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Measuring Production Function and Technical Efficiency of Onion, Tomato, and Chillies Farms in Sindh, Pakistan

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1. INTRODUCTION

Pakistan is blessed with vast agricultural resources on account of its fertile land, well-irrigated plains, huge irrigation system and infrastructure, variety of weathers, and centuries old experiences of farming. Agriculture is the single largest sector of the economy which contributes 20.9 percent in GDP and employees 43.4 percent of total work force. The estimated GDP of agricultural crops at current factor cost is Rs 1,608,522 million with major crops contributing Rs 579996 million and minor crops valued at Rs 191,835 million for the year 2006-07 [Pakistan (2007)]. The horticulture crops (fruits, vegetables and condiments) alone contribute Rs 116.645 billion, equivalent to US$ 2 billion, which is 26 percent of the total value of all crops and 81.8 percent of the total value of minor crops. Pakistan annually produces about 12.0 million tons of fruits and vegetables. Fruit and vegetable export trade in Pakistan amounts to US$ 134 million (2003-04), of which fruits account for US$ 102.7 million (76.6 percent), vegetables US$ 25.7 million (19.2 percent) and fruit and vegetable preparations (mostly juices) US$ 5.6 million which is 4.2 percent [Pakistan (2004)] .

Onion, tomato and chillies are most common and important kitchen items cooked as vegetables, used as condiments and salad. The consumption of tomato and onion has high income elasticity of demand. Thus, there will be more demand for these vegetables with population growth, economic growth, and urbanisation. The per capita consumption of vegetables in Pakistan is very low. People in upper income strata consume well above the national calculated average, while the bulk of the rural population and large percentage of the poorer strata among the urban population consume very few vegetables. Furthermore, Pakistan has a potential to export these products with trade liberalisation under the regime of World Trade Organisation. Production of these vegetables is profitable provided produced efficiently; nevertheless, it requires more labour work. Thus, it provides income support especially to small farmers and employment opportunity for landless labourers in rural areas.

Production of these vegetables is complex process where different inputs with different combinations are used. It is a function of farm inputs including land, labour, capital, management practices and other factors. Production not only depends on these resources only but the combinations of different inputs have a great contribution in total

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productivity. The differences across farms in use of various factors of production and various combinations of factors of production cause the changes in crop yields. These combinations are considered as technology. The input use level and its combinations are different across farms resulting different yields. Furthermore, the there is a wide gap in yields of experimental stations and farmer fields indicating the suboptimal use of inputs.

Technical efficiency studies the conversion of physical inputs such as land inputs, labour inputs, and other raw materials and semi finished goods, into outputs. Technical efficiency can be output, reflecting the maximum output that can be achieved from each input, or alternatively representing the minimum input used to produce a given level of output. It describes the current state of technology in any particular industry [Hassan (2004)]. The concept of technical efficiency including price efficiency and production efficiency was initially used by Farell (1957). Further this method has been continued by Hassan (2004), Shah, *et al.* (1994) and Ali, *et al.* (1994).

The purpose the paper is to estimate the extent of technical efficiency of onion, tomato and chillies production. The technical efficiency of these vegetables is measured by estimating a production function through stochastic frontier by using Cobb-Douglas production function approach.

2. METHODOLOGY

For this study, primary data were collected from farmers by conducting surveys in three districts of Sindh, namely Hyderabad, Thatta and Mirpurkhas. Hyderabad was selected for onion crop, Thatta for tomato crop and Mirpurkhas for chilies for primary data collection. Hyderabad was selected for onion, because area under onion is highest in Hyderabad among all districts of Sindh [Sindh (2005)]. Similarly Thatta district is major tomato producer and Mirpurkhas is major chillies producing district in Sindh [Sindh (2005)]. Sixty farmers for each vegetable were randomly selected from these districts so the total sample size was 180 farmers for this study. Data were collected by survey method using a pre-tested questionnaire.

2.1. Model

The functional form of the production function is specified as Cobb-Douglas function:

$$y = Ax_1^{\beta_1} x_2^{\beta_2} x_3^{\beta_3} e^{\varepsilon} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where y is output, x_1, x_2, x_3, are inputs, A, $ß_1$, $ß_2$, $ß_3$, are coefficients to be estimated, and e is the error. The error term represents all other variables which may affect output.

In the present study, both output and inputs are measured in value terms. Furthermore, output and inputs are measured for the whole farms of onion, tomato and chillies. Output y is value of production in rupees. Input x_1 is the cost in rupees on labour input for farm operations including ploughing, levelling, weeding, irrigating, and other activities up to harvesting the crop. Input x_2 is the cost in rupees on capital input incurred for the purchase of fertilisers, pesticides and seedlings. Input x_3 is the cost in rupees on land input which includes land rent and land tax.

The coefficients of the model in Equation (1) are the measures of elasticity of production. Coefficient $ß_1$ is the percent change in output resulting from a one percent change in the input x_1. Similarly, the coefficient on each input is the percent change in output resulting from a one percent change in the input. In a Cobb-Douglas production function, the sum of these coefficients, $ß_1+ß_2+ß_3$, is the degree of homogeneity, which measures whether the production function is constant, increasing, or decreasing returns to scale. Three possibilities exist:

(1) If $(ß_1+ß_2+ß_3) = 1$, there are constant returns to scale.
(2) If $(ß_1+ß_2+ß_3) < 1$, there are decreasing returns to scale.
(3) If $(ß_1+ß_2+ß_3) > 1$, there are increasing returns to scale.

In order to test the significance of $(ß_1+ß_2+ß_3)$, we rearrange the terms of the model in Equation (1). Multiplying and dividing it by $x_3^{\beta_1} x_3^{\beta_2}$ will keep the model unchanged because we can multiply by 1:

$$y = Ax_1^{\beta_1} x_2^{\beta_2} x_3^{\beta_3} e^{\varepsilon} \frac{x_3^{\beta_1} x_3^{\beta_2}}{x_3^{\beta_1} x_3^{\beta_2}} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Rearranging the terms of Equation 2:

$$y = A\left(\frac{x_1}{x_3}\right)^{\beta_1} \left(\frac{x_2}{x_3}\right)^{\beta_2} x_3^{\beta_1+\beta_2+\beta_3} e^{\varepsilon} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Let $ß_1+ß_2+ß_3 = h$, then Equation (3) can be written as:

$$y = A\left(\frac{x_1}{x_3}\right)^{\beta_1} \left(\frac{x_2}{x_3}\right)^{\beta_2} x_3^{h} e^{\varepsilon} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

This model in Equation (4) shows that the degree of homogeneity can directly be estimated and tested for its significance.

2.2. Returns to Scale

For estimating the model, Equation (4) is transformed into linear equation by taking natural logarithm:

$$\ln y = \beta_0 + \beta_1 \ln\left(\frac{x_1}{x_3}\right) + \beta_2 \ln\left(\frac{x_2}{x_3}\right) + h \ln x_3 + \varepsilon \qquad \ldots \quad \ldots \quad (5)$$

Where the constant $ß_0 = \ln(A)$. The ordinary least square (OLS) method is used for estimating Equation (5) with standard assumptions described in Greene (2003).

2.3. Statistical Frontier Model (Corrected OLS)

The basic production function for each vegetable was defined by the following log transformed equation.

$$\ln Y = ß_0 + ß_1 \ln\left(\frac{x_1}{x_3}\right) + ß_2 \ln\left(\frac{x_2}{x_3}\right) + h \ln x_3 \qquad \ldots \qquad \ldots \qquad \ldots \qquad (6)$$

Where

Y = is total revenue productivity of each individual far, while $X1$, $X2$ and $X3$ are labour, capital and land inputs in revenue terms. The above equation was estimated using OLS method for onion, tomato and chillies separately. The intercept was then corrected by shifting the function until no residual is positive and at least one is zero.

The individual technical efficiency score for each vegetable crop is calculated by taking the ratio of actual product to the predicted level of product. The predicted level of product is obtained from the corrected vectors of residuals.

e_j = Log Y_j – Log Y_j *
j = 1, 2, 3 ……… 60 (Onion)
j = 1, 2, 3 ……… 54 (Tomato)
j = 1, 2, 3 ……… 60 (Chillies)
ej = 0
$TE_j = \exp(e_j) = Y_j / Y_j^*$

3. RESULTS

3.1. Socioeconomic Profile of the Respondents

Socioeconomic factors are most important and always remain responsible for not only cropping patterns but for production technology and efficient trading system in a healthy and competitive important. The socioeconomic background has been defined and described in the following section in order to help in understanding the production environment of these vegetables.

This section presents the socioeconomic characteristics of all stakeholders in the production process of onion, chillies and tomato in Sindh province of Pakistan ranging from producers to the retailers. The information regarding socioeconomic characteristics of the onion, tomato and chillies farmers is presented in Table 1. This table presents the averages and standard errors of the selected indicators, where standard errors indicate the robustness of the mean. The results show that average farm size of the tomato, chillies and tomato farmers was 27, 34.62 and 40.27 acres respectively, while the average family size of tomato producers was 9.93, onion 7.2 and chillies 8.18 members. The table further shows that average age of tomato, onion and chillies farmer was 42.81, 43.65 and 41.68 years respectively. The farming experiences of the selected farmers were 20, 17, and 19 and vegetable farming experience of the selected farmers was 12, 13 and 16 years for tomato, onion and chillies farmers respectively. The distance of farm from road for tomato, onion and chillies producers was 0.93, 1.21 and 2.15 kilometres respectively.

Table 1

Socioeconomic Characteristics of Onion, Tomato, and Chillies Farmers

Characteristics	Tomato		Onion		Chilies	
	Mean	STD Error	Mean	STD Error	Mean	STD Error
Farm Size	27	7.99	34.62	4.57	40.27	3.87
Family Size	9.93	0.60	7.2	1.01	8.18	1.13
Age	42.81	1.86	43.65	1.96	41.68	1.57
Farming Experience	20.17	1.68	17	1.39	19.15	1.39
Vegetable Farming Experience	12.11	0.97	13.23	0.95	16.38	1.20
Distance from Road	0.93	0.15	1.21	0.14	2.15	0.31

The educational status and farm location of the onion, tomato and chillies farmers is presented in the Table 2. The results revealed that majority of onion (38 percent) and tomato (39 percent) farmers were primarily educated, while the majority (42 percent) of chillies farmers was illiterate. The higher rate of illiteracy rate in chillies farmers can be the reflection of lower level of literacy in Umerkot district. The results further revealed that 18 percent of both onion and tomato farmers had their farms located in the tail areas of secondary canal, while 52 percent of chillies farmers have their farms located in the head areas.

Table 2

Educational and Location-wise Status of the Sampled Producers

Characteristics	Onion		Chillies		Tomato	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Education						
Illiterate	11	18	25	42	9	17
Primary	23	38	14	23	21	39
Secondary	13	22	11	18	19	35
Higher	13	22	10	17	5	9
Total	60	100	60	100	54	100
Farm Location						
Head	23	38	31	52	22	41
Middle	26	43	18	30	16	30
Tail	11	18	11	18	16	30
Total	60	100	60	100	54	100

3.2. Production Function Analysis

Agricultural production is a complex process particularly vegetable production including onion, chillies and tomato crops. The onion, tomato and chillies production is function of number of variables used in production process. The production of these vegetables depends on natural environment, input use and combination of inputs and management practices. Knowledge of the importance in relative terms of the resource inputs influencing the production of these vegetables is very essential for the producers for introducing desirable changes in their operations at the micro level, and for policy makers for formulating plans for improvement in the productivity of theses vegetables based on sound economic principles at the national level.

For assessment of on-farm production efficiency and returns to scale, production function analysis has been carried out. The production function has been estimated through input and output relationship of these vegetables produced in Sindh Pakistan.

3.3. Returns to Scale

Production function for onion was estimated using the model specified in Equation (1). The Cobb-Douglas production function was estimated to measure the degree of returns to scale for onion producing farms in Hyderabad district of Sindh. The regression results were presented in Table 3. The table presented coefficient estimates, their standard error, *t* statistics, and p-values for testing the significance. The 2 percent critical value of Student's *t* distribution for sample size of 60 was 2.00. First, *t*-statistics were presented for testing the null hypothesis that the coefficients are zero. As *t*-statistics are greater than 2.00, the test rejected the null hypothesis and coefficients were significantly different from zero. For testing that the production function was constant returns to scale, the null hypothesis that h=1 was also tested. In this case, *t* statistic and p-value were presented in parentheses. As the *t*-statistic in absolute terms was less than 2.00, the test maintained the null hypothesis, and the coefficient h was equal to 1 by this test. As described in methodology, $h = ß_1+ß_2+ß_3$, which measured the degree of geneuity. As $ß_1+ß_2+ß_3 = 1$ by the above test, these results showed that the production function for onion exhibited constant returns to scale.

Table 3

Regression Results for Production Function of Onion with Dependent Variable Ln(Y)

Regressor	Coefficient	Coefficient Estimate	Standard Error	*t*-statistics	p-value
Constant	β_0	2.043	0.171	11.922	0.000
$\ln\left(\frac{x_1}{x_3}\right)$	β_1	0.531	0.108	4.924	0.000
$\ln\left(\frac{x_2}{x_3}\right)$	β_2	0.262	0.118	2.229	0.030
$\ln\ x_3$	h	0.989	0.015	67.237	0.000
				(–0.715)*	(0.600)*

* *t*-statistic and p value given in parentheses are for the null hypothesis that the coefficient is equal to 1. The remaining *t*-statistics and *p*-values are for the null hypothesis that coefficient is zero.
The results showed that the onion production exhibits constant returns to scale as h= 0.989, *t*-statistics and *p*-values were significant. These results indicated that if all inputs are increased proportionately, the output is increased by the same proportion.

Table 4

Regression Results for Production Function of Tomato with Dependent Variable ln(y)

Regressor	Coefficient	Coefficient Estimate	Standard Error	*t*-statistics	p-value
Constant	β_0	2.491	0.197	12.631	0.000
$\ln\left(\frac{x_1}{x_3}\right)$	β_1	0.262	0.104	2.515	0.015
$\ln\left(\frac{x_2}{x_3}\right)$	β_2	0.256	0.059	4.329	0.000
$\ln\ x_3$	*h*	0.986	0.021	46.215	0.000
				(-0.651*)	(0.518*)

* *t*-statistic and *p*-value given in parentheses are for the null hypothesis that the coefficient is equal to 1. The remaining *t*-statistics and *p*-values are for the null hypothesis that coefficient is zero.

The Cobb-Douglas production function was estimated to measure the degree of returns to scale for tomato producing farms in Thatta district of Sindh. The results showed that the tomato production exhibited constant returns to scale. These results indicated that if all inputs are increased proportionately, the output is increased by the same proportion.

Table 5

Regression Results for Production Function of Chillies with Dependent Variable ln(y)

Regressor	Coefficient	Coefficient Estimate	Standard Error	*t*-statistics	p-value
Constant	β_0	2.051	0.203	10.115	0.000
$\ln\left(\frac{x_1}{x_3}\right)$	β_1	0.392	0.098	3.983	0.000
$\ln\left(\frac{x_2}{x_3}\right)$	β_2	0.594	0.105	5.628	0.000
$\ln\ x_3$	*h*	0.978	0.019	50.482	0.000
				(–1.135*)	(0.261*)

* *t*-statistic and *p*-value given in parentheses are for the null hypothesis that the coefficient is equal to 1. The remaining *t*-statistics and *p*-values are for the null hypothesis that coefficient is zero.

The above results presented in Table 5 shows that the chillies production exhibited constant returns to scale, hence the null hypothesis is accepted. These results also indicated that if all inputs are increased proportionately, the output is increased by the same proportion.

3.4. Technical Efficiency

Technical efficiency is a way to measure the level and extent of inefficiencies in production system. Technical efficiency describes the relationship between output and input by considering different combinations of input for output. Technical efficiency was measured by using the production function estimates. The intercept was than corrected by shifting the function until no residual is positive and at least one is zero. By doing this the frontier function for onion, tomato and chillies has been worked out as under:

Onion $Y^* = 2.41 + 0.531\ X_1/X_3 + 0.262\ X_2/X_3 + 0.989X_3$

Tomato $Y^* = 2.8 + 0.262\ X_1/X_3 + 0.256\ X_2/X_3 + 0.986X_3$

Chillies $Y^* = 2.239 + 0.392\ X_1/X_3 + 0.593\ X_2/X_3 + 0.978X_3$

The above frontier function indicate that Y* is at higher level from the given level of inputs and combinations of input for all the three vegetables. Given on the actual inputs on a farm for each vegetable the actual Y would be equal to the predicted Y*, only if the farm operates on the frontier production function, otherwise its actual productivity will be less than the predicted revenue productivity.

The individual technical efficiency score for each vegetable crop is calculated by taking the ratio of actual product to the predicted level of product. The predicted level of product is obtained from the corrected vectors of residuals.

$e_j = \text{Log } Y_j - \text{Log } Y_j{}^*$

$j = 1, 2, 3 \ldots\ldots\ldots 60$ (Onion)

$j = 1, 2, 3 \ldots\ldots\ldots 54$ (Tomato)

$j = 1, 2, 3 \ldots\ldots\ldots 60$ (Chillies)

$ej = 0$

$TE_j = \exp(e_j) = Y_j / Y_j{}^*$

The following Table 6 presents the frequency distribution of individual farmers of onion, tomato and chillies crop technical efficiency. The mean efficiency of chillies, tomato and onion was 83, 74 and 59 respectively. The minimum efficiency ratio for onion, tomato and chillies was 30, 51 and 60 respectively. Results further revealed that chillies farmers were at average producing 17 percent lower than the efficiency level while tomato and onion producers were 26 and 41 percent lower than the efficiency level. One reason of onion farmers being less efficient was the unstable and unreliable prices of output and some times the highest prices of seed and seedlings. The reason of efficiency in chillies could be that it had standard practices in input use and stable prices.

The results show that mostly (40.1 percent) of onion farmers lied between (50-65) in the efficiency rating ratio, while the majority of chillies farmers were close to the maximum level of efficiency rating lying higher than 75. Majority of the tomato farmers (25 percent) were also in higher efficiency rating ratio ranging from 70-80.

Table 6

Frequency Distribution of Technical Efficiency of Individual Farms in Statistical Frontier Production Function

Efficiency Rating	Onion		Tomato		Chillies	
	No	Percentage	No	Percentage	No	Percentage
>30<35	4	6.7	0	0.0	0	0.0
>35<40	6	10.0	0	0.0	0	0.0
>40<45	4	6.7	0	0.0	0	0.0
>45<50	3	5.0	0	0.0	0	0.0
>50<55	9	15.0	1	1.9	0	0.0
>55<60	9	15.0	1	1.9	0	0.0
>60<64	7	11.7	7	13.0	2	3.3
>65<69	5	8.3	9	16.7	4	6.7
>70<74	5	8.3	15	27.8	5	8.3
>75<79	3	5.0	10	18.5	11	18.3
>80<84	0	0.0	3	5.6	11	18.3
>85<89	1	1.7	4	7.4	11	18.3
>90<94	2	3.3	2	3.7	9	15.0
>95=100	2	3.3	2	3.7	7	11.7
Mean	0.59		0.74		0.83	
Min	0.30		0.51		0.60	
Max	1.00		1.00		1.00	

4. SUMMARY AND CONCLUSION

4.1. Production Function and Returns to Scale

Measuring the degree of returns to scale is of significant importance for understanding the agriculture sector and the long-run changes in the structure of agriculture including fragmentation or concentration of farmland. Furthermore, it is useful for making policies that affect the welfare of the whole society, such as those concerning land reforms and government support services. The degree of returns to scale measures the change in output when all inputs are changed proportionately. For a given proportional increase of all inputs, if output is increased by the same proportion, there are constant returns to scale; if output is increased by a larger proportion, the firm enjoys increasing returns to scale; and if output is increased by a smaller proportion, there are decreasing returns to scale [Varian (1992)]. Cobb-Douglas type of production function has been used for measuring returns to scale. This approach is commonly used for estimation of input and output relationships [Upton (1979); Heady and Dillon (1961); Chennareddy (1967)]. This method is easy to interpret results and it also provides a sufficient degree of freedom for statistical testing [Heady and Dillon, (1961); Griliches (1963)]. Although there have been many studies in Pakistan on production function estimation for yield or per hectare output, very few studies have estimated production function for total output. [Iqbal, *et al*. (2003)] evaluated the impact of credit on agricultural production in Pakistan. Hussain (1991) estimated production function for measuring the degree of returns to scale in Peshawar valley. Khan and Akbari (1986) used production function approach in studying the impact of agricultural research and extension on productivity of agriculture in Pakistan. All the coefficients in the model were significant and he suggested more investment in research and extension. There have been no previous studies on returns to scale in Sindh province of Pakistan.

The results of returns to scale in onion, tomato and chillies suggested constant returns to scale. The 5 percent critical value of Student's *t* distribution for sample size of 60 is 2.00. First, *t*-statistics are presented for testing the null hypothesis that the coefficients are zero. As *t*-statistics are greater than 2.00, the test rejects the null hypothesis and coefficients are significantly different from zero. For testing that the production function is constant returns to scale, we also test the null hypothesis that h=1. In this case, *t*-statistic and p-value are presented in parentheses. As the *t*-statistic in absolute terms is less than 2.00, the test maintains the null hypothesis, and the coefficient h is equal to 1 by this test. As described in methodology, $h = ß_1+ß_2+ß_3$, which measures the degree of geneuity. As $ß_1+ß_2+ß_3 = 1$ by the above test, these results show that the production function exhibits constant returns to scale. These results of the present study are consistent with the results by Hussain (1991), who also found that agricultural production function exhibits constant returns to scale.

4.2. Technical Efficiency

Farm efficiency is one of the important issues of production economics and production function analysis. Technical efficiency is a way to measure the level and extent of inefficiencies in production system. Technical efficiency describes the relationship between output and input by considering different combinations of input for output. Since the pioneering work on technical efficiency by Farrell in 1957, which drew upon the work of Debren (1951) considerable effort has been directed at refining the measurement of technical efficiency.

The mean efficiency of chillies, tomato and onion was 0.83, 0.74 and 0.59 respectively. The minimum efficiency ratio for onion, tomato and chillies was 0.30, 0.51 and 0.60 respectively. Majority (40.1 percent) of onion farmers lied between (0.50-0.65) in the efficiency rating ratio, while the majority of chillies farmers were close to the maximum level of efficiency rating lying higher than 0.75. Majority of the tomato farmers (25 percent) also fall in higher efficiency rating ratio ranging from 0.70-0.80. Ali and Flinn (1989) used a stochastic profit frontier of the modified translog type to examine the level of profit inefficiency in Basmati Rice production in Pakistan. They concluded that poor education, lack of credit, late application of fertiliser and shortage of irrigation water significant factors in profit losses. Hussain (1991) measured and compared economic efficiencies of the four irrigated cropping regions in the Punjab province of Pakistan by using probabilistic production function. The analysis showed that the average technical efficiency ranged from 80 percent in the rice region and 87 percent in the sugarcane region. This implied that farmers' income could be improved by 13 to 20 percent with the existing level of available resources. Parikh, Ali and Shah (1995) used SFA and concluded that the mean level of inefficiency was 12 percent ranging from 3 to 41 percent. They suggested education, extension and credit as means to reduce inefficiency. The technical efficiency estimates of this study obtained by using SFA method are consistent with the findings of Hassan (2004), Hussain (1999), Bettese (1997), and Parikh, Ali, and Shah (1999).

Lastly it can be concluded that returns to scale in vegetable production are constant showing that if we increase the inputs, the output will increase with the same proportion. Further, it can be concluded that the vegetable production is not an efficient one. Therefore, it is suggested that production of agriculture particularly vegetables be increased without consolidation of land so that the benefits are distributed among a large number of households, and agricultural support services be made available to all farmers particularly the small farmers in order to increase the total production. The production can further be increased by introducing improved technologies suitable for small farmers and by taking steps to add in the efficiency of vegetable production.

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