Analysis of technical Efficiency of traditional wheat farming in Fezzan region, Libya

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Although the efforts to enhance the productivity of wheat in Libya, it is still low and there is no improvement in wheat yield over the last decade indicating the usage of inputs in process of production is not efficient. Though some farms use modern methods in planting wheat, nevertheless a lot of wheat farmers are still using the traditional method of production. This paper aims to examine the technical efficiency of traditional wheat farming in Fezzan region, Libya as well as factors affecting technical inefficiency. A set of questionnaires was used to obtain data from 149 traditional wheat farmers selected by using a simple random sampling technique. The slack based data envelopment analysis model (SBM) was used to estimate technical efficiency and fractional regression model to determine factors response for inefficiency. Results showed that, the average technical efficiency of the farms was 0.69 indicating that farmers were operating at a low level of technical efficiency. This indicates that there is a need to improve technical efficiency by about 0.31 with the same level of inputs. The results of slack analysis revealed that the total inputs used by the traditional farmers would be reduced by 42 kg/ha for DAP, 58 kg/ha for seed, 14kg/ha for urea, 33 kg/ha for organic fertilizers and 12.9 man-days/ha for labour.

Keywords: Technical Efficiency, Slacks-Based Measure Model, fractional regression model, tradition wheat farms.

INTRODUCTION

In Libya wheat farmers are still using traditional method of wheat farming though some have reverted to modern farming systems. The traditional farm is a type of farms that use traditional technique and their farming planned is based around mixed crops that complement to one another. Moreover, Crop timing and farm management are based on traditional experience and thus one of the features of these traditional farms is low crop yield. Wheat is one of the most important strategic food crops for humans and animals in Libya. It is called the first food crop. Wheat flour is used in the manufacturing of bread, pasta, biscuits and other industries related to wheat. Cultivated areas of wheat in Libya about 165000 hectares in 2017 and quantity produced about 200,000 tons in 2017 with average yield about 1.25 tons /ha (USDA, 2017). Libyan citizens consume large quantity of wheat; the average quantity consumed about 1600000 tons in 2017. (USDA, 2017) about 329.32 kg/ capita. However, current production covers about 27% of needs of the population (Elfagehia, 2014) . Although wheat farming has been spread among districts of Libya, the productivity of wheat is low and there is no improvement during last period indicating that there are problems related to production.

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One major solution to improve production is to enhance productivity which can be reached by rational usage of inputs and improvement on the skills of wheat farmers on growing management and planting systems. Thus, it is inevitable to estimate efficiency of wheat farms and evaluate the effective solution in short term to increase wheat productivity. In addition, determining input factors that effect on efficiency is essential to improve productivity. The Fezzan region located in southern west Libya provides about 53% of total wheat production in Libya. Recently, Water became the most limiting factor for agriculture in Libya and the underground water is the only non-renewable source of water. Fezzan region is rich in underground Water and it is the main reason that made government to encourage local farmers in this region to plant wheat in order to increase its production. Therefore, Wheat farming became a feature of farming in the south Libya in recent times.

Traditional farms which use old machines with average area of about 6 hectares, represent about 65% of total number of farms, therefore improving the productivity of traditional farms will help to improve production of wheat. Based on this background, this study aims to estimate technical efficiency of traditional farms system, in order to help farmers to understand the use of inputs and manage the farm accordingly during the production cycle and the possible adjustment in order to increase efficiency in the future.

LITERATURE REVIEW

Technical efficiency is one of the most significant factors of farming business for efficient use of resources; it is defined as the ability to achieve a high level of output given a same level of current inputs (Coelli, Rao, O'Donnell, and Battese, 2005). According to (Sadoulet and De Janvry, 1995), technical efficiency is a comparison between observed value of inputs and optimal value of outputs of production units. This comparison provides the ratio of observed to that of maximum potential output which can be reached from the given inputs.

The technical efficiency decomposes into pure technical efficiency and scale efficiency. Pure Technical Efficiency is regarding the capability of farmers to use the given resources, while the scale efficiency is related with exploiting scale economies by operating at constant returns to scale. Many researchers spent several years for enhancement and elaboration of the ways to measure efficiency. The methods used for assessing efficiency have a long history and it started with the works of (Farrell, 1957). Provided the concept of efficiency before it using by Charnes, Cooper and Rhodes (1978) by formulating and solving a linear programming under the assumption of constant returns to scale, which became known as Data Envelopment Analysis (DEA). (Banker, Charnes, and Cooper, 1984) extended the model to variable return to scale. The other public approach used for efficiency analysis is a parametric approach Stochastic Frontier Analysis (SFA) which proposed by (Aigner, Lovell, and Schmidt, 1977).

Many empirical studies have estimated the efficiency of various crops among different countries, number of literature review estimated technical efficiency of wheat production focused on the scale of farms.

Usman et al., 2016 used conventional DEA model to measure technical efficiency of wheat Farmers of district Layyah of Pakistan. The results found that mean technical efficiency was 0.84 and those farmers can decrease their inputs use by 16% and still produce the same level of output and he referred to the importance to promote the formal education of rural households to improve the technical efficiency thereby enabling farmers to make better technical decisions and helps them in allocating the inputs efficiently and effectively. In case of wheat farmers in Ethiopia, the situation was completely different.

Tiruneh and Geta (2016) analyzed technical efficiency of smallholder wheat farmers among different districts in Ethiopia. They observed that the average technical efficiency of the sampled farms was 57%. Their findings also show that sex, age and education level of the household head, livestock holding, group membership, farm size, fragmentation, tenure status and investment in inorganic fertilizers affect efficiency positively and distance to all weather affect negatively.

Bhatt and Bhat, (2014) also measured technical efficiency and farm size productivity - micro level evidence from Jammu and Kashmir. Their findings show that, large farms are higher technically efficient compared to small farm size categories. Equally, (Mburu, Ackello-Ogutu, and Mulwa, 2014) estimated technical efficiency and farm size Wheat farmers in Nakuru district, Kenya and discovered that mean technical efficiency of both small and large farmers were high about 85% and 91% for small and large farms respectively.

Hashmi, Kamran, Bakhsh, and Bashir, (2015) assessed technical efficiency of Wheat production in Southern Punjab, Pakistan found to be 73%. (Khanal, Maharjan, and Sapkota, 2012) found that, wheat farmers in Nepal were operating at 78% level of technical efficiency and those farmers could improve their performance by the good land quality and access to public irrigation thereby, agricultural policies should focus on the promotion of public irrigation scheme as well as land quality to improve the productivity. (Kalra, Mondal, and Sarangi, 2015) estimated the average technical efficiency of wheat farmers by 84%. However, the study pointed to the importance to the link between the output and the cost of inputs which were found to depend on the quality of inputs. Therefore, to improve the
productivity, farmers should obtain this good quality of inputs by state support.

Although, a lot of technical efficiency studies on wheat farms all over the world, however, rarely focused on TE and its determinants in Libya.

To achieve the objectives of the study, the study will apply DEA model to measure the technical efficiency of wheat production. The merit of DEA is that it does not need to put hypotheses (mathematical formula) for the function that links between dependent and independent variables as in case of stochastic frontier approach. Moreover, by using the slack-based data envelopment analysis (SBM), the efficiency estimates can be saved from outliers values thus the results will be more accurate. Thus, the SBM model gives better and more reliable results than SFA model that used translog function or Cobb-Douglas production function and the traditional DEA (Tone, 2001)

METHODOLOGY

This section includes the sampling method, data collection technique and the models used in data analysis.

Sampling method

This study was carried out in five states (Murzuq, Taragen, Wadiatba, Gdwa and Um Alaranb) which located in Murzuq area of the south of Fezzan region, Libya, during production period of 2014–15. Fezzan region (Sebha area) is located in the southwest of Libya with an area of 566 thousand kilometers cubes which represents 32% total area of Libya and it includes five states names Murzuq, Wadi al haya, Sebha, Wadi al shati and Ghat. Fezzan region occupying 53% of the total wheat production has the largest area under cultivation. Murzuq area is provided about 93% of the total wheat production in Fezzan region. (Department of statistics Libya. Finally, Sample farms were randomly selected from the study area using a simple random sampling technique.

Data Collection

Data were collected from the wheat producers by using a structured questionnaire administered to the selected wheat farmers in Fezzan region. This is because there is no available data on traditional farms super set from the Ministry of Agriculture, Data collected first from wheat farmers, using the method established by Yamane (1967) which given by:

\[
n = \frac{N}{(1 + Ne^2)}
\]

Where; \(N\) = Sample frame of the population). \(e =\) Sampling error at 5% (0.05). \(n =\) Sample size= 149 traditional wheat farms

Analytical Technique

Measuring technical efficiency

In this study we employed the Slacks-based measure (SBM) of efficiency by using DEA Frontier Software to measure technical efficiency of traditional wheat farmers as well as fractional regression model to measure the determinists of technical inefficiency. Although conventional DEA still be used to measure technical efficiency of crop production, it fails to provide an efficiency estimate that can help to determine the DMU’s performance. Nevertheless (Tone, 2001) proposed a slack-based measure of technical efficiency (SBM) which estimates efficiency scores that are unit invariant, monotone and reference-set dependent.

In the agriculture, farmers have ability to control on the inputs rather than the outputs, thus in this study, we apply input oriented slack based model to measure the technical efficiency and examine the values of input slacks. Moreover, The SBM model can be under variable return to scale (VRS) assumption or constant return to scale. According to (Coelli et al., 2005), the estimating technical efficiency using constant returns to scale (CRS) is only appropriate when all firms/farms are operating at an optimal scale. Thus this is the one reason why the variable returns to scale option was more appropriate for this study. Slack based model (input oriented) is defined by the linear program of the form:

\[
P_{in} = 1 - \frac{1}{m} \sum_{i=1}^{m} s_{i}^{-} \\
\text{s.t.} \\
x_{io} = \sum_{j=1}^{N} \lambda_{ij} x_{ij} + s^{-}, \quad j = 1, \ldots, m \\
y_{ro} = \sum_{j=1}^{N} \lambda_{ij} y_{ij} - s^{+}, \quad r = 1, \ldots, n \\
\lambda_{ij}, s^{-}, s^{+} \geq 0, \quad j = 1, \ldots, N
\]

Where

- \(P_{in} = TE\), \(S_{i} =\) input excess. \(s^{+}\) = output shortage. \(n =\) different type of \(y\) products. \(x_{io} =\) Value of inputs. \(m =\) number of inputs. \(y_{ro} =\) output set . \(\lambda =\) a non-negative vector.

Thus, the inputs and output variables used to estimate SBM above are as below:

- Wheat output/hectare (kg)
- Quantity of seeds kg/hectare
- Quantity of Ammonium phosphate. DAP /hectare (kg)
- Quantity of Urea kg/hectare
- Quantity of organic fertilizers by kg/ha
- Labour by (man-day/ha)

Dependent variable output represents total quantity produced by each farmer by kg/hectare (Yi). DAP, Urea and organic fertilizers represent total quantity per hectare. Quantity of seeds represent seeds planted by kg/ha. Labour include a total number of family and hired labour per production cycle by (man-day/ha).
Table 1: Definition of Variables used in fractional regression model

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>The dependent variable</td>
<td>technical inefficiency (1-TE)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>Age of farmers by year</td>
<td>Year</td>
</tr>
<tr>
<td>Member of cooperative</td>
<td>Dummy (1 = member, and 0 = otherwise)</td>
<td>Dummy</td>
</tr>
<tr>
<td>Education level</td>
<td>Years of education</td>
<td>Years</td>
</tr>
<tr>
<td>Household size</td>
<td>Number of the wheat farmer family</td>
<td>Number</td>
</tr>
<tr>
<td>Main occupation</td>
<td>Dummy (1 = farmer, and 0 = otherwise)</td>
<td>Dummy</td>
</tr>
<tr>
<td>Farm size</td>
<td>Size of farm by hectare</td>
<td>Hectare</td>
</tr>
<tr>
<td>Experience</td>
<td>number of years the farmer spent in farming</td>
<td>Year</td>
</tr>
<tr>
<td>Seed type</td>
<td>Dummy (1 = non improved seed, 0 = improved seed)</td>
<td>Dummy</td>
</tr>
</tbody>
</table>

Fractional regression model

To measure the sources of technical inefficiency in the second stage of DEA, generally, Ordinary least squares (OLS) and Tobit procedures are commonly used. Some of the literature reviewed apply Tobit model under the assumption that technical efficiency is ranged between 0 and 1 and the distribution is censored distribution not normally distributed when the distribution is censored, OLS will yield inefficient, inconsistent and biased estimates. However, (McDonald, 2009) argued that OLS regression model is the most appropriate because the dependent variable estimates (technical efficiency) are fractions and not generated by a censoring process. On the other hand, in (1996), Papke and Wooldridge explained that using the OLS method, many predicted values would fall outside the unit interval. Therefore, following some of the Reviewed literatures, for instance, (Ahmed 2017), (Gelan and Muriithi, 2012) this paper applies fractional regression model (FRM) by Papke and Wooldridge (1996) which developed direct models for the conditional mean of the fractional response in which the predicted value is the unit interval, using a quasi-maximum likelihood estimation (QMLE) to determine the source of technical inefficiency in which the dependent variable is the technical inefficiency scores (1-TE) and the model was estimated using STATA 14.

The analytic model can be derived and explained as follow:

\[ y' = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8 + \varepsilon \]

The socio-economic and farm-specific factors using in the fractional regression model were; The age of farmers is calculated by years and it is expected to have a positive effect on technical inefficiency. Variable of education level is calculated as years of schooling and it is expected to have a negative effect on technical inefficiency indicating that the more farmers are educated the less technically efficient are. On the other hand, the household size represents the number of wheat farmer’s family and it can be positively or negatively effect on technical inefficiency. The farmer’s main occupation is included in the model as dummy variable; 1 if respondent is farmer and he practices farm work in full time as a main source of income. 0 if respondent is not farmer and he depends on other work as main source of income.

Table 2: Descriptive Statistics of traditional wheat farms in Fezzan region

<table>
<thead>
<tr>
<th>Inputs</th>
<th>MIN</th>
<th>MAX</th>
<th>MEAN</th>
<th>S.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production (kg/ha)</td>
<td>400</td>
<td>2857.14</td>
<td>1981.21</td>
<td>525.03</td>
</tr>
<tr>
<td>Crop Area (ha)</td>
<td>2</td>
<td>12.5</td>
<td>6.46</td>
<td>2.64</td>
</tr>
<tr>
<td>Labor (man-day/ha)</td>
<td>34.62</td>
<td>87.56</td>
<td>56.84</td>
<td>23.29</td>
</tr>
<tr>
<td>Seed (kg/ha)</td>
<td>75.5</td>
<td>225</td>
<td>210.42</td>
<td>73.46</td>
</tr>
<tr>
<td>Urea (kg/ha)</td>
<td>156</td>
<td>250</td>
<td>200.67</td>
<td>17.78</td>
</tr>
<tr>
<td>Organic fertilizers (kg/ha)</td>
<td>152.8</td>
<td>234.75</td>
<td>115.60</td>
<td>49.32</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2015

The result of the findings in Table 2 above revealed the average size of farm allocated for wheat was 6.46 hectare with a maximum of 12.5 hectare and minimum about 2 hectares. The mean wheat productivity of traditional system was 1.9 ton/ha. The yield was gained by using 210.42 kg/ha of seed, 185.20 kg/ha of DAP, 200.67 kg/ha of Urea and 115.6 kg/ha of organic fertilizers.

Estimates of technical efficiency

The results of slack based model for technical efficiency revolved the average technical efficiency of traditional
wheat farmers were 0.69 with a low of 0.21 and a high of 1.0 indicating that farmers operate at low level of efficiency and they could decrease their input utilization, on an average by 31% and still produce the same level of output. The technical efficiency of the majority of sample farms less than 0.70 represents about 56% of sample farms and only 18% of farms having technical efficiency more than 90%. These results reflect the weak situation of traditional farming system. The low level of technical efficiency of traditional farming system is perhaps due to the traditional method that has been in use for quite sometimes for wheat planting. 

Table 3 summarizes technical efficiency of sample farms.

### Slack variables analysis

Slacks and targets of inputs were calculated in order to explain the chances for improving of inefficient farmers explained in Table 4. A slack variable represents the excess inputs used in the farm production process which mean inefficient use of the inputs.

Fertilizers are considered one of the most important factors to improve soil quality and production. The estimated average quantity of fertilizers slacks (DAP, Urea, Organic fertilizers) were quite high, perhaps due to the consideration that adding more quantity of fertilizers will lead to improve soil and production, ignoring the negative effect of high quantity of fertilizers on soil and production. farmers depend on their experience in adding quantity of fertilizers but the experience has to be improved and extension services is very important to disseminate the knowledge in order to change farmers' perspective, otherwise there will be wastage and losses in input used and profit respectively.

About 34% of farms have seed slacks, the possible reasons for this level of slack can be attributed to way of seeding in which farms sample depend on broadcast seeding by using traditional seed machine, other possible reason that farmers add extra quantity of seed Intentionally to covered up losses due to seeds eaten by bird.

Only 29% of sample farms have labour slack and average slack per hectare represent 12% from labour use, that could be due to excess family labour. Results also revealed that as farmers remove all slacks, the amount of inputs that can be saved will be 16809 kg/ha of DAP, 166.47 kg/ha of seed, 154.22 kg/ha of seed, 16.656 kg/ha of urea, 86.56 kg/ha of organic fertilizers and 48.53 man-day of labour. These results have significant impact for decision makers not only on their efficiency but also improve their profit.

### Technical Inefficiency Analysis

With regard to determination of the sources of technical inefficiency among sample farmers, Fractional regression model is applied and results are shown in Table 6. Generally, the parameters with a positive sign indicate increase in technical inefficiency, while a negative sign denotes a decrease in technical inefficiency.

Out of the eight variables used, five variables (experience, age, education, farm size and main occupation were found to affect have a significant effect on inefficiency

Age of farmers has a positive and significant effect on technical inefficiency indicating that older farmers are operating less efficiently than their younger counterparts. This result conform to the findings of (Boundeth, Nanseki,
Table 5: Fractional regression results of traditional wheat farms

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>z-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.0216254</td>
<td>.0063296</td>
<td>3.42</td>
<td>0.001*</td>
</tr>
<tr>
<td>Household size</td>
<td>-.0051023</td>
<td>.0174966</td>
<td>-.29</td>
<td>0.771</td>
</tr>
<tr>
<td>Education level</td>
<td>-.4521428</td>
<td>.0847291</td>
<td>-5.34</td>
<td>0.000*</td>
</tr>
<tr>
<td>Member of cooperative</td>
<td>.0046964</td>
<td>.0823338</td>
<td>0.06</td>
<td>0.955</td>
</tr>
<tr>
<td>Main occupation</td>
<td>-.3450489</td>
<td>.0881087</td>
<td>-3.92</td>
<td>0.000*</td>
</tr>
<tr>
<td>Farm size</td>
<td>-.0411042</td>
<td>.0156445</td>
<td>-2.63</td>
<td>0.009*</td>
</tr>
<tr>
<td>Years of experience</td>
<td>-.0172638</td>
<td>.0092167</td>
<td>-1.87</td>
<td>0.061**</td>
</tr>
<tr>
<td>Seed type</td>
<td>.0303433</td>
<td>.0816892</td>
<td>0.37</td>
<td>0.710</td>
</tr>
<tr>
<td>Cons</td>
<td>-.7126395</td>
<td>.3524283</td>
<td>-2.02</td>
<td>0.043</td>
</tr>
</tbody>
</table>

(*=1%, **5%, ***10% level of significance)

Table 6: The relationship between older-fulltime farmers and technical inefficiency

| Technical inefficiency | Coef.  | S. E   | Z     | P>|z| | [95% Conf. Interval] |
|------------------------|--------|--------|-------|--------|----------------------|
| Old –full time farmers | .41477 | .15462 | 2.68  | 0.007  | .11171 -.71783       |
| Cons                   | -.97498| .10315 | -9.45 | 0.000  | -1.1771 -.77280      |

Source: Field Survey, 2015

and Takeuchi, 2012) and (Iliyasu, Mohamed, and Terano, 2016). The possible explanation for this is that, older farmers that represent more than 36% of sample farmers depend on their experience generated during a long time and most of them inflexible to change their knowledge and methods about wheat farming.

Years of farming experience is negative and statistically significant at 1%level significance indicating that farmers with more experience tend to be more efficient than with less experience. The result is in line with the finding of (Bhatt and Bhat, 2014) and (Abdallah and Abdul-Rahman, 2017). The positive sign of age and the negative sign of experience reflect that age has a positive effect on technical inefficiency while experience has a negative one. Older farmers are more technically inefficient than younger farmers this means that an increase in age by one year will have corresponding increase in technical inefficiency by 0.216 units.

The negative revealed by experience on the other hand indicates that, the more experience farmers are the less efficient they are technically.

The results of age and experience are quite unusual, but the possible explanation for that is older farmers start to practice their farm work at the retirement age that lead them to become less experience although the advanced age. The correlation between age and experience in sample farms is 0.196 and the VIF= 1. Indicating that, the correlation between age of farmers and the years of experience is weak. To prove that, we crosstab the old full-time farmers against technical inefficiency by use fractional regression model and the results are shown in following Table 6.

First, we categorized farmers into two groups based on the retirement age which is 50 years, group one farmers are less than 50 years and group two farmers are 50 and above. Then we chose only the full-time farmers (56 farmers). Finally, we use the dummy variables of 1, if the farmer joined farming after retirement and 0, if the farmer is the one that toiled the land since they were young and both of those farmers group are full – time farmers. The results show that there is a positive relationship between old- full time farmers and technical inefficiency indicating that those farmers who are joining late as farmers are more technically inefficient than who join farm work at the early age. According to this result, an inference will be drawn that the older retired officers who become farmers at old age are not efficient and the inefficiency increase increases as more people became farmers at old age.

The effect of education on technical inefficiency is negative and statistically significant indicating that educated farmers are more technically efficient because they can improve their skills, knowledge and agricultural information about inputs usage efficiently, This result is in line with the results of (Tiruneh and Geta, 2016).

The negative sign on the main occupation variable indicates that farmers who are practice farm work in full-time were more technically efficient than those who are not farmers and practice farm work in part-time. Farmers who practice farm work in full-time take farming as the main source of income and so they put more effort to make their work economically and profitable.

Farm size has a negative effect on technical inefficiency and statistically significant; the bigger the size of the farm, the lesser its inefficiency.

Seed type has a positive effect on technical inefficiency but statistically insignificant reflecting that there is no meaningful effect on technical efficiency if farmers use improved or non-improved seeds. Finally, member of cooperative increase the technical inefficiency but statistically insignificant.
CONCLUSION

Slack based DEA model is used in this study to analyze the technical efficiency of a sample of 149 traditional wheat farmers located in Fezzan region, Libya. These farms have an average efficiency score about 69 % and about 47% of those farmers whose technical efficient are less than 0.50. The study observed there is need to train the traditional wheat farmers on how to use inputs so as to enable them improve their level of efficiency through better use of farm inputs. The study also showed that technical efficiency of wheat farmers varied due to the presence of technical inefficiency effects in the wheat production represented in five variables, namely: age, experience, farm size, education level and main occupation. Based on these results, Farmers of wheat are hereby requested to improve their skills and knowledge on the use of farm input to enhance the productivity of wheat. Moreover, this paper estimated technical efficiency of traditional wheat production by examining five variables in SBM; future studies should add other variables like machine hours to improve the model.

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