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Determinants of Technical Efficiency of Wheat Production in Afghanistan: The Case of Wheat Farmers in Paktia Province

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Keyword list

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Likelihood ratio
Wheat productivity
Potential output
Paktia, Afghanistan

Abstract

There is a large variation in wheat production due to the variation of technical efficiency among the Afghan rural wheat farmers. These variations can be attributed to some exogenous and endogenous explanatory variables. This empirical study measures and analyzes technical efficiency in the theoretical framework of stochastic production frontier approach. The parameters of the stochastic frontier production function and the determinants of the technical inefficiency model were estimated simultaneously, through the single stage maximum likelihood estimation procedure, by using the computer program FRONTIER version 4.1.

The estimated value of Gamma (\( \gamma \)), 0.913, significant at 1% level, implies that on average 91.3% of total variation in wheat output is due to technical inefficiency. The mean technical efficiency is about 64% with a range between 6% and 93%, which indicates that on average the wheat farmers obtain 64% of their potential output, and the average loss in wheat production due to the technical inefficiency is 36%, which varies between 7% and 94%. This wide variation in technical efficiency can be interpreted that there still exist opportunities to increase 36% of wheat production at the existing level of inputs and current technology by operating at technically fully efficient level.

Description of Data

Primary data constitute the core of the data in this paper. The necessary primary data has been collected from the sampled households through using a structured questionnaire. Different quantitative and qualitative questions concerning the household’s characteristics, resource use, and socio-economic status were included in the questionnaire and after a pre-test by few farmers, the finalized version of the questionnaire has been distributed.
The sample size of 122 wheat farm households selected through multi-stage method of random sampling in sixty-six villages belonging to the five districts of Paktia province. The sample size for each sampled district and village has been allocated based on the assumed proportion of arable land especially wheat cultivated area. The three sampled districts (Sayed Karm, Ahmad Aba, and Samkani) are the districts have more population as well as the larger amount of arable land and irrigated water comparing to the district of Mirzaka that is largely mountainous district and has less amount of irrigated land. Gardez is the provincial capital and a large amount of area is occupied by buildings and bazaar, and the majority of its farmers grow vegetables and fruits instead of wheat to sell it in Gardez bazaar. On the other hand, all villages are not equal in terms of land area and population, therefore, the sample size has not been allocated equally to each sampled district and villages.

A three-stage method of random sampling has been used for selecting a representative sample of wheat farm households. At the first stage, all the thirteen districts of the province including the provincial capital have been listed, and by using the lottery system, five districts of them have been selected. In the second stage of sampling, a research team created in which ten educated and familiar enumerators have been employed, and sixty-six villages of 198 villages of the sampled districts have been selected randomly by using the lottery system. The third and last stage of the sampling was very time-consuming because the team was responsible for giving appropriate code number for each house of the sampled villages and then randomly selecting one or few of households based on the number of households. In the small sampled villages whose number of houses was less than 60, the allocation of the sample size for such a small village was one household, thereby for medium size villages two households, for large size villages three households and for very large size villages the sample size of four households has been allocated. Hence, a sample of 122 households finally selected in the 66 sampled villages from the five sampled districts in the province. The secondary data gathered through desk studies on literature, past research of the field, scientific journal articles, working papers, governmental statistical documents, and other credible organization reports.

**Research Question/Theoretical contextualization**

Wheat is the main food crop which is consumed almost with every meal in Afghanistan. According to the World Bank report, annual per capita wheat consumption is very high in the country (160 Kgs). Furthermore, wheat flour supplies 57% of the total caloric content of the average bundle of food items of the poor in Afghanistan (The World Bank, 2014). About 80% of the total land under cereal production in the country is cultivated by wheat. Thus, raising wheat yields is a critical issue for food security and poverty reduction especially in the rural areas of the country. The alleviation of the rural poverty and improving food security through the increase of agricultural output via
raising farm productivity and efficiency is a strategic objective for the agricultural and rural development sector in the Afghanistan National Development Strategy (ANDS).

It is apparent that an appropriate policy to increase agricultural productivity through the increase of farmers’ efficiency cannot be devised without proper information concerning the current efficiency posture of the product and determining the effects of different factors that influence the production efficiency. Therefore, this study will help to the relevant policy makers in identifying the factors and variables that significantly affect wheat efficiency and productivity.

One way to increase wheat output is to increase technical efficiency in wheat production. Therefore, it is necessary to analyze and quantify the current level of technical efficiency so as to estimate losses in production that could be attributed to inefficiencies due to differences in socio-economic and wheat farm characteristics. This study is to find answers to the following research questions:

1) How large is the variation of technical efficiency among Afghan rural wheat farmers?
2) What are the socio-economic and farm-specific variables that influence the technical efficiency of wheat production?

Efficiency is one of the important theme of production economics and production function analysis, which has very close relation to productivity. Changes in production technology, as well as changes in efficiency levels can changed the level of productivity. The terms of efficiency and productivity are used interchangeably in many productivity and efficiency literature, However, they are not precisely the same things. Productivity is the ratio of the output(s) to its input(s), but efficiency is a relative concept and is measured by comparing the actual ratio of outputs to inputs with the optimal ratio of outputs (Dao, 2013).

Technical efficiency of a firm or industry is defined as the ability of the firm or industry to either produce maximum possible output from a given set of inputs and a given technology (output orientated measures); or to obtain the given level of output from the possible minimal quantity of inputs (input orientated measures) (Wabomba, 2015).

These two measures of TE is equivalent if the production function is constant returns to scale (CRTS), whereas they are not equivalent in non-constant or variable returns to scales. Since TE is defined technically by production frontier, therefore we sketch two production frontier where is used a simple example of a single input (x) for producing a single output (y). Figure 1 indicates that farmer, P, is not technically efficient and can increase his/her output to point D with the same vector and amount of inputs and given technology, or other way around, farmer P can produce the same quantity of output with the less or minimum amount of the inputs if he/she use its inputs efficiently. The production frontier of figure, a, shows CRTS technology while figure, b, exhibits
decreasing returns to scale (DRTS) technology. Thus, the both measure of TE are equivalent in CRTS production technology:

\[
\frac{AB}{AP} = \frac{CP}{CD} \quad (1)
\]

However, these two measures are not equivalent in DRTS, see figure, b:

\[
\frac{AB}{AP} \neq \frac{CP}{CD} \quad (2)
\]

**Figure 1:** Production Frontiers and Technical Efficiency

Source: Coelle et al., 2005, p.55.

In the stochastic frontier model the deviation from the maximum or frontier output is attributed to the technical inefficiency effects as well as to the effects of a random variable or shock that is not under the control of the firms.

The stochastic frontier production function model was proposed independently by Aigner, et al. (1977) and Meeusen and Julien van Den Broeck (1977), that is defined:

\[
\ln y_i = f(x_i; \beta) + v_i - u_i \quad (3)
\]

Where \( \ln y_i \) denotes the log output of the i-th farm household; \( x_i \) is a 1×k vector of inputs and other explanatory variables of the farmer i; \( \beta \) is a k×1 vector of unknown parameters to be estimated; \( u_i \) are non-negative random variables associated with technical inefficiency of production which are assumed to be independently distributed such that \( u_i \) is obtained by truncation (at zero) of the normal distribution with mean, \( z_i \delta \) and variance, \( \sigma_u^2 \). Moreover, the random variable \( u_i \) in equation 3 is the log difference between the maximum and the observed output (i.e. \( u_i = \ln y_i^* - \ln y_i \)), thus, \( u_i \times 100\% \) is the %age by which the actual output can be increased by using the same vector of inputs if the production is fully efficient (Kumbhakar and Wang, 2010).

The error component \( v_i \) represents symmetric distribution of disturbance and is assumed to be independently and identically distributed over the observation as \( N (0, \sigma_v^2) \), and independent of the \( u_i \) which is a non-negative random variable and assumed to account for technical inefficiency.
in production and often assumed to be independently and identically distributed, such that \( u_i \) is obtained by truncation (at zero) of the normal distribution with mean, \( z \delta \) and variance, \( \sigma_u^2 \).

\( z_i \) is a \((1 \times m)\) vector of explanatory or firm-specific variables associated the technical inefficiency, and \( \delta \) is a \((m \times 1)\) vector of unknown coefficients of explanatory inefficiency variables.

The statistical noise \((\nu_i)\) arises from the inadvertent omission of related variables from the input vector \( x_i \) as well as from the measurement errors and approximation errors relevant to the choice of functional form. Some researchers, the term of statistical noise use to refer the effects of weather, strikes, luck, damaged product, etc., on the value of the production variable (Kumbhakar and Wang, 2010).

TE of an individual farmer can be defined as the ratio of his/her observed output to the corresponding maximal possible output \((y^*)\), conditional on the vector of inputs used by that farmer (Battese,1992):

\[
TE_i = \frac{y_i}{y_i^*} = \frac{\exp(x_i; \beta + \nu_i - u_i)}{\exp(x_i; \beta + \nu_i)} = \exp(-u_i) \quad (4)
\]

The maximum likelihood method is used for simultaneous estimation of the parameters of the stochastic production frontier and the model for technical inefficiency effects. The likelihood function is presented in terms of variance parameters as follows:

\[
\sigma^2 = \sigma_v^2 + \sigma_u^2 \quad \text{and} \quad \gamma = \frac{\sigma_u^2}{\sigma^2} \quad (5)
\]

Where \( \sigma^2 \) represents the overall farms’ output deviations from the maximum possible output; \( \sigma_v^2 \) denotes the deviations from the frontier due to the noise. \( \sigma_u^2 \) indicates the output deviations from the frontier which relates to the technical inefficiency. Thereby, the, \( \gamma \), parameter is the ratio of output deviations due to technical inefficiency to overall deviations, and the value of \( \gamma \) lies between zero and one. If \( \gamma = 0 \), it means that the output deviations from the frontier are not due to technical inefficiency \((\sigma_u^2 = 0)\). Thereby all deviations from the frontier are attributed to the noise effects \((\sigma_v^2 = \sigma_u^2)\). While \( \gamma = 1 \) means that all deviations from the frontiers are due to technical inefficiency \((\sigma_v^2 = 0, \sigma_u^2 = \sigma_v^2)\).

The technical efficiency for the i-th farmer is defined by the following equation:

\[
TE_i = \exp(-u_i) = \exp(-z_i\delta - w_i) \quad (6)
\]

The following hypotheses are tested in this study:

1. \( H_1: \gamma = \delta_0 = \ldots = \delta_q > 0 \): The first alternative hypothesis identifies that there is the presence of technical inefficiency effects in wheat production among the Afghan wheat farmers in the study area.
2. $H_1: \delta_1 = \delta_2 = \ldots = \delta_8 \neq 0$: The second alternative hypothesis indicates that the inefficiency effects in the wheat production are a linear function of age and schooling of the farmers, the literacy rate of the farm households, the farming experience of farmers, the size of the farm households, extension contacts, non-farm activities and cooperative membership of the farmers. Furthermore, it indicates that there are joint effects of these eight socio-economic or frim-specific explanatory variables on inefficiencies of the wheat production.

Field research design/ Methods of data gathering

This case study was carried out in Paktia province of Afghanistan in 2015 agricultural year. The province is located in the southeastern area of the country and divided into 13 districts. Gardez is the capital of the province and according to the estimation of the Central Statistics Organization (CSO), the population size of the province was 551987 people in 2015.

The empirical model and operational definition of the variables are stated as follows:

$$\ln y_i = \beta_0 + \beta_1 \ln \text{Land}_i + \beta_2 \ln \text{PILand}_i + \beta_3 \ln \text{Hlabor}_i + \beta_4 \ln \text{Tr.Labor}_i + \beta_5 \ln \text{Seed}_i + \beta_6 \ln \text{Ferti} + \beta_8 \ln \text{FYMi} + \nu_i - \mu_i \quad (7)$$

Where

- $y_i$ is the dependent variable which denotes the quantity of wheat harvested (in kilograms);
- Land is the total area of irrigated and unirrigated land (in hectares) cultivated by Wheat;
- PILand is the proportion of wheat land that is irrigated (irrigated wheat land / total wheat land);
- Hlabor is the total amount of human labor (in man-days$^1$), including both household’s members and hired laborers used in the production and harvesting of wheat;
- Trlabor is the total amount of tractor labor (in hours) including owned and rented tractor labor used for growing and harvesting of wheat;
- Seed represents the total quantity of wheat seed (in kilograms) sown;
- Fert is the total amount of DAP$^2$ and urea fertilizer (in kilograms) applied on land for wheat production;
- FYM is the total amount of farm yard manure (in trollies) applied on land for wheat production;
- $\beta$ is unknown parameter to be estimated;

$^1$ Working of one adult male for one day is equaled to one man-day. One day working of a female or a child is usually equaled to 0.75 or 0.50 man days, respectively. (Battese et al., 1996)

$^2$ Diammonium phosphate
\( \nu_i \) and \( \upsilon_i \) are the error components. \( \nu_i \), accounts for statistical noise and represents symmetric distribution of disturbance and assumed to be independently and identically distributed over the observation as \( N (0, \sigma^2_v) \), and independent of the \( u_i \) which is a non-negative random variable and assumed to account for technical inefficiency in production and often assumed to be independently and identically distributed, such that \( u_i \) is obtained by truncation (at zero) of the normal distribution with mean, \( z_i \delta \), and variance, \\

The technical inefficiency effects \( (u_i) \) are defined as:

\[
\begin{align*}
    u_i &= \delta_0 + \delta_1(Age_i) + \delta_2(Schooling_i) + \delta_3(HHLiteracy_i) + \delta_4(Experience_i) + \delta_5(HHSize_i) + \\
    &\quad \delta_6(ExContact_i) + \delta_7(NFActivity_i) + \delta_8(Coop. Membership_i) + w_i
\end{align*}
\]

Where \( i \) is the subscript i here also refers to the i-th farm household; \\
\( u_i \) are the non-negative technical inefficiency effects; \\
\( Age \) represents the age of household’s head (in years); \\
\( Schooling \) denotes the years of formal schooling of the household’s head; \\
\( HHLitracy \) represents the literacy rate of the household or it shows the %age of the household’s members who can read and write; \\
\( Experience \) denotes the years of farming experience of the household’s head; \\
\( HHSize \) is the total number of household’s members; \\
\( ExContact \) denotes the number of meetings of household’s head with the extension office concerning the wheat cultivation; \\
\( NFActivity \) is a dummy variable equal to one if the household’s head has a further job beside of farming activities, zero otherwise; \\
\( Coop. Membership \) is a dummy variable equal to one if the farm household has a membership of an agricultural cooperative, zero otherwise; \\
\( w \) is a random variable that is defined by the truncation of the normal distribution with zero mean and variance, \( \sigma^2_u \), such that the point of truncation is \(-z_i \delta\) that is, \( w_i \geq -z_i \delta \). \\
\( \delta \) are unknown parameters to be estimated; \\
The output and all the inputs are transformed to their corresponding log values in estimating the production function. As the log value of zero is undefined, for the variables out of which production is possible (Fertilizer and FYM) zero values in the data set are changed to nearly zero (0.000001) value before transforming the data to its log form.
**Results**

The summary statistics of the variables used in the study with respect to their mean standard deviation, minimum, and maximum values are presented in table 1.

**Table 1: Summary Statistics for Variables Used in the Study**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample Mean</th>
<th>Sample Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat output (in kilograms)</td>
<td>1387.3</td>
<td>1160.25</td>
<td>56</td>
<td>8400</td>
</tr>
<tr>
<td>Land operated (in hectares)</td>
<td>1.11</td>
<td>1.04</td>
<td>0.10</td>
<td>7.40</td>
</tr>
<tr>
<td>Proportion of the operated land that is irrigated</td>
<td>0.63</td>
<td>0.34</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Human labor (in man-days)</td>
<td>35.06</td>
<td>23.39</td>
<td>5</td>
<td>120</td>
</tr>
<tr>
<td>Tractor labor (in hours)</td>
<td>15.88</td>
<td>12.07</td>
<td>1.5</td>
<td>66</td>
</tr>
<tr>
<td>Seed (in kilograms)</td>
<td>138.67</td>
<td>97.33</td>
<td>17.5</td>
<td>659</td>
</tr>
<tr>
<td>Fertilizer (in kilograms)</td>
<td>141.2</td>
<td>124.39</td>
<td>0</td>
<td>600</td>
</tr>
<tr>
<td>FYM (in trollies)</td>
<td>2.69</td>
<td>3.89</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Age of farmer (in years)</td>
<td>44.33</td>
<td>12.13</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>Schooling of farmer (in years)</td>
<td>4.3</td>
<td>5.18</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Households literacy rate (in %)</td>
<td>30.98</td>
<td>18.56</td>
<td>0</td>
<td>88.9</td>
</tr>
<tr>
<td>Farming experience (in years)</td>
<td>19.2</td>
<td>10.9</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>Household Size (in number of household members)</td>
<td>18.4</td>
<td>10.04</td>
<td>6</td>
<td>70</td>
</tr>
<tr>
<td>Extension contact (in number of meetings)</td>
<td>0.71</td>
<td>2.6</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Dummy for non-farm activity (=1 if yes; 0 otherwise)</td>
<td>0.76</td>
<td>0.43</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Dummy for cooperative membership (=1 if yes; 0 otherwise)</td>
<td>0.1</td>
<td>0.30</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sample size</td>
<td></td>
<td></td>
<td></td>
<td>122</td>
</tr>
</tbody>
</table>

Source: own computation (2016)

As shown in table 1, the average wheat output of the sampled farm households was 1387.3 kg with a range between 56 kg and 8400 kg. Considering the mean value of the sample household...
size (18.4), it indicates that on average the annual per capita wheat production for these households was 75.4 kg, is nearly half the amount of the annual per capita wheat consumption.\(^3\)

The average operated land was 1.1 ha, which confirms that the farmers involved were smallholders. The average used amount of human labor was about 35 man-days and of tractor labor was recorded approximately 16 hours.

On average, the amounts of seed and fertilizer (DAP and urea) used in the wheat farms were about 139 kg and 141 kg, respectively. The mean amount of farmyard manure used was 2.69 tractor trollies.

The average age of the farmers was about 44 years. 48% of the farmers have attended formal schooling, and the average number of the sampled farmers’ schooling was about 4 years. The average literacy rate of the households was about 31%. The average of farming experience was 19 years, and the average of household size was about 18 members.

Almost 14% of the farmers had contacted to the extension offices, and the average number of meetings with extension office was about 0.7. 76% of farmers were occupied in non-farming activities besides the farming. 10% of the farmers have membership of the agricultural cooperatives. The sample size was 122 farm households.

The average wheat yield per hectare (ha) in the sampled area was 1255.3 kg in which the average yield of irrigated wheat and rain-fed wheat was 1683 kg / ha and 530.4 kg / ha, respectively. This wheat productivity is much lower comparing to world average (3 tons/ha) and Germany average (7.9 tons/ha).

The stochastic production frontier defined by equation 7 for the sampled farmers estimated as follows:

\[
\ln y = 6.205 + 0.604 \ln(\text{Land}) + 0.193 \ln(\text{PILand}) + 0.224 \ln(\text{Hlabor}) + 0.151 \ln(\text{Tlabor}) \\
+ 0.086 \ln(\text{Seed}) - 0.018 \ln(\text{Fert}) + 0.006 \ln(\text{FYM}) \\
\]

\[(9)\]

The coefficient for wheat land (ha) is 0.604, significant at less than 1% level of significance, indicates that 1% increase in the wheat area increases the wheat production by 0.604%.

The coefficient for the proportion of irrigated land is 0.193, and is significant at less than 1% level. Which indicates that 10% increase in this proportion will increase the total quantity of wheat production by 1.93%. These findings are in line with those of Abedullah et al. (2007), Hassan and Ahmad (2005), Battese and Coelli (1995) and Bettese and Broca (1997).

The coefficient of human labor (man-days) is 0.224 and significant at 10% level of significance. The coefficients of tractor labor (hours) and seed (kgs) are 0.151 and 0.086, respectively, but statistically insignificant. The coefficient of the fertilizer (kilograms) is -0.018. This unexpected result is not because of its intensive use. It might be either due to the poor quality of the fertilizer.

\(^3\) According to the World Bank data the annual per capita wheat consumption in Afghanistan is 160 Kgs (see The World Bank, 2014, p. 11).
or might be due to the water shortage, an improper combination of DAP and urea, continuous usage of only these two types of fertilizer and using it in an inappropriate time. Shafiq and Rahman (2000) estimated the similar effect of fertilizer on cotton production, and Backsh et al. (2007) estimated the similar effect of fertilizer on a bitter gourd in Pakistan. The coefficient for the farm yard manure (Trollies No.) is positive but statistically insignificant. This result is in line with Hassan and Ahmad (2005).

Table 2: Maximum Likelihood Estimates for Parameters of the Stochastic Frontier and Inefficiency Model for Wheat Farmers in Paktia Province of Afghanistan

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter</th>
<th>Coefficient</th>
<th>Standard-error</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stochastic frontier</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>$\beta_0$</td>
<td>6.205</td>
<td>0.818</td>
<td>7.582***</td>
</tr>
<tr>
<td>Ln(Land)</td>
<td>$\beta_1$</td>
<td>0.604</td>
<td>0.154</td>
<td>3.919***</td>
</tr>
<tr>
<td>Ln (PILand)</td>
<td>$\beta_2$</td>
<td>0.193</td>
<td>0.044</td>
<td>4.410***</td>
</tr>
<tr>
<td>Ln (Hlabor)</td>
<td>$\beta_3$</td>
<td>0.224</td>
<td>0.115</td>
<td>1.948*</td>
</tr>
<tr>
<td>Ln (Tlabor)</td>
<td>$\beta_4$</td>
<td>0.151</td>
<td>0.103</td>
<td>1.468</td>
</tr>
<tr>
<td>Ln (Seed)</td>
<td>$\beta_5$</td>
<td>0.086</td>
<td>0.153</td>
<td>0.560</td>
</tr>
<tr>
<td>Ln (Fert)</td>
<td>$\beta_6$</td>
<td>-0.018</td>
<td>0.011</td>
<td>-1.667*</td>
</tr>
<tr>
<td>Ln (FYM)</td>
<td>$\beta_7$</td>
<td>0.006</td>
<td>0.006</td>
<td>1.049</td>
</tr>
<tr>
<td>Inefficiency model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>$\delta_0$</td>
<td>1.919</td>
<td>0.905</td>
<td>2.121**</td>
</tr>
<tr>
<td>Age</td>
<td>$\delta_1$</td>
<td>-0.028</td>
<td>0.026</td>
<td>-1.081</td>
</tr>
<tr>
<td>Schooling</td>
<td>$\delta_2$</td>
<td>-0.067</td>
<td>0.042</td>
<td>-1.582</td>
</tr>
<tr>
<td>HHLiteracy</td>
<td>$\delta_3$</td>
<td>-0.004</td>
<td>0.010</td>
<td>-0.407</td>
</tr>
<tr>
<td>Experience</td>
<td>$\delta_4$</td>
<td>-0.024</td>
<td>0.032</td>
<td>-0.745</td>
</tr>
<tr>
<td>HHSize</td>
<td>$\delta_5$</td>
<td>0.028</td>
<td>0.015</td>
<td>1.821*</td>
</tr>
<tr>
<td>ExContact</td>
<td>$\delta_6$</td>
<td>-0.204</td>
<td>0.119</td>
<td>-1.714*</td>
</tr>
<tr>
<td>NFActivity</td>
<td>$\delta_7$</td>
<td>-1.353</td>
<td>0.448</td>
<td>-3.019***</td>
</tr>
<tr>
<td>Coop. Membership</td>
<td>$\delta_8$</td>
<td>1.390</td>
<td>0.494</td>
<td>2.812***</td>
</tr>
<tr>
<td>Variance parameters</td>
<td>$\sigma^2 = \sigma^2_v + \sigma^2_u$</td>
<td>0.768</td>
<td>0.203</td>
<td>3.790***</td>
</tr>
<tr>
<td></td>
<td>$\gamma = \sigma^2_v / \sigma^2$</td>
<td>0.913</td>
<td>0.048</td>
<td>19.068***</td>
</tr>
</tbody>
</table>

Log likelihood function   -80.1321

*** significant at 1% level, ** significant at 5% level, * significant at 10% level

Source: Own Computation (2016).
Since the sum of the coefficients for the estimated production function is greater than one (\(\sum_{n=1}^{\beta_n} = 1.246 > 1\)), it exhibits increasing returns to scale, which means if the inputs are increased by 1%, then the wheat output is increased by more than 1% (1.25%).

The inefficiency model defined by equation 8 for the sampled wheat farmers has been estimated through maximum likelihood estimates as follows:

\[
u = 1.919 - 0.028Age - 0.067Schooling - 0.004HHLiteracy - 0.024Experience + 0.028HHSIZE - 0.204ExContact - 1.353NFActivity + 1.390Coop.Membership\tag{10}
\]

The estimated coefficients of the socio-economic or/and firm-specific variables in the inefficiency model are of particular interest to this study. The age coefficient is negative, which indicates that the older farmers are more technically efficient than the younger ones. However, the relationship is weak and not significant in the desired significance level. This result is in line with Hasan and Islam (2010), Hassan and Ahmad (2005) and Battese, Malik and Gill (1996).

The coefficients of the farmer’s schooling and literacy rate of the households are insignificant it might be due to poorer quality of the education and teaching system in the area. This finding is in line with Battese et al. (1996) and Battese and Coelle (1993).

The coefficient of farming experience is negative for the wheat farmers. This negative sign indicates that technical inefficiency decreases with the increase of farming experience. This result is consistent with Ali and Khan (2014) and Binuomote et al. (2008).

The coefficient for household size is positive and significant at 10% level of significance. This implies that the wheat farmers with larger size of household to be more technically inefficient than farmers whose household size is smaller. This finding agrees with Effiong (2005) and Idiong (2006) who reported that this result might be due to underutilization of labor.

The coefficient for the extension contact is negative and significant at 10% level, which implies that increased extension services to farmers tend to increase technical efficiency in wheat production. The significance of extension in this study corroborates the findings of Amaza et al. (2006).

The coefficient for non-farm activity is negative and significant at less than 1% level, which indicates that the employed farmers in non-farm activity were technically more efficient than farmers who were busy only in farming activates. Such positive association between non-farm activity or off-farm income and technical efficiency is also reported in other studies by Abebe (2014) and Rizov et al. (2001).

The coefficient of cooperative membership is positive and significant at 1% level. This unexpected result indicates that the farmers who had the membership of cooperative were more technically inefficient than farmers who had not membership of any cooperative. This result might be the poor organization and management of the cooperatives. This finding is in consonance with the work of Daniel et al. (2013).
Finally, the parameter, $\gamma$, is estimated to be 0.913, which is statistically significant at less than 1% level.

Generalized likelihood ratio test\(^4\) of null hypotheses is presented in table 3. The first null hypothesis, specifies that the inefficiency effects are absent from the model, which is strongly rejected. The second null hypothesis, specifies that the inefficiency effects are not a linear function of age and schooling of the farmers, literacy rate of the farm households, farming experience of the farmers, size of the farm households, extension contacts, non-farming activities and cooperative membership of the farmers, which is also strongly rejected.

**Table 3: Tests of Hypotheses for Parameters of the Inefficiency Frontier Model for Wheat Farmers in Paktia Province of Afghanistan**

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Log likelihood Function</th>
<th>Test Statistic</th>
<th>Critical Value</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_0 : \gamma = \delta_0 = \ldots = \delta_8 = 0$</td>
<td>-115.387</td>
<td>70.51</td>
<td>18.307</td>
<td>Reject</td>
</tr>
<tr>
<td>$H_0 : \delta_0 = \delta_2 = \ldots = \delta_8 = 0$</td>
<td>-99.061</td>
<td>37.50</td>
<td>15.507</td>
<td>Reject</td>
</tr>
</tbody>
</table>

Source: Own computation (2016)

The mean TE of the farmers was about 64% with a range between 6% and 93%. Figure 2 denotes that the TE distribution of the farmers is skewed to the left-hand side, and the TE scores for most of the farmers are on the upper side of the sample mean.

**Figure 2: Distribution of Technical Efficiency Estimates**

Source: Own Computation (2016)

\(^4\) The likelihood-ratio test statistic is calculated as, $\lambda = -2\{\log[Likelihood(H_0)] - \log[Likelihood(H_1)]\}$, which has approximately chi-square distribution with parameter equal to the number of parameters assumed to be zero in the null hypothesis, $H_0$. 
Discussion & Conclusion

The hypotheses test identified that the inefficiency effects are present in wheat production significantly, which confirms the appropriateness of using stochastic frontier production function over conventional production function. According to Gamma value (γ= 0.913), it can be interpreted that 91.3% of the variation in wheat output was due to the presence of technical inefficiency in wheat production. The tests further indicate that this inefficiency is significantly related to the joint effects of age and schooling of farmers, literacy rate of the farmer’s household, farming experience of the farmers, size of the farmer’s household, extension contacts, non-farming activities and cooperative membership of the farmers. However, individually the effects of age, schooling, household literacy rate and experience of farmers were not statistically significant on the desired significance level. The insignificance of the schooling and literacy rate might be due to poor quality of education in the study area. The signs for these estimated coefficients were negative as expected, with the exception of the positive signs for household size and cooperative membership. The possible reasons for these unexpected result might be underutilization of labor and poor organization and management of the cooperatives.

The estimated frontier production function for the farmers shows increasing returns to scale, and indicates that 1% increase in the inputs results 1.25% increase in the output.

The total land under wheat crop, the proportion of irrigated land, human labor, and fertilizer had significant effect on wheat production. However, the effect of fertilizer was negative on production, which might be due to its poor quality or it may have some other reasons that require further investigation. The coefficients of seed, tractor labor and farmyard manure were found statistically insignificant.

The predicted value of TE ranges from 6 to 93 % with the mean of 64 %. It indicates that on average, the wheat farmers have achieved 64 % of their potential output, and the average loss in wheat production due to technical inefficiency is 36 %, which varies between 7% and 94% among the wheat farmers. This wide variation in TE can be interpreted that most of the farmers are still using their inputs inefficiently in the production process and there still exists opportunities for increasing 36% of wheat production at the existing level of inputs and current technology by operating at fully technically efficient level.

For better studying of the determinants of efficiency of wheat production, additional research is required to be conducted in the area. Other explanatory variables can be included in the empirical model and beside the TE, allocative and economic efficiency of wheat production can be studied in Paktia province as well as in other parts of the country.
References


