the efficiency of farms (Seyoum *et al.* (1998); Coelli and Battese (1996); Wilson *et al.* (1998)) and another set of studies concluded that land use, credit availability, land tenure and household labor, education (Kalirajan and Flinn (1983); Lingard *et al.* (1983); Shapiro and Muller (1977); Kumbhakar (1994)) are important determinants of efficiency. Techniques of cultivation, share tenancy, and farm size also influence the efficiency (Ali and Chaudhry (1990); Coelli and Battese (1996); Kumbhakar (1994)). Some environmental factors and non-physical factors like information availability, experience, and supervision might also affect the capability of a producer to utilize the available technology efficiently (Parikh *et al.* (1995); Kumbhakar (1994)).

The impact of farm size is ambiguous on efficiency. According to Sharif and Dar (1996), farm size is positively related with technical efficiency, because large farmers have much greater access to public services, credit and other inputs. On the other hand small farmers could be more efficient in utilizing limited available resources for their survival and due to economic pressure, but they could be less efficient too because of not using modern technologies due to financial constraints or because they are not viable for use on small farms. However, it might not be true to correlate the farm holding with inefficiency, especially in the case of vegetables where farmers have large farm holdings, but the area allocated to vegetable cultivation is only a part of total area available for cultivation. Hence, it is not rational to study the impact of farm size (total cropped area) on technical efficiency and that is why we attempted to study the impact of area allocated to only potato production on technical inefficiency rather than total land holding.

Step 3: Identifying Sources of Technical Inefficiency

The farm specific inefficiency ($1\text{-}TE_i$) is considered as a function of six different variables and the inefficiency effects model is estimated as:

$$IE_i = \delta_0 + \sum_{j=1}^{6} \delta_j Z_{ji} \tag{11}$$

where, δ_o is the intercept term and δ_j is the parameter for the *j*-th explanatory variable and

Z_{1i} = Age of the respondent in years

Z_{2i} = Education, i.e. Schooling years of the farmer

Z_{3i} = Ownership status, i.e. if owner then Z_{3i} = 1 otherwise zero

Z_{4i} = Consultation with extension staff, i.e. if consulted then Z_{4i} = 1 otherwise zero

Z_{5i} = Consultation with input dealers i.e. if consulted then Z_{5i} = 1 otherwise zero

Z_{6i} = Area allocated to potato production

4. Results and Discussion

Step 1 Results: Selection of the Cobb-Douglas Production Function

We tested the hypothesis whether the Cobb-Douglas production function is an adequate representation of the data using equation 8, given the specifications of the translog model. Alternatively, we tested to see if the coefficients of interaction and square terms in the translog production function were zero. The values of the log likelihood for the Cobb-Douglas and translog production functions were 43.7 and 20.1, respectively. By employing equation 7 we estimated the value of "LR" equal to 47.2. This value was compared with the upper five percent point for the χ^2_{35} distribution, which is 43.77. Thus the null hypothesis that the Cobb-Douglas stochastic production frontier is an adequate representation of the data was accepted, given the specifications of the translog stochastic production frontier.

Step 2 Results: Estimation of the Stochastic Frontier

The results of the Ordinary Least Square (OLS) and Maximum Likelihood Estimation (MLE) for the Cobb-Douglas production function as described in equation 8 are reported in Table-2.[4] Here we are interested in testing the null hypothesis $H_{0:}\ \delta_i = 0 = \gamma$ where, i = 1 ...7. It should be noted that the log-likelihood function for the full stochastic production frontier model is calculated to be 43.71 and the value for the OLS fit for the production function is 27.25. This implies that the generalized likelihood-ratio statistic for testing the absence of the technical inefficiency effect from the frontier is calculated to be LR = -2*(27.25-43.71) = 32.93. This value is estimated by Frontier 4.1 and reported as the "LR" test of the one sided error. The degrees of freedom for this test are calculated as q+1,

[4] The Ordinary Least Square (OLS) and Maximum Likelihood Estimation (MLE) for equation 8 are reported because the value of log likelihood function for OLS and MLE allow to test whether technical inefficiency exits or not. In case technical inefficiency does not exist then technically there will be no difference in the parameters of OLS and MLE.

where q is the number of parameters, other than γ specified to be zero in H_0, thus in our case q = 8. The value of the "LR" test is significant because it exceeds the value taken from Kodde and Palm (1986). Kodde and Palm (1986) is used in the cases where more than one parameter restriction with mixed chi-square distribution are involved. The log likelihood ratio test indicates that inefficiency exists in the data set and hence the null hypothesis of no technical inefficiency effects in potato production is rejected.

The sign of coefficients of all variables in equation 8 when estimated with MLE technique are positive except fertilizer and irrigation hours which are negative but insignificant (Table-2)[5]. This implies that fertilizer and irrigation hours do not affect the yield of the potato crop significantly. However, the negative sign of fertilizer might be due to the reason that farmers are using more fertilizer than the recommended level or at a declining marginal productivity level. However, future research should focus on exploring this critical issue. The irrigation hours have negative but non-significant impact on yield. This may be because the quality of ground water which is being used for irrigation is not suitable for agriculture purposes, or there could be over use of water in potato production. Further research is needed to determine the quality of ground water and its impact on potato production.

The Cobb-Douglas production function parameters can be interpreted directly as output elasticities. The parameters of tractor hours, quantity of seed and labor have positive signs and are statistically significant at the 1 percent level. This implies that these inputs are playing a major role in potato production. The elasticity of labor hours is highest compared to all variables included in the model, implying that the contribution of labor hours in total factor productivity is dominant. A one percent increase in the use of labor hours leads to a 0.236 percent increase in potato yield. This increase in yield is the result of better weeding and cultivation practices. Another important input is tractor hours used for land preparation. Results show that the potato yield could be improved up to 0.183 percent by using one percent more tractor hours in land preparation, because seed germination is high on well-prepared beds. Another important input in terms of its effect on the potato yield is seed. An addition of one percent seed increases output by 0.038 percent. The greater use of seed

[5] To analyze the impact of variety and planting date on output, variety dummies and planting week of the year was included in the production function as explanatory variables but we found all these variables insignificant and therefore excluded them in the final estimation.

increases the plant population in the field and thus increases yield. The mean technical efficiency is 84 percent, indicating that further potential exists to improve productive efficiency of the resources allocated to potato production (Table-4).

It is observed that the MLE estimate (using equation 8) of γ is 0.824 with estimated standard error of 0.096 (Table-2). This is consistent with the theory that the true γ-value should be greater than zero and less than one. The value of the γ-estimate is significantly different from one, indicating that random shocks are playing a significant role in explaining the variation in potato production, which is expected especially in the case of agriculture where uncertainty is assumed to be the main source of variation. This implies that the stochastic production frontier is significantly different from the deterministic frontier, which does not include a random error. However, it should be noted that 82 percent of the variation in yield is due to technical inefficiency and only 18 percent is due to the stochastic random error.

Step 3 Results: Identifying the Sources of Technical Inefficiency

In order to investigate the determinants of inefficiency, we estimated the technical inefficiency model elaborated in equation 11, where inefficiency is assumed to be the dependent variable. We used age of the decision maker as a proxy variable for experience in farming and the coefficient is highly statistically significant with a negative sign, which indicates that experience is inversely related with inefficiency. The education of the farmer also has a negative sign consistent with our expectations, but it is statistically insignificant. The sign of the coefficient of ownership status indicates that owners are less efficient than tenants, although the coefficient is not statistically significant. Consultation with extension workers significantly contributes to improved technical efficiency in potato production and this implies that the extension department should be one of the major targeted variables from the policy point of view in order to improve technical efficiency in potato production. Hence, there is a need to strengthen the role of the extension department in the crop sector and to make its role more effective. Due to a lack of extension services and their effective role, we find that farmers also discuss their crop related problems with input dealers. We find that contact with input dealers improves technical efficiency but the coefficient is not statistically significant. Finally, we try to explore the impact of total vegetable area on farm inefficiency and the results indicate that as area under vegetable production increases, inefficiency decreases (Table-3). It might be due to the reason that modern technologies such as tractors and irrigation are more viable for use on large vegetable farms compared to small ones.

The frequency distribution of technical inefficiency is reported in Table-4. The maximum and minimum values of technical efficiency are 98 and 49 percent, respectively. The mean technical efficiency in potato production is 84 percent showing that potential exists to increase potato yield by using available resources more efficiently. The estimated mean technical efficiency is greater than that found by Amara, *et al.* (1999) for potato farmers (80.27 percent) in Quebec, Canada. For studies conducted in Pakistan, it is noted that the levels of technical efficiency for potato growers is less than that found by Hassan (2004) for wheat crops (93.6 percent) in the mixed farming system of Punjab, and by Ahmad, *et al.* (1999) for rice (85 percent) farmers.

In our case, seventy farmers are more than 80 percent technically efficient and 17 farmers are more than 70 but less than 80 percent technically efficient. Thirteen farmers are less than 70 percent technically efficient.

By improving technical efficiency from 84 to 100 percent, the average yield will increase from 8.33 ton per acre to 9.92 ton per acre with the available resources. The total area in the province of the Punjab under potato production is 226,600 acres and improvement in technical efficiency up to 100 percent would allow increasing potato production from 1,887,578 tons to 2,247,872 tons per year. This additional 360,294 tons of potato would raise Rs. 990.81 ($16.51) million of revenue each year. The results clearly demonstrate the substantial benefits of more efficient input use in the production of potatoes. If similar results prevail in the production of all vegetables, then it implies that improvement in resource use efficiency can contribute remarkably to increase revenue at the farm level.

5. Conclusion

The study employed the stochastic production frontier approach to estimate technical inefficiency in potato production. It is observed that potato farmers are 84 percent technically efficient, indicating that a substantial potential exists that can be explored by improving resource use efficiency in potato production. This improvement in resource use efficiency would generate an additional Rs. 990.81 ($16.51) million in the province. The results are derived only from potato production, which is only one vegetable among many others.

The coefficients on fertilizer and irrigation are negative but insignificant implying that both inputs are possibly being over utilized. Future research should focus on determining the optimum use of fertilizer nutrients for potato production. However, the coefficient on irrigation could be negative due to poor quality of ground water. The study also identifies that extension services are not being properly disseminated in the study area. Currently only 37 percent of farmers have any contact with extension workers. Given the large coefficient estimate on extension services in Table-3, improvement in these services can play a significant role in improving technical efficiency in potato production. It would be useful to focus future research on the economic evaluation of extension services by estimating the costs versus benefits of these services, which will enable policymakers to design appropriate agricultural policies with regard to the future role of extension services.

The above conclusions are valid only for potato production but it will be quite useful to conduct a comprehensive study on the other major vegetables to develop a clear-cut policy for vegetables, a neglected food frontier in Pakistan. Such information will facilitate policy managers to strike a balance in resource allocation among agricultural and non-agricultural sectors and even among different crops within the agricultural sector.

Table-1: Summary statistics for different variables of potato farmers in the Okara and Kasur regions of Punjab, Pakistan

Variables	Okara			Kasur		
	Mean	Min.	Max.	Mean	Min.	Max.
Household Characteristics						
Operator's age (years)	45.7 (12.8)	24.0	85.0	42.9 (14.6)	25.0	80.0
Operator's education (years)	7.9 (3.6)	0.0	12.0	7.2 (3.8)	0.0	12.0
Tenure						
Owners (frequency)	25			25		
Tenants (frequency)	23			25		
Consultation with extension staff (no.)	17			20		
Consultation with input dealers	18			13		
Vegetable Production						
Land preparation (tractor hours/acreage)	6.5 (1.5)	4.5	9.0	6.9 (1.3)	3.8	9.5
Seed (tons/acreage)	1.3* (0.1)	1.2	1.8	1.2* (0.2)	0.9	1.6
Labor (hours)/acreage	70.8* (32.5)	27.8	190.3	54.1* (15.5)	29.2	102.3
Plant protection measures (Rs/acreage)	1496.0* (477.9)	500.0	2300.0	1731.1 * (550.4)	455.0	3000.0
Farmyard manure (trolley/acreage)	1.2* (1.9)	0.0	6.0	1.9* (1.8)	0.0	5.0
Fertilizer (kg/acreage)	223.1 (56.8)	121.0	340.0	231 (45.8)	133.0	321.0
Irrigation (hours/acreage)	13.1* (4.4)	0	22.5	19.7* (3.7)	10.0	24.0
Vegetable area (acreage)	48.9* (53.7)	3.0	200.0	21.1* (21.5)	1.0	75.0
Yield (ton/acreage)	8.2* (2.1)	4.0	15.0	8.9* (2.3)	5.9	17.0

Figures in parenthesis are standard deviation

* indicates significance of means between two districts at the ten percent probability level

Table-2: OLS and Maximum Likelihood Estimates of the Cobb Douglas Stochastic production Frontier Function[a]

Variable	OLS Coefficients	MLE Coefficients
Intercept	1.242*	1.010*
	(0.637)	(0.509)
Ln Tractor hours	0.079	0.183*
	(0.096)	(0.076)
Ln Seed	0.038*	0.038*
	(0.013)	(0.001)
Ln Labor hours	0.238*	0.236*
	(0.061)	(0.054)
Ln Plant Protection cost	-0.015	0.018
	(0.055)	(0.048)
Ln Farm Yard Manure	0.002	0.006
	(0.073)	(0.006)
Ln Fertilizer (NPK)	-0.038	-0.026
	(0.088)	(0.070)
Ln Irrigation Hours	0.024	-0.006
	(0.064)	(0.054)
σ^2	0.036	0.055
		(0.083)
Γ		0.824*
		(0.096)
Log Likelihood function	27.251	43.717

Figures in parenthesis are standard errors

* and ** indicates significance at one and ten percent probability levels respectively

a. Coefficient estimated by employing equation 8 with OLS and MLE techniques, respectively.

Table-3: Inefficiency Effect Model[b]

Variables	MLE coefficients
Intercept	0.697*
	(0.229)
Age of the respondent	-0.010*
	(0.005)
Education	-0.008
	(0.012)
Ownership status	0.058
	(0.086)
Consultation with extension staff	-0.500*
	(0.251)
Consultation with input dealers	-0.056
	(0.083)
Vegetable area	-0.002**
	(0.002)

Figures in parenthesis are standard errors

* and ** indicates significance at one and ten percent probability level respectively

[b] Coefficient estimated by employing equation 11

Table-4: Frequency Distribution of Technical Efficiency for Individual Farms

Efficiency interval[b]	Frequency
0.800<TE<1.00	70
0.700<TE<0.800	17
0.600<TE<0.700	9
0.500<TE<0.600	3
0.400<TE<0.500	1
Average	0.844
Minimum	0.493
Maximum	0.976

[b.] TE close to one indicates higher level of technical efficiency

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