Analysis of Price and Production Efficiency of Sesame: Dual Cost, Stochastic Frontier and Tobit Model Approach
(Study Sesame Sesamum Indicum L Production in Babogambel District of Ethiopia)

Hika Wana

Department of Agricultural Economics, Wollega University
Shambu, Wollega Zone, Oromia Region, Ethiopia

Abstract: The aim of the study was to measure the levels of price and production efficiencies of sesame producers and identify factors affecting them in Babogambel district of Oromia Region, Ethiopia. The study was based on cross-sectional data collected in 2016 production season from 124 randomly selected farm households. Stochastic production frontier model by dual cost method was used to estimate price and production efficiency levels, whereas Tobit model was used to identify factors affecting efficiency levels. Accordingly, the mean price and production efficiencies of sample households were 72.95% and 53.95%, respectively. The results indicated that there was substantial amount of inefficiency in sesame production in the study area. Land, labor and oxen were the variables that positively affected the production of sesame. Results of the Tobit model revealed that experience in sesame production, family size and extension contact affected price efficiency negatively and significantly but soil fertility and education level affected price efficiency positively and significantly. Education level, experience in sesame production and soil fertility affected production efficiency positively and significantly. However, extension contact affected production efficiency negatively and significantly. Results indicate that there is a room to increase the efficiency in sesame production of the study area. Therefore, government authorities and other concerned bodies should take into consideration the above mentioned socio economic and institutional factors to improve the productivity, cost effectiveness and production of sesame in the study area.

Keywords: Babogambel, price efficiency, production efficiency, stochastic, tobit.
1. INTRODUCTION

Sesame is produced in around 75 countries of the world. The production of sesame seeds in the world is dominated by a few countries that lie in the African and Asian continents. The top five sesame producing countries are China, India, Myanmar, Sudan, and Tanzania. Ethiopia is the second top exporter of sesame seed next to India (IEA, 2016). Ethiopia is one of the centers of biodiversity for several oilseeds which can be considered as specialty high value seeds on the international markets. The major sesame seed producing areas in the country are Tigray region, Western and North Western zones, (especially Humera, Tsegede and Welkaite districts); Amhara region, North Gondar zone (specifically Metema, Kuara, West Armachiho, Tach Armachiho and Tegede districts); Oromiya region: Western Wollega (Oda, SirbaAbay, Jarso, Babo-gembel, Gimbi and Manasibu and the surroundings), Eastern Wollega (Gidayana, Diga and Gutin), Horo-guduru (Abedongoro), Keluem Wollega, Jima as well as Illubabor zones; and Benshangul Gumuz region (Assossa, Sherkole, Homsha, Mengie, Kumruk, Kamashi, Aqelo Meti, Yaso, and surroundings) (ECX, 2015). Despite the high oil seed crop productivity variations across the region, the growth rate of productivity is significantly increased within each region except sesame during the same period.

The annual average oil seed crop productivity growth rate was: Neug 11.12%, 8.61% & 4.81% Linseed 12%, -8.45% & 9.36% and Sesame 0.01%, 5.62% & -1.04% in Tigray, Amhara and Oromia regions respectively, Sesame crop productivity shows the list productivity growth among the other oil seed crops in the last ten years in all three major oilseed growing regions of Ethiopia (CSA, 2015). According to CSA (2015), in 2013/14 production year, sesame covered 299,724 ha of land at national level. The total production of sesame in the same year at national level was 2.2 million qt. In the same year, the total productivity of the crop at national level was 7.35qt per ha. From 2013/14 to 2014/15 production season, production of sesame has increased by 27.27% but productivity has decreased by 6.53% at national level.

The same source indicated that in Oromia region, the total area covered by sesame in the production year of 2013/14 was 48,182ha and 379,240qt of sesame have been produced with the productivity of 7.87qt per ha. From 2013/14 to 2014/15, production of sesame has increased by 41.3% but productivity has decreased by 6.6% in Oromia region. Even though there is an effort by some research centers in Ethiopia in variety development and agronomic practices, surprisingly from 1995/96 (1988 E.C) to 2014/15 (2007 E.C) sesame productivity was drastically reduced from 9.8qt per ha to 6.87qt per ha. This implies the research attention that has been given to improve this crop is not comparable with the contribution of this crop in Ethiopian economy for long period of time. Therefore, possible ways should be sought to improve the efficiency of the farmers in Ethiopia.

Babogambel district, which is one of the districts of West Wollega Zone, is known by oilseed production specially sesame and Niger. Out of the total 86400 hectares of land in the district, land used for cultivation occupies 41 percent of it. As sesame is concerned for this study, it occupies 12.1 percent of the total cultivable land of the district. In 2014/15 production year, the total production and productivity of sesame in the district was 27,860.95 qt and 7.15 qt/ha respectively (BDARDO, 2015). Among the oil crops of Ethiopia, sesame seed commands a leading position because it is highly adapted to arid and semiarid low land environment and yields well. Accordingly, sesame is the major oilseeds crop in the country in terms of exports next to coffee, accounting for over 85 percent of the value of oilseeds exports (MoARD, 2015). However, the Ethiopian Statistical Agency report of 2014 indicated that the sesame productivity level was 7.35 and 7.87 quintals per hectare at national level and in Oromia region respectively. However, it is understood that in 2015 the productivity level of sesame in national and regional level were decreased to 6.87 and 7.3 quintals per hectare respectively (CSA, 2015).

Despite of the fact that Babogambel district has high potential for sesame production, the yield has been 7.15 quintals per hectare which is below regional average in 2014/15 production season. Its production only increased by .05% and 0.02% in 2014 and 2015, respectively (BDARDO, 2015). This shows as production and productivity of the crop remain in a question for a long period of time in Ethiopia in general and in study area, Babogambel in particular. The general objective of this study was therefore, to
analyze production efficiency of smallholder farmers in the production of sesame in Babogambel district of Western Wollega Zone. Hence, the study was undertaken with the following specific objectives: To estimate the level of price and production efficiencies of sesame production in the study area; and to identify factors affecting price and production efficiencies in the study area.

2. LITERATURE REVIEW
Analytical Framework
Models of efficiency measurement provides analytical framework for analysis of frontier in the economic literature. There has always been a close link between the measurement of efficiency and the use of frontier functions. Different techniques have been utilized to either calculate or estimate these frontier functions. The production frontier, or the maximum potential output of a completely efficient DMU, cannot be observed directly and a wide range of techniques has been developed to overcome this problem, the foremost techniques being non parametric (DEA) and parametric (DFA and SFA). The selection of specific frontier model depends upon many considerations such as the type of data, cross-sectional or panel data, the underlying behavioral assumptions of firms, the relevance to consider and extent of noise in the data and the objective of the study. The following reviews focus mainly on these two broad categories of frontier models.

Non-parametric frontier models
The mathematical programming approach to the construction of frontiers and the measurement of efficiency relative to the constructed frontiers goes by the descriptive title of data envelopment analysis. It truly does envelop a data set; it makes no accommodation for noise, and so does not “nearly” envelop a data set the way the deterministic kernel of a stochastic frontier does. Moreover, subject to certain assumptions about the structure of production technology, it envelops the data as tightly as possible (Fried et al., 2008).

Like the econometric approach, the programming approach can be categorized according to the type of data available (cross-section or panel), and according to the types of variables available (quantities only, or quantities and prices). With quantities only, technical efficiency can be estimated, but if quantities and prices data are available economic efficiency can be estimated and decomposed into its technical and price (allocative) components. DEA involves the use of linear programming methods to construct a non-parametric piece-wise surface (or frontier) over the data. Efficiency measures are then calculated relative to this surface. Charnes et al. (1978) proposed a model that had an input orientation and assumed constant returns to scale (CRS). An input-oriented CRS model of DEA can be presented as:

Max_{\mu,\nu}(\mu' y_i),
Subjected to: \nu' x_i = 1
\mu' y_j - \nu' y_j = 0, \quad j = 1, 2, 3 \ldots N
\mu,\nu \geq 0

Where \mu is an Mx1 vector of output weights and \nu is a Kx1 vector of input weights. \nu' x_i = 1 is the restriction to avoid infinite solution to the problem. Using the duality in linear programming, one can derive an equivalent envelopment form of this problem:

Min_{\theta,\lambda},
Subjected to: - y_i + Y\lambda \geq 0
\theta x_i - X\lambda \geq 0,
\lambda \geq 0,

Where, \theta is a scalar and \lambda is an Nx1 vector of constants. The value of \theta will be the efficiency score for the \textit{i}th firm. It will satisfy \theta \leq 1 with a value of 1 indicating a point on the frontier and hence a technically efficient firm Farell (1957) and Coelli et al.(2005).
Parametric frontier models

The parametric approach is naturally subdivided into deterministic and stochastic models. Deterministic models envelope all the observations, identifying the distance between the observed production and the maximum production, defined by the frontier and the available technology, as technical inefficiency. On the other hand, stochastic approaches permit one to distinguish between technical efficiency and statistical noise.

Deterministic frontier model

Aigner and Chu (1968) were the first researchers to estimate a deterministic frontier production function using Cobb-Douglas production function. They argued that, within a given industry, firms might differ from each other in their production processes, due to certain technical parameters in the industry, due to differences in scales of operation or due to organizational structures. Under this assumption, they considered a Cobb-Douglas production function, with an empirical frontier production model such as:

\[ q_i \leq f(x_i) \]

This inequality defines a production relationship between inputs, \( x_i \), and output \( q_i \), in which for any given \( x_i \), the observed value of \( q_i \) must be less or equal to \( f(x_i) \). Since the theoretical production function is an ideal (the frontier of efficient production), any non-zero disturbance is considered to be the result of inefficiency, which must have a negative effect on production function:

\[ q_i = f(x_i, \beta) - u_i \]

Taking natural logarithms, the model becomes:

\[ \ln q_i = \beta \ln x_i - u_i \]

Where: \( \ln q_i \) is the natural logarithm of the output of the \( i^{th} \) firm;
\( \ln x_i \) is the natural logarithms of inputs;
\( \beta \) is a column vector of the unknown parameters to be estimated;
\( u_i \) is a non-negative random variable associated with technical inefficiency, representing the shortfall of actual output from its maximum possible value. Nevertheless, in this case, the model is deterministic, and all deviations from the frontier are assumed to be the result of technical inefficiency and no account is taken of any measurement errors or any statistical noise (i.e. omission of relevant variables from the vector \( x_i \)).

Stochastic frontier model

The stochastic frontier model was independently proposed by Aigner et al. (1977) and Meeusen and van Den Broeck (1977). The model can be expressed as:

\[ Y_i = F(X_i; \beta) + \varepsilon_i \]

Where \( Y_i \) is the output of the \( i^{th} \) firm, \( X_i \) is vector of input variables for the \( i^{th} \) firm, \( F() \) is the appropriate functional form and \( \beta \) is vector of unknown parameters to be estimated. \( \varepsilon_i \) is the composed error term, which equals \( V_i - U_i \). The random factor (V) is a symmetric error, which accounts for random variations in output due to external factors beyond the control of the farmer, e.g., weather and disease outbreak, and it is assumed to be independently and identically distributed (IID) with \( N(0, \sigma^2_v) \) while the technical inefficiency effects, (U), is often assumed to have a half normal distribution \( |N(0, \sigma^2_u)| \). \( U_i \) reflects the fact that each farm’s output must lie on or below its frontier \( \{ f(x_i; \beta) + V_i \} \). Any such deviation is the result of factors under the firm’s control, such as technical inefficiency. But the frontier itself can vary randomly across firms and on this interpretation the frontier is stochastic, with random disturbance \( V_i \leq 0 \) being the result of favourable as well as unfavourable external events.

As in Bravo-Ureta et al (1991) and Jema (2008) the parametric technique used in this study follows the Kopp and Diewert (1982) cost decomposition procedure to estimate technical, allocative, and economic efficiencies. SFA models a cost, or a production frontier with an error component that is decomposed into two. The technical efficiency of a farmer, which can be predicted using the frontier program, which
calculates the maximum likelihood estimators, is between 0 and 1 and is inversely related to the level of the technical inefficiency effect. For instance, if output is measured in logarithms, the farm specific technical efficiency can be estimated as:

\[ \text{TE} = \exp^{-U} = z_i \delta \]

\[ i = 1, 2, \ldots, n, 0 \leq \text{TE}_i \leq 1 \]

Where, \( i \) refer to the \( i \)th farmer, \( z_i \) is the vector of firm specific factors determining inefficiency. The \( \sigma_s \)s are unknown parameters to be estimated together with the variance parameters expressed as:

\[ \sigma_s^2 = \sigma_u^2 + \sigma_v^2 \]

\[ \gamma = \frac{\sigma_u^2}{\sigma_v^2} = \sigma_v^2/\sigma_s^2 \]

The variance ratio \( \gamma \), explains the total variation in output from the frontier level of output attributed to technical inefficiencies. And it has a value between zero and one, such that the value of zero is associated with the traditional response function, for which the non-negative random variable, \( u_i \), is absent from the model. In this specification, the parameters, \( \beta, \delta, \sigma_u^2, \sigma_v^2, \) and \( \gamma \) can be estimated by method of maximum likelihood using the computer program, STATA version 14.

Unlike that of the deterministic frontier approaches, the stochastic frontier approach measures productive efficiency by the ratio of observed output to the stochastic production frontier, \( Y_i/[f(X_i;\beta) + V_i] \) rather than by the ratio of observed output to the deterministic frontier, \( Y_i/[f(X_i;\beta)] \). This simply distinguishes productive efficiency from other source of disturbance that are beyond the firm’s control (Aigner et al., 1977).

Both SPF and DEA approaches come with their strengths. Indeed, the debates on efficiency have still not come into consensus on the superiority of one approach over the other but Stochastic frontier approach (SFA) utilized in this study has at least two advantages over nonparametric approaches. The primary advantage of the stochastic frontier production function is that it enables one to estimate farm specific technical efficiencies. The merit of the SFP function over the former (deterministic) is that the estimation of standard errors and tests of hypothesis is possible, which the deterministic model fails to fulfill because of the violation of the maximum likelihood regularity conditions (Coelli, 1995). Most importantly, the model allows segregating the effect of statistical noises from systematic sources of inefficiency.

The measure of technical efficiency is equivalent to the production of the \( i \)th farm to the corresponding production value if the farm effect \( u_i \) were zero. However, the estimation of efficiency using stochastic method requires a prior specification of functional form and needs distributional assumptions (half-normal, gamma, truncated, etc.) for the estimation of \( U_i \), which cannot be justified given the present state of knowledge (Coelli et al., 2005). Though both stochastic and deterministic methods have their merits and demerits, they have been used widely in estimating productive efficiency in different sectors of the economy. Therefore stochastic frontier production function was appropriate and selected to estimate the, price and production efficiencies of sesame producers in the study area. Besides, the technique is consistent with most of the agricultural production efficiency studies (Jema, 2008; Kareem et al., 2008; Kehinde and Awoyemi, 2009).

3. MATERIALS AND METHODS

Description of the Study Area

This study was conducted in Babogambel district, in West Wollega Zone of Oromia region, which is found 560km from capital city of Ethiopia (Finfine), Babogambel is one of 180 districts of the Oromia region of Ethiopia and Babogambel is located at 120km away from Gimbi (Western Wollega Zone) in east direction, it is bounded by Jarso and Nejo in the east, Manasibu and Kiltukara in the North; Begi in the
West, Kondala and Kellem Wollega Zone in the south. This district was created from a portion Jarso district; Babo Dabeka is its administrative center.

The district has 21 kebele administrations with two town dwellers (Shimal-Tokkee and Babo Dabeka). The 2007 National census reported a total population for this district was 60513 in 11, 283 households, of whom 30,689 (51%) were men and 29,824 (49%) were women; 3,717 or 6.14% of its population were urban dwellers and 56,796 residents were rural dwellers. Based on Babogambel district agricultural department in 2017/18 the total area coverage of this district is estimated to 86400 hectare. From this 41% hectares were cultivated.

The altitude of the district ranges from 1400 to 1615 meters above sea level. The temperature of the district range from 25 – 30 degree centigrade with 1850 millimeters annual average rain fall and 70% of the district is fall under lowland and the left 30% is midland. Agricultural production is the main means of livelihoods for the district. The production season of sesame in the study area starts from the ending of June up to beginning of October. Livestock husbandry is dominated by cattle, sheep, goat chicken, mule and donkey.

The major types of agricultural inputs used in the area were: organic fertilizers (Green manure, animal waste and compost), chemical fertilizers (DAP and Urea), different varieties of improved seed and different types of chemicals that enables them to achieve the target production goal of many cereal crops but more than half of sesame producer were non-user of fertilizer for sesame production.

The farming system in Babogambel district is mixed farming (crop-livestock) where-by crops contribute larger share to farmers’ income. Major crops grown around the area were cereals such as: maize, teff, sorghum, legumes such as beans, peas and root crops like potato and sweet potato and vegetables such as cabbage and onion crops, cash crops such as: coffee, nueg, sesame and so on. Annual crops are predominant and rain-fed agriculture is mainly practiced using drought power.

Figure 1: Location of Babogambel district
Types, Sources and Methods of Data Collection

In order to generate sufficient information for this study, both primary and secondary data from different sources were used. Accordingly, secondary data were collected from Babogambel district agricultural department, CSA and different report. Besides, different and relevant published and unpublished reports, bulletins, websites were consulted to generate relevant secondary data on economic efficiency of sesame. The primary data were collected entirely from sample households using a semi-structured questionnaire. The data were collected on inputs, output, socio-economic characteristics, different production and marketing constraints, costs, prices of sesame for the year of 2015/16 cropping season by using face to face interview with the aid of trained enumerators under close supervision of the researcher.

Sampling Technique and sample size

Babogambel district was purposively selected for the study because of the presence of large number of sesame producing farmers and its extent of production. To determine the sample kebeles and households, a two stage random sampling procedures was used. In the first stage, three kebeles out of seventeen sesame producing kebeles namely Ambalo-Dila, Malka-Ebicha and Shimal-Tokke were selected randomly. In the second stage, 124 farm households were selected randomly from those who were producing sesame taking into account probability proportional to the size of sesame producers in each sample kebeles. The sample size was determined based on the following formula given by Yamane (1967):

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

Where, \( n \) is sample size, \( N \) is number of population and \( e \) is the desired level of precision. By taking \( e \) as 9%, and the total population of 60,513, the sample size was 124.

\[ n = \frac{60,513}{1 + 60,513(0.09^2)} = 124 \]

Table 1. Distribution of the total households and sample households by Kebeles

<table>
<thead>
<tr>
<th>Kebeles</th>
<th>Total number of households</th>
<th>Sample household</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Male</td>
</tr>
<tr>
<td>Ambalo-Dila</td>
<td>641</td>
<td>596</td>
</tr>
<tr>
<td>Malka-Ebicha</td>
<td>944</td>
<td>900</td>
</tr>
<tr>
<td>Shimal-Tokke</td>
<td>1014</td>
<td>972</td>
</tr>
<tr>
<td>Total</td>
<td>2599</td>
<td>2468</td>
</tr>
</tbody>
</table>

Source: Own survey (2017)

Model specifications and Methods of Data analysis

Descriptive statistics

This method of data analysis refers to the use of ratios, percentages, means, range, variances and standard deviations. It is employed in the process of examining and describing farm household demographic and socio-economic characteristics, production cost and resource allocation for sesame production.

Econometric models

The stochastic frontier production function was used to estimate the allocative and economic efficiencies of sesame in the study area. The model was specified as:

\[ \ln Y_i = \beta_0 + \ln \sum \beta_j X_{ij} + \varepsilon_i \]

\[ \varepsilon_i = v_i - u_i \]

(i = 1, 2, ......... n)
Where,
\[ \ln(y_i) = \text{natural log of output of } i\text{th farmer} \]
\[ i = \text{number of farmers in the study} \]
\[ x_i = (k+1) \text{ row vector whose first element is 1 and remaining 'x' elements are log of 'k' input quantities used by } i\text{th farm}. \]
\[ \beta = (\beta_0, \beta_1, \ldots, \beta_k) \text{ is a (k+1) column vector of unknown parameters to be estimated.} \]
\[ v_i = \text{random error term (ie. random effect)} \]
\[ u_i = \text{error term related with technical inefficiency.} \]

Aigner et al. (1977) proposed the log likelihood function for the model in equation above, assuming half normal distribution for the technical inefficiency effects \( u_i \). They expressed the likelihood function using \( \lambda \) parameterization, where \( \lambda = \sigma_u/\sigma_v \). However, Battese and Corra (1977) proposed that the \( \gamma \) parameterization, where \( \gamma = \sigma_u^2/(\sigma_v^2+\sigma_u^2) \), to be used instead of \( \lambda \). The reason is that \( \lambda \) could be any non-negative value while \( \gamma \) ranges from zero to one and better measures the distance between the frontier output and the observed level of output resulting from technical inefficiency.

However, there is an association between \( \gamma \) and \( \lambda \). According to Bravo and Pinheiro (1997) gamma \( (\gamma) \) can be formulated as:
\[ \gamma = \lambda^2/(1+\lambda^2) \]

Hence, by following Battese and Corra (1977) the log likelihood function of the model is specified as:
\[ \ln(L) = -\frac{N}{2} \left( \ln \left( \frac{\sigma^2}{2} \right) + \ln \sigma^2 \right) + \sum_{i=1}^{N} \ln \left[ 1 - \Phi \left( \frac{e_i\sqrt{\gamma}}{\sigma \sqrt{1-\gamma}} \right) \right] - \frac{1}{2\sigma^2} \sum_{i=1}^{N} e_i^2 \]

Where \( e_i = \ln Y_i - \ln X_i \beta \) is the residual of (3.3); \( N \) is the number of observations; \( \Phi(.) \) is the standard normal distribution; \( \sigma^2 = \sigma_v^2 + \sigma_u^2 \), and \( \gamma = \sigma_u^2/\sigma_v^2 \) are variance parameters.

The minimization of above equation with respect to \( \beta, \sigma^2 \) and \( \gamma \) and solving the resulting partial derivatives simultaneously, produces the ML estimates of \( \beta, \sigma^2 \) and \( \gamma \). The \( \gamma \) parameter is used to test whether the technical inefficiency affects output or not. Likewise, the significance of \( \sigma^2 \) indicates whether the conventional average production function adequately represent the data or not.

**Elasticity of production:** It is the measure the effect of change in the factor input output. In Cobb-Douglas production function, the regression coefficients stand for the elasticity’s of the individual resources (land, labor, seed, fertilizer, herbicide and oxen). The sum of these parameters indicates the nature of returns to scale, i.e., If the sum is equal to 1, it indicates constant returns to scale, if it is greater than 1, it shows increasing returns to scale and if sum is less than 1 it implies that decreasing returns to scale.

**Dual cost frontier model:** The production function could also be estimated through an alternative form, called dual, such as cost or profit function. Sharma et al. (1999) suggests that the corresponding dual cost frontier of the Cobb Douglas production functional form can be rewritten as:
\[ C_i = C \left( W_i, Y_i^*; \alpha \right) \]

Where \( i \) refers to the \( i^{th} \) sample household; \( C_i \) is the minimum cost of production; \( W_i \) denotes input prices; \( Y_i^* \) refers to farm output which is adjusted for noise \( v_i \) and \( \alpha 's \) are parameters to be estimated. The economically efficient input vector of the \( j^{th} \) household \( X_{ie} \) is derived by applying Shepards’ lemma (Arega and Rashid, 2005) and substituting the firms input prices and adjusted output level, a system of minimum cost input demand equation can be expressed as:
\[ \partial C_i/\partial W_n = X_{ie} \left( W_i, Y_i^*; \alpha \right) \]

Where \( n \) is the number of inputs used. The observed, technically and economically efficient costs of production of the \( i^{th} \) farm are then equal to \( W'X_i, W'X_{ie} \) and \( W'_{ie} \); respectively. The minimum cost is
derived analytically from the production function, using the methodology used in Arega and Rashid (2005). Given input oriented function, the efficient cost function can be specified as follows:

\[
\text{Min } \sum_{x} C = \sum_{j=1}^{6} X_j W_j \\
\text{Subject to } Y_i^* = \hat{A} \prod X_i^{\hat{\beta}_j} \\
\text{Where } \hat{A} = \text{Exp}(\hat{\beta}_o) \\
\text{The solution for the problem in the above equation is the basis for driving dual cost frontier.} \\
\text{Substituting the input demand equations derived using shepherd’s lemma (below equation) and Output adjusted for stochastic noise (predicted value of yield) in the minimization problem above, the dual cost function can be written as follows:} \\
C(Y_i^*, w) = HY_i^\mu \prod W_j^{\mu} \\
\text{Where; } \alpha_j = \mu \hat{\beta}_j, \mu = (\sum \hat{\beta}_j)^{-1} \text{ and } H = \frac{1}{\mu} (\hat{A} \prod \hat{\beta}_j)^{-\mu} \\
\text{All the Parameters are known; hence we can calculate the minimum (efficient) cost of production.} \\
\text{According to Sharma et al. (1999), the above cost measures are used to estimate the technical, allocative and economic efficiencies respectively. We can define the farm–specific technical efficiency in terms of observed output (Yi) to the corresponding frontier output (Yi*) using the existing technology.} \\
\text{TE}_i = Y_i / Y_i^* \\
\text{The farm specific economic efficiency is defined as the ratio of minimum observed total production cost (C*) to actual total production cost (C).} \\
\text{EE} = C*/C \\
\text{Following Farrell (1957), the AE index can be derived from above two continuous Equations} \\
\text{AE = EE/TE} \\
\text{In this study, a Cobb-Douglas function was fitted to both stochastic production frontiers and cost frontier function of the Sesame farmers using the Maximum Likelihood method. This functional form has been used in many empirical studies.} \\
\text{The production function model for this study is specified as follows:} \\
\text{ln } Y = \text{ln } b_0 + b_1 \text{ln } X_1 + b_2 \text{ln } X_2 + b_3 \text{ln } X_3 + b_4 \text{ln } X_4 + b_5 \text{ln } X_5 + b_6 \text{ln } X_6 + \epsilon_i \\
\text{Where, } Y \text{ is output of sesame (Qt), } X_1 \text{ is size of land (hect), } X_2 \text{ is amount of seed used (Kg), } X_3 \text{ is the amount of DAP used (kg), } X_4 \text{ is the number of oxen (MD), } X_5 \text{ is the amount of labor used (MD), } X_6 \text{ is the amount of herbicide used (Ltr), and Ln is natural logarithm, } b_0 \text{ – } b_6 \text{ are coefficients to be estimated, } \epsilon_i \text{ is composed error term which is also defined as } V- U. \text{ It is expected a priori that the coefficients of } X_1, X_2, X_3, X_4, X_5, X_6 \text{, will be positive. The cost frontier function is also specified as:} \\
\text{ln } C = \text{ln } a_0 + a_1 \text{ln } P_{x_1} + a_2 \text{ln } P_{x_2} + a_3 \text{ln } P_{x_3} + a_4 \text{ln } P_{x_4} + a_5 \text{ln } P_{x_5} + a_6 \text{ln } P_{x_6} + a_7 Y^* \\
\text{Where, } C \text{ is minimum cost of production per sesame farmer, } P_1 \text{ is the seasonal rent of a hectare of land in the study area (Birr), } P_2 \text{ is the price of seed per kilogram (Birr), } P_3 \text{ is the cost of DAP (Birr), } P_4 \text{ is the unit cost of oxen (Birr), } P_5 \text{ is the unit cost of labor (Birr) and } P_6 \text{ is the unit price of herbicide (Birr), } Y^* \text{ is the output of sesame in quintals adjusted for statistical noise, } a_1 \text{ – } a_6 \text{ are } \text{parameters to be estimated, } a_0 \text{ is the y – intercept. It is expected a priori that the coefficients of } P_{x_1}, P_{x_2}, P_{x_3}, P_{x_4}, P_{x_5} \text{ and } P_{x_6} \text{ will be positive.} \\
\text{In SPF hypothesis tests can be made using ML ratio test that are not possible in non-parametric models. A number of tests of hypotheses were made in this study using the usual Likelihood Ratio (LR) test given as:} \\
\text{LR} = \lambda = -2 \text{ln } [L(H_0) / L(H_1)] \\
\lambda = -2 [\text{ln } L(H_0) - \text{ln } L(H_1)] \\
\text{Where, } \lambda \text{ is the likelihood ratio (LR), } \\
\text{L (H_0) = the log likelihood value of the null-hypothesis,} \\
\text{L (H_1) = log likelihood value of the alternative hypothesis, and ln is the natural logarithms.}
All the tests were carried out using generalized likelihood ratio statistics. The test statistics is defined by \( \chi^2 = -2 \left[ L(H_0) - L(H_1) \right] \), where \( L(H_0) \) and \( L(H_1) \) are the values of the likelihood function for the model under the null hypothesis, \( H_0 \), and the alternative hypothesis, \( H_1 \), that are involved.

**Two stage estimation procedure**

This study had adopted the two stage estimation procedure. A two-step economic procedure is used first to estimate efficiency scores and then a Tobit model is used to determine the relationship between the efficiency scores and factors that may influence efficiency indices. This is the most commonly used procedure and it examines the determinants of efficiency, in that the inefficiency or efficiency index is taken as a dependent variable and is then regressed against a number of other explanatory variables that are hypothesized to affect efficiency levels (Bravo-Ureta and Rieger, 1991; Sharma et al., 1999; Arega, 2003; Jema and Andersson, 2006).

In this study price (allocative) and production efficiency estimates that were derived from stochastic production frontier were regressed using a censored Tobit model on farm-specific explanatory variables that were explain variation in efficiency across farms. The rationale behind using the Tobit model is that there are a number of farms for which efficiency is one and the bounded nature of efficiency between zero and one (Jackson and Fethi, 2000). That is, due to the large number of fully efficient SPF estimates, the distribution of efficiency measures is censored above from unity. Estimation with Ordinary Least Squares (OLS) regression of the efficiency scores would lead to biased parameter estimates since OLS assumes normal and homoscedastic distribution of the disturbance and the dependent variable (Greene, 2003). Therefore tobit model was used to estimate determinants that affect production of sesame. According to Green (2003), Tobit (Censored Regression) model is specified as:

\[
E_i^* = \sum_j \beta_j X_j + \nu_i
\]

\[
E_i = \begin{cases} 
E_i^* & \text{if } E_i^* \geq 1 \\
0 & \text{if } E_i^* < 1
\end{cases}
\]

Where \( E_i \) is an efficiency score, representing price and production efficiencies; and \( \nu_i \sim N(0, \sigma^2) \) and \( \beta_j \) are the vector of parameters to be estimated, \( X_j \) represent various farm variables: \( X_1 = \) Age of household head \( X_6 = \) Sesame production experience

- \( X_2 = \) Level of Education
- \( X_3 = \) Farming Experience
- \( X_4 = \) Family Size
- \( X_5 = \) soil fertility
- \( X_7 = \) proximity to sesame farm
- \( X_8 = \) Number of Oxen
- \( X_9 = \) Total cultivated land
- \( X_{10} = \) Extension contact
- \( X_{11} = \) credit access
- \( X_{12} = \) Sex

and \( E_i^* \) is the latent variable.

**Definition of Variables and Hypotheses**

**Production function variables**

**Output:** This is the dependent variable of the production function. It is the physical quantity of sesame produced in quintals per hectare by the sample household.

**Land:** This refers to the total area of land in hectares (ha) operated by the farmer, including that owned, rented in, contracted in and obtained through gift.

**Labor:** This represents the aggregate labor used for sesame production in the production season. It was measured in man days (eight hours are equivalent to one man day) and converted to homogenous variable using the standard conversion set by Storck et al. (1991).

**Seed:** This refers to the quantity of sesame seed used (in kg) for sesame production by each household in the production season.
DAP: This refers to the amount of DAP used (in kg) by the sample household for sesame production during 2015/16 production season.

Oxen: It represents the amount of oxen power utilized for sesame production by a household. It was measured in oxen-days (one oxen-day is equivalent to eight working hours).

Herbicide: It represents the amount of chemical (in Ltr) utilized for sesame production by each household during production season.

Price: In computing total cost of sesame production both variable and fixed costs were considered. In the countries where purchasing agricultural land is hardly exists but considerable tenancy, rental value of land probably provides a fairly good indication of the net value of production. Similarly, opportunity cost of rural labor measured in market wage paid of peak seasons can be accepted as the economic value of the rural labor (Gittinger 1982). As far as seed, herbicide and DAP are concerned, the current market value was taken as measurement.

Factors affecting efficiency
After a thorough review of previous studies and the prevailing situation in the study area, socio economic and institutional factors that would affect efficiency are hypothesized as follows:

Age of a household head (AGEHH): This refers to the age of the household head measured in years. It is believed that age can serve as a proxy for experience. In this case farmers with more years of experience are expected to be more efficient. On the other hand, older farmers are relatively unlikely to change their long life farming exercise, which is usually traditional and less efficient. Moreover, labour productivity decreases with age; younger farmers tend to be relatively more productive, because of the tough nature of farm operations (Ike and Inoni, 2006). Therefore, in this study it hypothesized indeterminate relationship between age and efficiency.

Education of the household head (EDULVL): This is used as a proxy variable for managerial ability of the decision making unit (household head). It is assumed that through education the quality of labour is improved and he/she become active to use resources efficiently. (Tewodros, 2001). Education of the household head was measured in years of formal schooling and hypothesized to affect efficiency positively.

Experience in sesame production (SESPROEXP): This refers to sesame production experience of the household head measured in years. As one gets proficient in the methods of production, optimal allocation of resources at his/her disposal would be achieved (Hyuha, 2006). In this case, farmers with more years of experience are expected to be more efficient.

Oxen number (NOFOXEN): This represents the number of oxen owned by a household. It is hypothesized that farmers who own more number of oxen will be more efficient than others. This is because; oxen ownership would help farmers to carry out agricultural operations like ploughing, sowing and others on time that would improve productivity.

Soil fertility status (SOILFERT): It was treated as a dummy variable that takes the value of 1 if a household head perceives his land as fertile and 0 otherwise. The more the land is fertile, the better the gain will be (Abebayehu, 2011). Therefore, it is hypothesized that a farmer with a fertile land may be more efficient than a farmer with less fertile land.
**Proximity (PROX):** This is the distance of sesame farm from homestead measured by walking time required. It is hypothesized that distance of sesame farm could be negatively related to efficiency. This is because those farms far away from home could receive less management attention by the farmer (Kinde, 2005).

**Family size (FAMSIZ):** This is a continuous variable representing the total number of family members in the household. Family is an important source of labor supply. Family labor is the main input in crop production as the farmer has large family size he would manage crop plots on time and may able to use appropriate input combinations (Essa, 2011). Thus, family size is expected to have a positive influence on efficiency of the farmer.

**Extension contact (EXTN):** This variable is measured as the frequency that the household head contacted with DA during the survey year. It is expected that farmers that have frequent contact with extension workers will have better access to information and new technology that enhance productivity of their farm (Fekadu, 2004). Hence, it is hypothesized to affect efficiency positively.

**Off/Non-farm income (NONFRMINC):** off/non-farm activities can supplement the agricultural activities in terms of providing cash income by there to purchase necessary inputs timely. On the other hand, off/non-farm works can compete with agricultural activities in terms of time and labor (Hyuha, 2006). Hence, the hypothesis is that the sign of this variable is indeterminate a priori.

**Credit (CRDT):** Is a dummy variable which represents whether the farmer has obtained credit or not during the production season. If the farmer has access to credit facility, the variable takes a value of one and zero, otherwise. It is hypothesized that farmers who have access to credit sources are more efficient than others. This is because, access to credit is an important source of financing and it enables the smallholder farmers to purchase agricultural inputs in time that would increase their productivity (Ike and Inoni, 2006 as cited in Ermias et al., 2015).

**Total cultivated land:** This refers to the area of cultivated land (own, shared or rented in) that the household head managed during 2015/16 production season. Farmers with larger area of cultivated land have the capacity to use compatible technologies that could increase the efficiency of the farmer, enjoy economies of scale. According to Andreu (2008), large farms were relatively better efficient than small size farms. Hence, it was hypothesized that total land holding would have a positive effect on efficiency of sesame production.

**Sex of the household head (SEXHH):** This is a dummy variable measured as 0 if the household head is female and 1, otherwise. Since women are the one who are responsible for many household domestic activities, they may not accomplish the farming activities on time and efficiently (Kinde, 2005). Therefore, it is hypothesized that women’s are less efficient than males.

**4. RESULTS AND DISCUSSION**

**Descriptive Statistics of Variables Used in the Stochastic Frontier Model**

To draw some picture about the distribution and level of inputs, the mean and range of input variables is discussed as follows: On average, the total cost of 4021.36 Birr was required to produce 5.13 quintals of sesame. Among the various factors of production, the cost of human labor accounted for the highest share (1760.96 Birr). Following the cost of labor, cost of oxen labor takes major share out of total cost of production which is 621.08 Birr. Among other inputs, cost of seed takes the smallest (158.82 Birr) share out of the total cost of sesame production.
Table 2. Summary statistics of variables used to estimate the cost function

<table>
<thead>
<tr>
<th>Variable description</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output (Qt)</td>
<td>0.5</td>
<td>19</td>
<td>5.13</td>
<td>3.74</td>
</tr>
<tr>
<td>Total cost of production</td>
<td>719.437</td>
<td>10314.6</td>
<td>4021.3</td>
<td>2078.2</td>
</tr>
<tr>
<td>Cost of land (Birr)</td>
<td>50</td>
<td>1500</td>
<td>426.84</td>
<td>294.04</td>
</tr>
<tr>
<td>Cost of seed (Birr)</td>
<td>24</td>
<td>504</td>
<td>158.82</td>
<td>86.8</td>
</tr>
<tr>
<td>Cost of DAP (Birr)</td>
<td>0</td>
<td>3300</td>
<td>575.77</td>
<td>665.02</td>
</tr>
<tr>
<td>Cost of human labor (Birr)</td>
<td>437.5</td>
<td>5567</td>
<td>1760.96</td>
<td>1002.4</td>
</tr>
<tr>
<td>Cost of Herbicide (Birr)</td>
<td>52.5</td>
<td>1260</td>
<td>425.645</td>
<td>272.82</td>
</tr>
<tr>
<td>Cost of oxen labor (Birr)</td>
<td>93.75</td>
<td>2018.75</td>
<td>621.08</td>
<td>389.5</td>
</tr>
</tbody>
</table>

Source: Own survey (2017)

Estimated observed and potential (frontier) level of output

The difference between the actual level and the frontier level of output was computed by estimating the individual and the mean level of frontier output. The mean levels of the actual and frontier output during the production year were 5.13Qt and 7.18Qt/ha, with the standard error of 3.74 and 4.25, respectively. Moreover, paired sample t-test was used on the actual and potential output to compare the difference in the amount of yield between two scenarios. There was a significant difference between potential output and actual output. The mean difference of the actual and the potential output was found to be statistically significant at 1% probability level.

Table 3. Comparison of estimated actual and potential output of sample households

<table>
<thead>
<tr>
<th>Efficiency category</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 – 0.6999</td>
<td>37</td>
<td>6.5</td>
<td>4.27</td>
<td>3.514</td>
<td>3.13</td>
</tr>
<tr>
<td>0.7 – 0.7999</td>
<td>43</td>
<td>7.15</td>
<td>4.26</td>
<td>4.66</td>
<td>3.07</td>
</tr>
<tr>
<td>0.8 – 0.8999</td>
<td>23</td>
<td>7.166</td>
<td>3.86</td>
<td>5.92</td>
<td>3.5</td>
</tr>
<tr>
<td>0.9 – 0.9999</td>
<td>21</td>
<td>8.48</td>
<td>4.58</td>
<td>8.1</td>
<td>4.46</td>
</tr>
<tr>
<td>Overall</td>
<td>124</td>
<td>7.18</td>
<td>4.25</td>
<td>5.13</td>
<td>3.74</td>
</tr>
</tbody>
</table>

Paired sample t-test: t = 13

Econometric Result

This section presents the econometric results of the study. The results of production and cost functions, efficiency scores and determinants of efficiency are discussed successively. Tests of hypotheses for the parameters of the frontier model and production function are conducted using the generalized likelihood ratio statistics, \( \lambda \).
Table 4. Generalized LR test of hypotheses for parameters of SPF

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>df</th>
<th>LH0</th>
<th>LH1</th>
<th>Calc χ²(LR)</th>
<th>Critical X²</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₀: CD (β₇….β₂₇=0)</td>
<td>20</td>
<td>-35.12</td>
<td>-34.14</td>
<td>1.96</td>
<td>31.41</td>
<td>fail to reject</td>
</tr>
<tr>
<td>H₀: CD (β₇….β₁₂=0)</td>
<td>6</td>
<td>-35.12</td>
<td>-37.94</td>
<td>5.64</td>
<td>12.6</td>
<td>fail to reject</td>
</tr>
<tr>
<td>H₀: μ=0</td>
<td>1</td>
<td>-53.11</td>
<td>-53.09</td>
<td>0.04</td>
<td>3.84</td>
<td>fail to reject</td>
</tr>
<tr>
<td>H₀: γ=0</td>
<td>1</td>
<td>-48.22</td>
<td>-53.11</td>
<td>9.78</td>
<td>3.84</td>
<td>Rejected</td>
</tr>
<tr>
<td>H₀=δ₀=δ₂…=δ₁₂ =0</td>
<td>12</td>
<td>-53.11</td>
<td>-35.12</td>
<td>34.64</td>
<td>21.026</td>
<td>Rejected</td>
</tr>
</tbody>
</table>

Source: own computation, 2017

Estimation of production and cost functions

Technical, price and production efficiency levels in sesame production in Babogambel districts were estimated using stochastic frontier production function (SFP). Input variables such as area under sesame cultivation (Land) (ha), oxen (days), labor (MD), quantity of seed(Kg), fertilizer(Kg) and amount of non-selective herbicide chemical(roundup) in liters were used in the model for estimating technical efficiency, while total price of each inputs in birr were used for estimating price(price) efficiency. From the total of six variables considered in the production function, three (Land, labor and oxen) had positive sign and significant effect in explaining the variation in sesame output among farmers and are significant variables in shifting the frontier output to the right or moving along the frontier. This indicated that a unit increase of these variables; increase the level of sesame output. The coefficients of the production function are interpreted as elasticity. Hence, high elasticity of output to land (0.44) suggests that sesame production was highly depending on size of land. As a result, 1% increase in size of land will result in 0.44% increase in sesame production, keeping other factors constant. Alternatively, this indicates sesame production was responsive to labor, land and oxen in the study area.

Table 5. MLE results of the production frontier for the sample households

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.12</td>
<td>0.47</td>
</tr>
<tr>
<td>Land</td>
<td>0.44***</td>
<td>0.1</td>
</tr>
<tr>
<td>Seed</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>Dap</td>
<td>0.001</td>
<td>0.00</td>
</tr>
<tr>
<td>Oxen</td>
<td>0.21**</td>
<td>0.12</td>
</tr>
<tr>
<td>Labor</td>
<td>0.26**</td>
<td>0.10</td>
</tr>
<tr>
<td>Herbicide</td>
<td>0.03</td>
<td>0.09</td>
</tr>
<tr>
<td>Diagnostic statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma (γ)</td>
<td>0.90***</td>
<td></td>
</tr>
<tr>
<td>Sigma square</td>
<td>0.35***</td>
<td>0.072</td>
</tr>
<tr>
<td>Lamda</td>
<td>3.02***</td>
<td>0.11</td>
</tr>
<tr>
<td>log_likelihood</td>
<td>53.11</td>
<td></td>
</tr>
</tbody>
</table>

Note: ** and *** refers to 5% and 1% significance level, respectively.
Source: Own computation (2017)

The productions function estimated from stochastic frontier model results:

\[ \text{Ln } Y = 0.12 + 0.44 \text{ ln(land)} + 0.09 \text{ ln(seed)} + 0.001 \text{ln(DAP)} + 0.26 \text{ ln(labor)} + 0.21 \text{ln(Oxen)} + 0.03 \text{ln (Herbicide)} + \epsilon_i \]
The diagnostic statistics of inefficiency component reveals that sigma squared \((\sigma^2)\) was 0.35 and statistically significant at 1 percent this indicates goodness of fit, and the correctness of the distributional form assumed for the composite error term. Using the formula in equation (3.3) the gamma \((\gamma)\) was 0.90 which was high enough and significant at 1% level. It gives an indication that the unexplained variations in output are the major sources of random errors. It also shows that about 90 percent of the variations in output of Sesame farmers are caused by technical inefficiency. It also confirms the presence of the one sided error component in the model; this rendering the use of ordinary least squares (OLS) estimation techniques inadequate in representing the data.

The scale coefficient was calculated to be 1.06, indicating increasing returns to scale. This implies that there is potential for sesame producers to continue to expand their production because they are in the stage I of the production surface, where resource use and production is believed to be inefficient. In other words, a one percent increase in all inputs proportionally will increase the total production by 1.06%. This result is consistent with Fikadu (2004), Amos (2007), Ermias et al. (2015) and DOO (2013).

Table 6. Elasticity and returns to scale of the parameters in the production function

<table>
<thead>
<tr>
<th>Variables</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>0.444</td>
</tr>
<tr>
<td>Seed</td>
<td>0.098</td>
</tr>
<tr>
<td>DAP</td>
<td>0.0018</td>
</tr>
<tr>
<td>Labor</td>
<td>0.268</td>
</tr>
<tr>
<td>Oxen</td>
<td>0.215</td>
</tr>
<tr>
<td>Herbicide</td>
<td>0.029</td>
</tr>
<tr>
<td>Return to scale</td>
<td>1.06</td>
</tr>
</tbody>
</table>

Source: Own computation (2017)

The dual cost function and derived analytically from the stochastic production function is given as follows:

\[
\ln C_S = 0.114 + 0.419\ln W_1 + 0.092\ln W_2 + 0.0017\ln W_3 + 0.204\ln W_4 + 0.254\ln W_5 + 0.028\ln W_6 + 0.945\ln Y_i
\]

*Where \(C_S\) is minimum cost of producing sesame; \(W_1\) refers to the price of land, \(W_2\) is price of seed; \(W_3\) is price of DAP; \(W_4\) is price of oxen; \(W_5\) is price of labor; \(W_6\) is average price of herbicide chemicals; \(Y_i\) is Output of sesame in Quintals adjusted for statistical noise.

In the cost frontier function, all the variables carried the expected positive signs. The coefficients of observed cost of land, cost of seed, labor cost, Oxen cost and cost of herbicide were significant at 1%, while the coefficients of output \((Y_i)\) adjusted for statistical noise was significant at 5% level, but cost of DAP were insignificant. This confirmed that more than 54% of respondents were non-user of DAP in the study area, thus cost of DAP is insignificant on cost frontier.
Table 7. MLE of the stochastic cost frontier with observed cost of input used.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>$t$-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.9</td>
<td>0.19</td>
<td>9.75***</td>
</tr>
<tr>
<td>Log of cost of land</td>
<td>0.356</td>
<td>0.02</td>
<td>17.06***</td>
</tr>
<tr>
<td>Log of cost of seed</td>
<td>0.084</td>
<td>0.011</td>
<td>7.28***</td>
</tr>
<tr>
<td>Log of cost of Dap</td>
<td>0.00042</td>
<td>0.00</td>
<td>0.73</td>
</tr>
<tr>
<td>Log of cost of oxen</td>
<td>0.217</td>
<td>0.017</td>
<td>12.7***</td>
</tr>
<tr>
<td>Log of cost of labor</td>
<td>0.214</td>
<td>0.018</td>
<td>11.9***</td>
</tr>
<tr>
<td>Log of cost of herbicide</td>
<td>0.042</td>
<td>0.013</td>
<td>3.20***</td>
</tr>
<tr>
<td>Output ($Y^*$)</td>
<td>0.01</td>
<td>0.005</td>
<td>1.99**</td>
</tr>
</tbody>
</table>

Diagnostic statistics
- Gamma ($\gamma$): 0.982
- Sigma square: 0.012
- Lamda: 7.54
- log_likelihood: 173.3

Note: ** and *** refers to 5% and 1% significance level, respectively.
Source: Own computation (2017)

The gamma ($\gamma$) estimate was 0.98 and was significant at 1% level indicating that 98% of the variation in minimum cost was caused by price inefficiency. The Coefficient of sigma square ($\delta^2$) was significant at 1% level, and indicated the goodness of fit and correctness of the specified assumptions of the distribution of the compound error term. This result is consistent with the results by DOO and JUM (2013).

Estimation of efficiency scores

The results of the efficiency scores indicate that there were wide ranges of differences in AE (price) and production efficiency among sesame producer farmers. Similarly, the mean AE and PE of sample households were 72.95% and 53.95%, respectively. Generally, there is a considerable amount of efficiency variation among sesame producer farmers in all measures of efficiency. This result is consistent with study of Jema (2008), Wondimu (2010), Ermias et al. (2015) and mustefa (2014).

Table 8. Descriptive statistics of efficiency score

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price eff</td>
<td>124</td>
<td>0.7295</td>
<td>0.133</td>
<td>0.437</td>
<td>0.974</td>
</tr>
<tr>
<td>Prod eff</td>
<td>124</td>
<td>0.5395</td>
<td>0.105</td>
<td>0.239</td>
<td>0.923</td>
</tr>
</tbody>
</table>

Source: Own computation (2017)

According to Figure 2, the AE distribution scores indicate that the largest efficiency group of sesame producers (24.19%) operated between 70% and 79.99%. Households in this group can save at least 20% of their current cost of inputs by behaving in a cost minimizing way. Only 20.15% of the total sample households had an AE score that ranged between 0.8 and 0.899. This shows that about (79.85%) sesame producing farmers can at least save 10% of their current input cost by reallocation of resources in cost minimization.
The distribution of EE scores (Figure 3) implies that the majority of the farmers were performing between (.6 - .699) average efficiency level. The low average level of EE was the total effect of both technical and allocative inefficiencies. This also indicates the existence of substantial economic inefficiency in the production of sesame during the study period.

On the other hand, if appropriate measures were taken to improve the level economic efficiency and operate at fully efficiency level, the sesame growing farmers could on average reduce their costs of production by 46.05%. Whereas about 3.226% of the sample farmers were operating at the economic efficiency level of more than 90% which is nearest to fully efficient level.
Determinants of efficiencies in sample farmers

After determining the presence of efficiency differential among farmers and measuring the levels of their efficiency, finding out factors causing efficiency differentials among farmers was the next most important objective of this study. To see this, the technical, price and production efficiency estimates derived from the model were regressed on socio-production and institutional variables that explain the variations in efficiency across farm households using Tobit regression model at specified left censoring limit which is below but more approach to minimum efficiency score with no right censoring limit to include all observation.

The model revealed that experience in sesame production, family size and extension contact affected price efficiency negatively and significantly but soil fertility and education level affected price efficiency positively and significantly. Education level, experience in sesame production and soil fertility affected production efficiency positively and significantly. However, extension contact affected production efficiency negatively.

Table 9: Tobit model estimates determinants for different efficiency measures

<table>
<thead>
<tr>
<th>Variables</th>
<th>Price efficiency</th>
<th></th>
<th>Production efficiency</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient (Std.Err)</td>
<td>Marginal Effect</td>
<td>Coefficient (Std.Err)</td>
<td>Marginal Effect</td>
</tr>
<tr>
<td>Age</td>
<td>0.002 (0.0007)</td>
<td>0.001</td>
<td>0.0003 (0.0005)</td>
<td>0.003</td>
</tr>
<tr>
<td>Sex</td>
<td>-0.0202 (0.0201)</td>
<td>-0.020</td>
<td>-0.0103 (0.0159)</td>
<td>-0.01</td>
</tr>
<tr>
<td>Education</td>
<td>0.0279 (0.0033) ***</td>
<td>0.0279</td>
<td>0.021(0.0026) ***</td>
<td>0.027</td>
</tr>
<tr>
<td>Family size</td>
<td>-0.0184 (0.0061) ***</td>
<td>-0.018</td>
<td>-0.0007 (0.0048)</td>
<td>-0.007</td>
</tr>
<tr>
<td>Experience</td>
<td>-0.0369 (0.0078) ***</td>
<td>-0.368</td>
<td>0.018(0.0062) ***</td>
<td>0.018</td>
</tr>
<tr>
<td>Proximity</td>
<td>-0.0009 (0.0002)</td>
<td>-0.009</td>
<td>-0.0003 (0.0002)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Soil fertility</td>
<td>0.0291 (0.0158) *</td>
<td>0.028</td>
<td>0.0254 (0.0126) **</td>
<td>0.025</td>
</tr>
<tr>
<td>Total cultvtd</td>
<td>0.0164 (0.0002)</td>
<td>0.016</td>
<td>0.0023 (0.0085)</td>
<td>0.002</td>
</tr>
<tr>
<td>No of oxen</td>
<td>-0.0052 (0.0043)</td>
<td>-0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non/off-farm</td>
<td>-0.0347 (0.0215)</td>
<td>-0.034</td>
<td>-0.0039 (0.0172)</td>
<td>-0.004</td>
</tr>
<tr>
<td>Extension</td>
<td>-0.0530 (0.0105) ***</td>
<td>-0.053</td>
<td>-0.0385 (0.0084) ***</td>
<td>-0.038</td>
</tr>
<tr>
<td>Credit</td>
<td>0.0109 (0.0169)</td>
<td>0.01</td>
<td>0.0099 (0.0135)</td>
<td>0.009</td>
</tr>
<tr>
<td>Log likely hood</td>
<td>171.7</td>
<td>158.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *, ** and *** refers to 10%, 5% and 1% significance level, respectively.
Source: Own computation (2017)

**Education:** The coefficient of education is positive for both price and production efficiencies and significant at 1 percent. Positive and significant impact of education on both types of efficiencies confirms that the importance of education in increasing the efficiency of sesame production. It is a variable that is expected to increase managerial ability and led to good decisions in farming. Because of their better skills, access to information and good farm planning; more educated farmers are better to manage their farm resources and agricultural activities and minimize cost of production than less educated one. Besides this, educated farmers have relatively better capacity for optimal allocation of inputs. In line with this study, research done by Abdul (2003), Arega and Rashid (2005) in Eastern Ethiopia, Ogundari and Ojo (2007), Kehinde and Awoyemi (2009), and Mustefa (2014) found education to influence price and production efficiency positively and significantly.

**Sesame production experience:** The coefficient of experience is positive as expected for production efficiency significant at 1 percent. This indicated that increased farming experience may lead to better assessment of importance and complexities of good farming decision, including efficient use of inputs.
Unexpectedly, experience in sesame production was found to have a negative and significant relationship with price efficiency in study area. Wilson et al. (1998) also found a negative relationship between experience and efficiency in potato production in UK, implying that farmers with fewer years of experience achieved higher levels of efficiency. Rahman (2002) also reported similar results for Bangladesh rice farmers and Ermias et al. (2015) also reported for Salamego sesame farmers in Ethiopia. The reason might be those with little experience are likely to seek out for new technology, unlike those with experience or are better at managing their resources.

**Soil fertility:** Soil fertility had a significant and positive impact on price and production efficiencies, as expected. This implies that fertility of land is an important factor in influencing the level of efficiency in the production of sesame. In other words, farmers with fertile farm were more efficient than farmers with less fertile farm. The result is consistent with that of Fekadu (2004) and Ermias et al. (2015).

**Extension contact:** Unexpectedly, extension contact was found to have a negative and significant relationship with price and production efficiency of farmers. This might be due to the fact that the involvement of extension workers in many non-extension activities such as credit applications processing, input distributions, and collection of loans. Moreover, during the survey, most farmers explained that they do not have new skills and information they learn from development agents and they inform that even if there are development agents who agree with the farmers concern, most of them are disregarding their primary activity and shift to other activity. The result is consistent with Jema (2008) and Ermias et al. (2015).

5. **CONCLUSION**

This study analyzed the price and production efficiencies and factors that explain the variation in efficiency among sesame producer farmers in Babogambel district of West Wollega zone, Oromia, Ethiopia. The study area was selected purposively based on the potential of sesame production in the zone. In this study both primary and secondary data were used. Primary data were collected through household survey from a sample of 124 households using a semi-structured questionnaire. Secondary data were collected from relevant sources to supplement the primary data. Data analysis was carried out using descriptive statistics and econometric techniques.

The Cobb-Douglas stochastic frontier production and its dual cost functions were estimated from which price and production estimates were extracted. Result of the production function indicated that Land, labor and oxen were limiting constraints, with positive sign as expected. The positive coefficients of these variables indicate that, increased use of these inputs will increase the production level to greater extent. The average price and production values of the sample households were 72.95 and 53.95%, respectively. This implies that sesame producers can reduce current cost of inputs, on average, by 28.05% if they were price efficiently. The result also indicated that if these farmers operate at full efficiency levels, on average they could reduce their costs of production by 46.05% and still produce the same level of output. In the other part of the analysis, relationships between price and production efficiency and various variables that were expected to have effect on farm efficiency were examined. This was relied on Tobit regression techniques, where price efficiency score and production efficiency were expressed as functions of 12 explanatory variables.

An important conclusion stemming from the analysis of the efficiency of sesame production is that, there exists a considerable room to enhance the level of technical, price and production efficiency of sesame producer farmers. The implication is that, there will be considerable gain in production level or reduction in cost of production if introduction and dissemination of agricultural technologies is coupled with improving the existing level of efficiency. Moreover, the study contributes to improve farm revenue, welfare and generally helps agricultural as well as production development.
6. RECOMMENDATIONS

The policy implications of this analysis are that efficiency estimates indicate both the distribution of the farmers’ efficiency and its socio-production determinants. Thus, the results of the study give information to policy makers on how to improve farm level efficiency of sesame production and identify the determinants for specific efficiency types. The study results revealed that there is a considerable variability in all efficiencies and efficiency score of sample household in the production of Sesame in the study area. This indicated that in the long run improving the existing level of price and production efficiency of farmers alone may not lead to significant increment in the level of sesame. So in the long run it needs attention to introduce other best alternative farming practices and improved technologies in order to change the lives of farmers. The policy makers should give due emphasis to increase the level of efficiencies. This is because the use of improved technologies is expensive since it requires large capital. In addition, farmers have serious financial problem since they are subsistence farmers. Thus, the following policy recommendations are forwarded based on the result of the study.

Education was very important factor that contributed positively to the improvement of price and production efficiency. So, the government should give more attention to provide educational service for all to attain educated farmers in order to increase efficiency and agricultural productivity of the country in the long run.

Fertility of sesame farm was found to be related to price and production efficiency of farmers positively. Therefore, development programs should give due emphasis to improve and maintain the fertility of land through awareness creation and introduction of technologies that improve and maintains fertility so that the efficiency of the farmers increases.

The result of the finding also indicated that, unexpectedly, extension contact was found to affect price and production efficiency of sesame producer farmers negatively. Despite the justification given by this study, it needs further study why it appears to affect efficiency negatively.

Even though experience in sesame production was found to affect price efficiency negatively, it had a positive impact on production efficiency. This indicates that increased farming experience may lead to better assessment of importance and complexities of good farming decision, including efficient use of inputs. Thus, the government should facilitate the infrastructure (especially road) to improve the market network of sesame producer which encourages the farmers to produce effectively and supply their products to the market with low transportation cost that increase farmers experience in the long run.

7. ACKNOWLEDGMENT

Ethiopia ministry of education is great fully acknowledged for rendering me this opportunity, and all the necessary facilities and assistance in conducting this research. I want to express my thanks to my beloved family specially for my mother Waynitu Obsa, my brother Mikael Wana and my Sister Hawi Wana and my relatives: Daniel Fufa, Daraje Taye and Yonas Negasa for their moral support throughout my study.

8. REFERENCES

Zambrut Journal, Link Access;

https://zambrut.com
https://zambrut.com/price-production/

© Copyright 2019 International Journal of Zambrut | Zambrut, Inc.
Wana, H. 2019. Analysis of Price and Production Efficiency of Sesame