Measurement of Technical, Allocative and Economic Efficiency of Tomato Farms in Northern Pakistan

Himayatullah Khan and Imranullah Saeed

Abstract—The study measures productive efficiency of tomato growers in village Akbarpura of District Nowshera in Khyber Pakhtunkhwa (KPK) Province of Northern Pakistan. The study uses household level data collected in summer 2010 from sample farmers selected by multi-staged sampling. The study uses a theoretical framework to measure productive efficiency and estimates the Cobb-Douglas frontier production and cost models. The study found that technical efficiency indices varied significantly, with technical efficiency index averaging at 65%. The indices of allocative efficiency also varied widely, with an average of 56%. There was a wide gap between the highest and lowest economic efficiency indices, with a mean economic efficiency of 35%. The study concluded that farmer education, extension visits, age and access to credit contributed significantly and positively to productive efficiencies. A policy implication of this study is that there is enough potential for farmers to increase tomato production and net profits. The study recommends that the government should further invest in public education and strengthen extension services farmer education and because extension visits constituted important determinants of productive efficiencies.

Keywords— Frontier production and cost function, technical efficiency, allocative efficiency, economic efficiency, inefficiency determinants, Pakistan.

JEL Classification: Q1, Q12, Q16, Q18, Q19.

I. INTRODUCTION

A. Background Information

The economy of Pakistan is heavily based on agriculture which is the main contributor to its national income. Agriculture accounts for 22% of the country’s GDP and serves as source of employment for about 45% of the total employed labour. Crop production is a sub-sector of agriculture which contributes a major chunk to value addition in agricultural sector. Major and minor crops account for 33.4% and 12%, respectively, of the overall value addition in agriculture (Govt. of Pakistan, 2009). Despite its pivotal importance in the economy of Pakistan, the contribution of agriculture in GDP is gradually decreasing over the years. The slow rate of agricultural growth leads to low income, low savings and low investment opportunities in rural community. As a result, the pace of development in nonagricultural sectors is also declining which in turn results in lack of employment opportunities as well as in increase in poverty in rural areas.

A number of studies advocate that the strategy for agricultural development should be based on enhancing crop yields, especially for small farmers. There is sufficient empirical evidence that small-scale farms are a source of jobs to unemployed labour force (Bravo-Ureta and Pinheiro, 1997; Bravo-Ureta and Evenson, 1994). Researchers and policy planners, therefore, have given much attention to the use of new technologies to enhance crop yields and income of households. However, in recent years, the use agricultural technology is already high. This calls for the increase in productivity through optimal and efficient use of available technologies (Bravo-Ureta and Pinheiro, 1997).

Tomato is an important vegetable in Pakistan which is used as food item on daily basis. It can be considered as the most ubiquitous of all vegetables. It is mostly used as fresh vegetable and can be used for making different products as well. The study aims to measure the possibilities of productivity gains from enhancing the efficiency of tomato farmers. The study aims at providing guidance to various stakeholders on how to increase tomato production by identifying the extent by which tomato production efficiency could be raised with the available technology and resource base in Pakistan. In order to provide policy implications, the efficiency measurements will be decomposed into technical, allocative and economic efficiencies using stochastic efficiency decomposition frontier analysis.

The plan of the study is as follows. Introduction, background information and objectives of the study are described in section I. The study area and data are given section II. In section III we discuss theoretical framework to measure technical, allocative and economic efficiency using the production and cost function frameworks. The analytical technique and formulation of econometric models are given in section IV. Section V presents results and discussion. Finally, section VI draws conclusions and policy implications from the findings of the study.

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II. THE STUDY AREA AND DATA

A. Study area

Village Akbarpura, the area of this study, is located in close vicinity of Peshawar. Peshawar is the capital city of KPK province. The study area is situated in North-Western part of Pakistan. The study area is famous for cultivation of major and minor crops as well as vegetables and fruits. Tomato is the most important vegetable in this area. It supplies all kinds of vegetables to urban market of Peshawar city as well as other areas of the country. Because of favorable climatic conditions, the area is well suited for the production of food crops including wheat and maize; perennial crops like sugar cane; all kinds of vegetables and fruits. The area is also irrigated. The fertility of the soil was also increased by heavy floods of summer 2010. Farmers of area have small land holdings in the range of 0.5-1.5 hectares with more than 45% of farmers cultivating up to 0.37 hectares of land.

B. Collection of data and sampling procedure

The data were collected by a farm level survey of 61 tomato growers. A multistage sampling technique was used. In the first stage, the village of Akbarpura was purposively selected. In the second stage, only tomato producing households were identified. Finally, sample households were selected by simple random sampling technique. The data were collected with the help of pre-tested interview schedule in summer 2010. The interview schedule contained questions about tomato production, cost of tomato production on various inputs used in tomato production, prices of variable and fixed input as well as of tomato production which we needed for analysis. The data were analyzed in SPSS as well as LIMDEP.

III. THEORETICAL FRAMEWORK

The concept of productive efficiency was first introduced by Michael Farrell (1957) who argued that there were two components of efficiency: technical efficiency (TE) and allocative efficiency (AE).

According to Farrell’s methodology, economic efficiency (EE) is equal to the product of TE and AE where, TE is associated with the ability to produce on the frontier isoquant, while AE refers to the ability to produce at a given level of output using the cost-minimizing input ratios. In other words, technical inefficiency reflects deviations from the frontier isoquant, and allocative inefficiency is related to deviations from the minimum cost input ratios. Thus, EE is defined as the capacity of a firm to produce a predetermined quantity of output at minimum cost for a given level of technology (Farrell 1957; Kopp and Dievert 1982). An economically efficient firm is the one which is technically as well as allocatively efficient.

In Fig. 1, it is assumed that there are two inputs ($X_1$ and $X_2$) used by a firm to produce a single output ($Y$) with assumption of constant returns to scale. The $II'$ curve represents the isoquant of fully efficient firms, and could be used to measure TE. If the firm employs amount inputs at point $R$ to produce a unit of output, the technical inefficiency of that firm could be measured by the distance $RS$. This is the proportion by which the use of inputs could be reduced without a decrease in output. This is expressed in percentage terms by the ratio $SR/OR$, which stands for the percentage by which all inputs need to be reduced to gain production which is technically efficient. The TE of a firm is measured by the ratio: $TE = OS/OR$. If a firm has TE equal to 1, it is technically efficient. The firm is technically inefficient if its TE value is less than 1.

At point S the firm could gain full technical efficiency because point S lies in the efficient production indifference curve.

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1 According to Farrell (1957) “TE is the ability of a firm to produce the maximum possible output from a given set of inputs or it is the ability of a firm to use the minimum inputs for a given level of output. The former is called input oriented measures and the latter is known as output-oriented measures of technical efficiency. AE is the ability of a firm to use inputs in optimal proportion, given their respective prices and the production technology. The use of an input is allocatively efficient if the value of marginal product is equal to its price.”
The index of EE also varies between 0 and 1 where the latter implies that the firm is economically efficient. If the value of EE is less than 1 then the firm is economically inefficient. The distance from R to T also represents the cost reduction in production if a firm produces at point T with technical and allocative efficiency, instead of at point R with technical and allocative inefficiency. Economic efficiency is a combination of technical and allocative efficiency.

The concept of efficiency of farms has widely been studied by a number of researchers including Bardhan (1973), Kalirajan and Flinn (1983), Fare, Grosskopf and Lovell (1985), Battese, Coelli and Colbi (1989), Kalirajan (1990), Battese and Coelli (1992), and Himayatullah (1994). Most studies that have measured technical efficiency using the stochastic frontier method because of the above stated advantages. Bravo-Ureta and Pinheiro (1993), Parikh and Shah (1994), Ajibefun and Abdulkadri (1999), Ajibefun and Daramola (1999), Sharma et al. (1999) and Ajibefun et al. (2002) have used the stochastic parametric model to measure the technical, allocative and economic efficiencies in recent agricultural production efficiency studies. In their study of peasant farming in the Dominican Republic, Bravo-Ureta and Pinheiro (1993), using the Cobb-Douglas production frontiers, found that younger, more educated farmers exhibited higher levels of technical efficiency and that, additionally, contract farming, medium-size farms and being an agrarian reform beneficiary had a positive association with economic and allocative efficiencies. In addition to determining the efficiency levels, for policy formulation purposes, it is also useful to identify the sources of these inefficiencies. The relationship between the farm/farmer characteristics and the computed technical, allocative or economic efficiency indices in a single step was investigated in this study, using a single step (Coelli, 1995).

The basis of a frontier function can be illustrated with a farm using n inputs \(X_1, X_2, \ldots, X_n\) to produce output \(Y\). Efficient transformation of inputs into output is characterized by the production function \(f(X_i)\), which shows the maximum output obtainable from various input vectors. The stochastic frontier production function assumes the presence of technical inefficiency of production. Hence, the function is defined as:

\[
Y_i = f(X_i; \alpha_i) + \varepsilon, \quad \text{for} \quad i = 1, 2, \ldots, n
\]

whereby \(Y_i\) is the output of farmer \(i\), \(X_i\) are the input variables, \(\alpha_i\) are production coefficients and \(\varepsilon\) is the error term that is composed of two elements, that is:

\[
\varepsilon = v_i - u_i
\]

(3)

Where \(v_i\) is the stochastic error which is assumed to be identically, independently and normally distributed with zero mean and a constant variance \((\sigma^2_v)\). The other second component \((u_i)\) is a one-sided error term which is independent of \(v_i\) and is normally distributed with zero mean and a constant variance \((\sigma^2_u)\), allowing the actual production to fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

We follow Jondrow et. al (1982) that the technical efficiency estimation is given by the mean of the conditional distribution of inefficiency term \(u_i\); given \(\varepsilon\); and thus is defined by:

\[
E(u_i | \varepsilon_i) = \frac{\sigma_u - \sigma_v}{\sigma} \left[ f(\varepsilon_i, \lambda | \sigma) - \frac{\varepsilon_i \lambda}{\sigma} \right] \left[ 1 - F(\varepsilon_i, \lambda | \sigma) - \frac{\varepsilon_i \lambda}{\sigma} \right]^{-1}
\]

(4)

here \(\lambda = \alpha_u / \sigma_v\), \(\sigma^2 = \sigma_u^2 + \sigma_v^2\) while \(f\) and \(F\) stand for the standard normal density and cumulative distribution function, respectively evaluated at \(\varepsilon_i / \lambda\).\(\sigma\). We define the farm-specific technical efficiency in terms of observed output \((Y_i)\) to the corresponding frontier output \((Y_i^*)\) using the existing technology derived from equation (4) above as:

\[
TE_i = \frac{\bar{Y}_i}{Y_i} = \frac{E(Y_i | u_i, X_i)}{E(Y_i | u_i = 0, X_i)} = e^{[E(u_i | \varepsilon_i)]}
\]

(5)

The values of TE range between 0 and 1 where the latter shows that the farm is fully efficient.

In order to estimate farm level overall economic efficiency, we specify the stochastic frontier cost functions model as follows:

\[
C_i = h(Y, P, \alpha) + \varepsilon_i \quad \text{where} \quad i \text{ varies from 1 to n.}
\]

(6)

Here \(C_i\) is the total production cost, \(Y_i\) stands for output produced, \(P_i\) is cost of input, \(\alpha\) represents the parameters of the cost function to be estimated and \(\varepsilon_i\) is the error term that is composed of two elements, that is:

\[
\varepsilon_i = v_i + u_i
\]

(7)

Here \(v_i\) and \(u_i\) are as defined earlier. Since, inefficiencies are assumed to add to costs, error components, therefore, have positive signs.

We define the farm specific economic efficiency as the ratio of minimum observed total production cost \((C^*)\) to actual total production cost \((C)\) using the result of equation 4 above. That is:

\[
EE = \frac{C^*}{C} = \frac{E(C_i | u_i = 0, Y, P)}{E(C_i | u_i, Y, P)} = e^{[E(u_i | \varepsilon_i)]}
\]

(8)

The EE also has values in the range of 0 and 1. Thus, a measure of farm specific allocation efficiency is obtained from technical and economic efficiencies estimated as follows:

\[
AE = EE/TE.
\]

(9)

This implies that \(0 \leq AE \leq 1\).
IV. ANALYTICAL FRAMEWORK AND MODEL SPECIFICATION

According to Kopp and Smith (1980), functional forms have a limited effect on empirical efficiency measurement. Battese (1992) has reported that any empirical studies relating to developing countries have used Cobb-Douglas functional forms. The Cobb-Douglas functional form also meets the requirement of being self-dual, allowing an examination of economic efficiency. In this study, the following Cobb-Douglas functional form was selected to model tomato production technology:

\[ Y_i = \beta_0 \times \prod_{j=1}^{d} X_{ij}^{\beta_j} \times e^{(V_i - U_i)} \]  \hspace{1cm} (10)

which, when linearized, becomes:

\[ \ell n Y_i = \ell n \beta_0 + \beta \sum_{j=1}^{d} \ell n X_{ij} + \epsilon_i \]  \hspace{1cm} (11)

where \( Y_i \) is the output of farmer \( i \), \( X_{ij} \) is the \( j \)th input used by farmer \( i \), and \( \epsilon_i \) is a “composed” error term. The error term \( \epsilon_i \) is explained by \( \epsilon_i = (v_i - u_i) \), \( i = 1, \ldots, N \). \( v_i \) is a two-sided \((-\infty < v < \infty\) normally distributed random error \( v \sim N(0, \sigma_v^2) \)) that represents the stochastic effects outside the farmer’s control (e.g., weather, natural disasters, and luck), measurement errors, and other statistical noise. \( u_i \) is a one-sided \((u \geq 0) \) efficiency component that represents the technical inefficiency of the farm (Thiam et al., 2001). In other words, \( u_i \) estimates the shortfall in output \( Y_i \) from its maximum value given by the stochastic frontier function:

\[ \ell n Y_i = \ell n \beta_0 + \beta \sum_{j=1}^{d} \ell n X_{ij} + v_i \]  \hspace{1cm} (12)

This one-sided term of distribution can be half-normal, exponential, or gamma (Aigner et al., 1977; Meesuen & Broeck, 1977). In this study, it is assumed that \( u_i \) is a half-normal distribution \( u \sim \mathcal{N}(0, \sigma_u^2) \) as it is typically used in the applied stochastic frontier literature. The two components \( v_i \) and \( u_i \) are assumed to be independent of each other.

In equations 10-12, \( \beta \)s are unknown parameters to be estimated, \( X_1 \) represents labor input; \( X_2 \) represents other variable cost (e.g. herbicide, insecticide and fertilizer); \( X_3 \) represents access to credit; \( X_4 \) represents farm size in ha; \( u_i \) represents the specific technical efficiency factor for farm \( i \); and \( v_i \) represents a random variable for farm \( i \).

The cost frontier for tomato farms dual to the production frontier can be expressed as:

\[ \ell n C_i = \alpha_0 + \sum_k \alpha_k \ell n P_{ik} + \gamma \ell n Y^* + (v_i + u_i) \]  \hspace{1cm} (13)

where \( C_i \) is the minimum cost to produce output \( Y_i \), \( P_{ik} \) is a vector of \( k^{th} \) input price, and \( \alpha_i \) is a vector of parameters. Further, \( P_2 \) is the average wage rate per man days of labour, \( P_3 \) is the average variable cost (of herbicide, insecticide and fertilizer), \( P_4 \) is the cost (rate of interest) on credit, \( P_5 \) is the average land rent per hectare and \( Y_i \) is as earlier defined above. The \( \beta \)s, \( \alpha \)s, \( \gamma \) are parameters to be estimated. The frontier functions (production and cost) are estimated through maximum likelihood methods.

The model for the technical, allocative and economic inefficiency effects was specified as follows:

\[ \Psi_{ti,ai,ei} = \omega_0 + \omega_1 X_5 + \omega_2 X_6 + \omega_3 X_7 + \omega_4 X_8 \]  \hspace{1cm} (14)

Where \( \Psi_{ti,ai,ei} \) represents inefficiency effects, the subscripts \( te, ae, \) and \( ee \) stand for technical, allocative and economic inefficiency effects. \( \Psi \) is the constant of the inefficiency model, \( X_5 \) represents farmer formal schooling, (years); \( X_6 \) represents the number of extension visits; \( X_7 \) represents access to credit (ratio of credit used and credit required); and \( X_8 \) represents age of farmers (years).

V. RESULTS AND DISCUSSION

A. Maximum Likelihood Estimates of the Frontier Production Function

Table 1 gives summary statistics of various variables used in stochastic production and cost function analysis. The maximum likelihood estimates (MLE) of equation 11 are given in Table 2. In order to check whether technical inefficiency effects are absent, we may use the important test. The important parameter of log-likelihood in the half-normal model is \( \lambda=\sigma_u/\sigma_v \). If the value of \( \lambda \) is equal to 0 there are no technical inefficiency effects and all deviations from frontier are due to noise (Aigner, Lovell, & Schmidt, 1977). The estimated value of \( \hat{\lambda} = 0.688 \) is significantly different from 0 and the null hypothesis that that there are no inefficiency effects is rejected at 5% significance level (in terms of the Z-statistic \( Z = \hat{\lambda} / \sigma_v \) which exceeds the critical value of \( Z_{0.05}=1.96 \)) implying there exists inefficiency effects among tomato growers in the study area. The ratio of the standard error of \( u \) (\( \sigma_u \)) to the standard error of \( v \) (\( \sigma_v \)), known as lambda (\( \lambda \)), is 0.688. Based on \( \lambda \), we can derive gamma (\( \gamma \)) which measures the effect of technical inefficiency on the variation of observed output (\( \gamma = \lambda^2 / (1+\lambda^2) = \sigma_u^2 / \sigma_v^2 \)). The estimated value of \( \gamma \) is 0.47, which means that 47% of the total variation in tomato output is due to technical inefficiency.

The estimated coefficients show relative change in tomato output (\( Y \)) due to a percentage change explanatory variable. These estimates show relative importance of various inputs in tomato production in Northern Pakistan. The coefficient of labour input was highest implying that it is the most important explanatory variable in tomato production which showed that the tomato production increases by 26% for each extra percentage of labor. This may also be due to the reason that tomato is a labour intensive vegetable in which few improved technologies (chemical and mechanical inputs) are employed. The estimated coefficient of capital was the lowest (0.05) but statistically significant at 0.05 implying 5% change in tomato production due to additional percentage change in capital. Coefficients of variable costs and farm size were also significant at 0.05. For the estimated Cobb-Douglas cost frontier model (equation 13), the coefficient of land expenses was the highest. This may be because access to land is still...
hampered by the type of tenure system and farm size in the study area. It can be inferred from this finding that that land could be described as scarce in the state. All other coefficients had positive signs and are significant at 5% level (Table 2).

B. Technical Efficiency

Technical efficiency indices varied significantly, with technical efficiency index ranging from 45% to 85% with mean at 65% (Fig. 2). Table 3 shows that the modal class (71–80%) had better technical efficiency than the lowest class (11–20%). This could be because these farmers had relatively larger farms, had relatively higher level of former schooling, were comparatively younger, and had higher number of contacts with extension workers. This trend was also found in the highest class (81–90%). None of the respondents had a technical efficiency of 100%. This implied that room for improvement in tomato production was existent in the study area with the given resource base and available technology.

C. Allocative Efficiency

The indices of allocative efficiency also varied widely, with an average of 56% (Fig. 3). It can be seen in Table 4 that the modal class (51–60%) had a higher allocative efficiency than the lowest class (11–20%) because farmers in the modal class had a higher level of formal education, were younger, and had more visits to the extension department and had been in the tomato production for quite sometime. These farmers, therefore, can be thought of as agents for the development of tomato production. Similarly, none of the sample farmers had a 100% allocative efficiency index. This implied that resources could be allocated to their best alternative uses and prices could as well be allowed to perform their allocative functions in the use of inputs.

D. Economic Efficiency

The range of economic efficiency indices is also high implying a huge gap between the lowest and highest economic efficiency indices, with a mean of 35% (Fig. 4). Farmers in the modal class (31–40%) had on the average larger landholdings, had a higher level of formal schooling, less experience, and were relatively younger than the farmers in the lower class (Table 5). This shows that there is a great potential that could be exploited by the farmers of the area by enhancing their tomato production and profit with the available technology and resource base only by improving utilization of the production factors.

E. Determinants of Efficiencies among Tomato Growers

Table 6 shows various factors that determine productive efficiencies of tomato growers in the study area.

1. Formal Education of Farmers: Education is an important factor that sharpens managerial capabilities of farmers. It helps farmers in timely decision making. Education of farmers may enable them to make good use of information about production inputs, thus improving the efficient use of inputs. The algebraic sign of estimated coefficient of farmer education was negative and statistically significant at 0.05. This means that as education of farmer increases the inefficiency effects decreases which alternatively means that farmer education and technical efficiency go side by side. Thus, our study found out that higher the level of formal schooling by farmers, higher the technical, allocative and economic efficiencies. However, our findings are in disagreement with some earlier studies by Page and John (1984) and Wang et al. (1996). These studies reported a negative relationship between technical efficiency and formal education.

2. Extension Visits: The estimated coefficient for extension visit had also a negative implying that extension visits affected productive efficiency negatively and it demonstrated that extension visit was an important factor in determining technical efficiency in the study area. Similar findings were also reported by other studies which found a positive relationship between farm level efficiency and availability of extension services (Kaliranjan, 1981; Kaliranjan and Flinn, 1983; Kaliranjan and Shand, 1985; Bravo-Ureta et al., 1994).

3. Age: The estimated age coefficients were positive with respect to various production inefficiencies. These coefficients were statistically significant at least at 5%. This implied that age contributed positively to inefficiencies which, in other words, means that younger farmers were relatively more efficient than older farmers. This is an important finding which younger farmers are comparatively more educated than the older farmers. Thus, it can be inferred from this finding that the younger and educated the farmer the more technically and economically efficient he is.

4. Access to Credit: Access to credit may enable farmers to purchase productive inputs on time. It may lead to higher productive efficiencies. The coefficients of access to credit were negative for production inefficiencies and were significant at 0.05. This shows that the higher the access to credit, the more efficient the farmer became. This is in disagreement with Okike et al. (2001), who showed that receiving credit contributed to farmers’ economic inefficiency. If production credit is invested on the farm, it is expected that this will lead to higher levels of output. Thus, access to credit is more likely to lead to an improvement in the level of technical and allocative efficiency.

VI. CONCLUSIONS AND RECOMMENDATIONS

This study has estimated the stochastic production and consumption frontier functions. It has predicted farmers’ productive efficiencies of 61 tomato growers in village Akbarpura, KPK province in Northern Pakistan. The Cobb-
Douglas stochastic frontier production and cost functions were estimated with maximum likelihood estimation method. The estimated productive efficiencies were explained by various socio-economic and demographic factors. The findings show that there was a wide gap between the highest and lowest technical efficiency indices, with an average technical efficiency index of 65 percent. There was not even a single farmer who had a technical efficiency of 100%. This implies that, using the subsisting resource base, improved efficiency can still be achieved. Here was also a huge gap between the highest and the lowest index of allocative efficiency of tomato growers implying that there was a substantial loss in net profit in tomato growing. Economic efficiency indices also varied significantly showing that there was a great potential for increasing the gross output and profit with the existing level of resource base. Regarding the sources of productive efficiencies, the study concluded that farmer education, extension visits, age and access to credit contributed significantly and positively to these efficiencies. One of the most important policy implications of this study is that there is enough potential to increase the present level of efficiencies for tomato production in the study area. The study recommends that the Govt. of Pakistan should invest more in education in general and farmer education (formal as well as informal education) in particular as farmer education would reduce productive inefficiencies. Another policy implication of the study is that extension education has a direct relationship with efficiency. Therefore, the government should strengthen the extension services of its Agriculture Department so that farmers have easy access to it. This may help them in increasing farm output and net profits.

REFERENCES


Comparison of Parametric and Nonparametric Approaches. Agricultural Economics, 20, pp. 23–35.


Table I

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average</th>
<th>Standard Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato Yield (Kg/hectare)</td>
<td>10546</td>
<td>3.8</td>
<td>7400</td>
<td>14200</td>
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<td>Farm Size (hectares)</td>
<td>0.50</td>
<td>2.3</td>
<td>0.23</td>
<td>0.84</td>
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<tr>
<td>Fixed Cost (Rs/hectare)</td>
<td>14869.6</td>
<td>9663.1</td>
<td>22708.4</td>
<td></td>
</tr>
<tr>
<td>Variable Cost (Rs/hectare)</td>
<td>9913.0</td>
<td>6442.1</td>
<td>15138.9</td>
<td></td>
</tr>
<tr>
<td>Credit (Rs.)</td>
<td>15000</td>
<td>-</td>
<td>10000</td>
<td>25000</td>
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<tr>
<td>Farmer Education</td>
<td>6</td>
<td>-</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Extension Visits</td>
<td>5</td>
<td>1.6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Age</td>
<td>42</td>
<td>11.9</td>
<td>28</td>
<td>65</td>
</tr>
<tr>
<td>Gross Revenues (Rs/hectare)</td>
<td>74595.0</td>
<td>-</td>
<td>53622.9</td>
<td>97608.5</td>
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<tr>
<td>Net Revenues (Rs/hectare)</td>
<td>49812.4</td>
<td>-</td>
<td>37517.6</td>
<td>59761.2</td>
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<tr>
<td>Cost of Land Input</td>
<td>5480.9</td>
<td>35</td>
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<td>Cost of Labour Input</td>
<td>6195.0</td>
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<td>3941.4</td>
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<td>Cost of Capital</td>
<td>13106.7</td>
<td>60</td>
<td>8160.6</td>
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<td>Total Production Cost (Rs./hectare)</td>
<td>24782.6</td>
<td>-</td>
<td>16105.2</td>
<td>37847.3</td>
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</table>

Variable Cost (VC) includes cost of herbicide, insecticide, chemical fertilizers, farm yard manure and seed/nurseries, cost of farm tools used for tomato growing.

1 US $ = Pak. Rs. 85.

Table II

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter Coefficients</th>
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<tr>
<td>Production Analysis</td>
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<tr>
<td>Intercept</td>
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<td>ln Labour</td>
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<td>ln VC</td>
<td>β_2</td>
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<tr>
<td>ln Capital</td>
<td>β_3</td>
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<td>ln Farm Size</td>
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<tr>
<td>Function Coefficient</td>
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<td>0.57</td>
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<tr>
<td>Ratio of the SE of u to the SE of v</td>
<td>λ</td>
<td>0.688</td>
</tr>
<tr>
<td>(λ=σ_u/σ_v=0.31/0.45)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total variance (σ^2 = σ_u^2 + σ_v^2)</td>
<td>σ^2</td>
<td>0.299</td>
</tr>
<tr>
<td>Log livelihood function</td>
<td>_</td>
<td>-0.6983</td>
</tr>
<tr>
<td>Cost Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>α_0</td>
<td>2.67</td>
</tr>
<tr>
<td>ln P_1</td>
<td>α_1</td>
<td>0.18</td>
</tr>
<tr>
<td>ln P_2</td>
<td>α_2</td>
<td>0.09</td>
</tr>
<tr>
<td>ln P_3</td>
<td>α_3</td>
<td>0.21</td>
</tr>
<tr>
<td>ln P_4</td>
<td>α_4</td>
<td>0.33</td>
</tr>
<tr>
<td>ln Output (Y)</td>
<td>γ</td>
<td>0.18</td>
</tr>
<tr>
<td>Ratio of the SE of u to the SE of v</td>
<td>λ</td>
<td>0.75</td>
</tr>
<tr>
<td>(λ=σ_u/σ_v=0.37/0.49)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total variance (σ^2 = σ_u^2 + σ_v^2)</td>
<td>σ^2</td>
<td>0.57</td>
</tr>
<tr>
<td>Log livelihood function</td>
<td>_</td>
<td>-0.73</td>
</tr>
</tbody>
</table>

Note: *** and ** shows significance at 0.01 and 0.05, respectively.
### Table III
Tomato Growers Classified by Technical, Allocative, and Economic Efficiency

<table>
<thead>
<tr>
<th>Efficiency Level</th>
<th>Technical Efficiency</th>
<th>Allocative Efficiency</th>
<th>Economic Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
<td>No.</td>
</tr>
<tr>
<td>11-20</td>
<td>1</td>
<td>1.6</td>
<td>1</td>
</tr>
<tr>
<td>21-30</td>
<td>1</td>
<td>1.6</td>
<td>2</td>
</tr>
<tr>
<td>31-40</td>
<td>3</td>
<td>4.9</td>
<td>7</td>
</tr>
<tr>
<td>41-50</td>
<td>10</td>
<td>16.4</td>
<td>9</td>
</tr>
<tr>
<td>51-60</td>
<td>12</td>
<td>19.7</td>
<td>25</td>
</tr>
<tr>
<td>61-70</td>
<td>15</td>
<td>24.6</td>
<td>10</td>
</tr>
<tr>
<td>71-80</td>
<td>17</td>
<td>27.9</td>
<td>5</td>
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<tr>
<td>81-90</td>
<td>2</td>
<td>3.3</td>
<td>2</td>
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<tr>
<td>91-100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>61</td>
<td>100</td>
<td>61</td>
</tr>
<tr>
<td>Mean</td>
<td>65</td>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>Minimum</td>
<td>45</td>
<td>100</td>
<td>45</td>
</tr>
<tr>
<td>Maximum</td>
<td>85</td>
<td>100</td>
<td>85</td>
</tr>
</tbody>
</table>

### Table IV
Determinants of Productive Inefficiencies

<table>
<thead>
<tr>
<th>Factor</th>
<th>Technical Inefficiency $\Psi_{TI}$</th>
<th>Allocative Inefficiency $\Psi_{AI}$</th>
<th>Economic Inefficiency $\Psi_{EI}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant ($\omega_0$)</td>
<td>Coefficient $t$ 2.83</td>
<td>t-ratio 7.64**</td>
<td>Coefficient $t$ 2.60</td>
</tr>
<tr>
<td>Farmer Edu ($\omega_1$)</td>
<td>-0.21</td>
<td>-2.1**</td>
<td>-0.19</td>
</tr>
<tr>
<td>Ext. Visits ($\omega_2$)</td>
<td>-0.18</td>
<td>-2.25**</td>
<td>-0.17</td>
</tr>
<tr>
<td>Credit ($\omega_3$)</td>
<td>-0.04</td>
<td>-2.10**</td>
<td>-0.04</td>
</tr>
<tr>
<td>Age ($\omega_4$)</td>
<td>0.11</td>
<td>2.2**</td>
<td>0.09</td>
</tr>
</tbody>
</table>
Figure 4. Frequency Distribution of Sample Farmers by Economic Efficiency Levels