



Economic Efficiency of Smallholder Farmers in the Production of Grass Pea: Case Study of Dawunt District, North Wollo Zone, Amhara Region, Ethiopia



Abebe Fentaw*¹, Andebet Ejigu²

¹Department of Economics, Wollo University, Dessie, Ethiopia

²Department of Economics, Debre Tabor University, Debre Tabor, Ethiopia

ABSTRACT

The study's main aim was to measure the economic efficiency of grass pea production in Dawunt Woreda. The Stochastic production frontier model has been used to estimate economic efficiency score, whereas the Tobit model has been used to identify factors affecting economic inefficiency. The study result shows that the average economic efficiencies of sampled households were 0.66. Results of the Tobit model show that the farmer's experience, credit access, soil fertility, household head, education, and farming system positively and significantly affect economic efficiency. Whereas, the distance from the market has a negative and significantly affects economic efficiency. The grass pea producer farmers in the study area could increase their economic efficiency by 0.34. Therefore, the study suggested the above-mentioned significant variables are necessary for policy implications in agricultural development so that the government may give fruitful attention to the existing level of inefficiency of farmers in grass pea production in the study area.

Keywords:- Economic Efficiency, Stochastic Frontier Model, Tobit Model

INTRODUCTION

Agriculture is the brake of all most African countries (AC) economies and political achievements. In Africa, especially in sub-Saharan African countries (SSAC), agriculture is the largest opportunity for overcoming economic achievement, reducing hunger, and maintaining food security, (Chiona, S., 2011). In particular, the agricultural sector of Ethiopia is the target point of economic development for the five-year growth and transformation plan (GTP). Based on the strategy, the smallholders are the major interesting body with attention on maximizing production by improving different technologies which is a crucial effort to attain food security, increase export earning, efficient mobilization, and utilization of scarce resources, (Solomon, B., 2015).

Accordingly, crop production is the soul of the economic performance of Ethiopia, the life standard of society, and the main saddle sector to food security (Moges, D., 2018). However, Ethiopia was well known as the largest receiver of food aid in Africa, receiving above 30% of the

global food aid given to sub-Saharan African countries mostly imported wheat. (Aderajew, G & Melkamu, M, 2020). In 2020 alone, due to low agricultural productivity, low consumer associations, unstable governments, civil war, and less private sector development, Ethiopia imported 1.5 million MT of agricultural products, which counts 30% of total domestic consumption, primarily from Ukraine, Russia, and the USA through trade (CSA, 2020).

In Ethiopia (CSA, 2018), the most grass pea-producing areas include Moret ena Jiru parts of Shoa, Dawunt, and Wadla part of North Wollo and Delanta, Tenta and Mekdela part of South Wollo and Tach-Gaint and Lay-Gaynt in south Gondar is the most mentioned. Grass pea is produced two times a year as winter (Meher) and spring (belg) season.

Therefore, Dawunt is one of the districts in the Amara Regional State of Ethiopia in part of the north Wollo Zone, which has high production of grass pea, which is

*Corresponding author: abexfen65@gmail.com

Received: 13-01-2024, Accepted: 19-12-2024, Published: 31-12-2024

Copyright: © The publisher, 2024, Open access. This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format as long as you give appropriate credit to the original author(s) <http://creativecommons.org/licenses/by/4.0/>.

Journal-homepage: <https://abjol.org.et/index.php/ajbs>

included in the ranking level productivity of the grass pea product in the north Wollo zone. Dawunt Woreda is unmasked to climate variability and change-induced hazards such as drought, flood, frosty weather, rust, land erosion, and erratic and heavy rainfall that affect the environment and agricultural production. These, climate variability leads to low agricultural production and productivity, poverty, and food insecurity.

In Zambia, the study was conducted to investigate the sustainability of Agricultural Informatization and Technical Efficiency in Maize Production by using Cobb-Douglas (CD) stochastic production frontier (SPF) to estimate the farmer technical efficiency score and propensity score matching to analysis factor that affects technical efficiency of the farmer. They found that family size affects the farmer's technical efficiency positively and gender of the head, experience, and education negatively affect the maize productivity of the farmer, (Mwalupaso, et al 2019)

In Ethiopia, according to (Tesema, T, 2021), the main determinants of allocative and economic efficiency in crop-livestock integration in the western part of Ethiopia are cropping season, the efficiency of smallholder farmers was affected by the extension, off-farm, and education levels of households positively. While economic efficiency is positively affected by credit use, terrace and extension service positively and distance to the market negatively.

Another study was conducted for the Economic Efficiency of Smallholder Farmers in Rice Production in the Case of Guraferda Woreda¹, SNNP Region of Ethiopia. The Cobb-Douglas stochastic production frontier approach to estimate the economic technical, and allocative efficiencies score and the Tobit model was used to identify determinants that affect the economic technical and allocative efficiency of the smallholder farmer. Accordingly, education, frequency of extension contact, and cooperative membership positively affected the farmer's economic technical, and allocative efficiency level, and variables like proximity to market and non-farm income affect negatively the farmer's economic, technical, and allocative efficiency (Meles, et al, 2019).

(Tesema, T, 2021, Gezahegn, 2022 and EDOSA, 2018) also realized that factors that affect the efficiency of grass pea production on farms, either directly or indirectly determined, are environmental, farmer barnyard, and institutional factors. Institutional factors such as land ownership, economic system and market infrastructure, credit service, and extension service have a significant effect on the efficiency of grass pea production. (EDOSA, 2018) defined that extension service, credit

service, and access to markets are important institutional factors that directly affect smallholder farmer efficiency. According to (Gudeta M.A, 2020) productive efficiency among farmers can be explained by environmental factors, such as coverage of vegetables, altitude, amount of rainfall, and others. Farmer Characteristics Level of the producer's literacy and years of farm experience, the farming system significantly affects the smallholder farmer production and controlling capacity.

However, the above-mentioned factors are not equally significant and different from one place to place at one time. The most significant factor in one place at a defined time may not necessarily be a significant factor in other places even in the same place after some time, since social development is dynamic and their study is restricted to only one district it does not represent the other district. On the other hand, there has not been any study done on the economic efficiency of smallholder grass pea products in the study area.

Likewise, no research considered the Farming system as an explanatory variable to measure the economic efficiency of crop productivity. In this study, therefore, the researchers used the stochastic frontier model in the 2020/2021G.C production year and the study has attempted to fill the existing methodological, study area, and time gaps and tried to measure the economic efficiency of the farmers with its main determinants in the study area. Thus, the objective of this study is to assess the economic efficiency of smallholder farmers in the production of grass peas in Dawunt Woreda: north Wollo Zone, Amhara region, Central highland of Ethiopia

LITERATURE REVIEW

Theoretical Review

Grass pea (*Lathyrus sativus* L.) has been cultivated worldwide from ancient to the present time and grass pea is one of the protein cheapest sources of dietary in the under-developed world and has very high economic significance, especially in developing nations including India, Bangladesh, Pakistan, and Ethiopia, (Dixit, et al 2016a)

In the Ethiopian mostly Amara region especially the Dawunt Woreda in Wollo Zone, grass pea is the dominant product next to teff and wheat. Therefore, in addition to food, farmers prefer to produce grass pea also to its income source significance and market share contribution. The residue of grass pea is among the major sources of animal feed, which is largely consumed by oxen and sheep for dry lot finishing, (DWAO 2022). According to (DWAO 2022) report shows that farmers who live in the Dawunt Woreda use 35% of their total farmlands for grass pea yield. Thus, it implies that a higher amount of grass pea yield and households

¹ District level

consume grain in large amounts and various forms, mainly during food shortages and famine periods.

There are three types of efficiency the first one is Technical efficiency (TE) can be defined as measuring the comparative capability of the farmers to get the maximum output within the present level of input technology (in case of output-oriented) or get the present amount of output yield in reducing the present input quantity (in case of input-oriented) and it is measured by comparing the observed output against the feasible (frontier) output. It is a technology science concept and refers to the physical input-output relationship (Asfaw.M.D & Ali, B.M 2022).

Allocative efficiency can also be defined as the average value of total costs of getting a given output using actual factor proportions in a technically efficient manner (Wollie et al., 2018). Which described that, $0 < AE < 1$. Following the same line of reasoning, $1 - AE$ measures the maximal proportion of cost the technically efficient firm can save technically in a cost-minimizing way $AE=1$ smallholder farmers are allocative efficient. (Tesema, T 2021)

The economic (production) efficiency (EE) is defined as the capacity of the smallholder farmer to produce a well-defined amount of cereal yield at a minimum cost for the present value of technology, (Bati, M 2020). It is the summation of output efficiency (TE) and price (AE) efficiency. Economic efficiency is a summation of both technical efficiency and allocative efficiency outcomes.

In general economic efficiency lies between zero and one if $EE = 1$ implies that the smallholder farmer was both technically and allocative efficient is said to be economically efficient. $1 - EE$ is therefore the largest proportional minimize in input and maximize price that can be achieved in crop production., diagrammatically distinguished between technical and allocative efficiencies using both input and output-oriented measures (Aminou, F.A and 2021 and Firsu, T.E, 2019).

Empirical Review

The Studies were conducted to analyze Technical and Economic Efficiencies in Lentil Production by using Cobb Douglass stochastic frontier model to specify the level of economic, allocative, and technical efficiency and the Tobit model was used to identify the factor that affects the efficiency of the farmer Shawkat .M & Corp.D,(2015). The result indicated that the average technical and economic efficiency indices of small-scale lentil farmers are 67.94% and 72.32% respectively. As a result, the education level of farmers, land fragmentation, soil fertility, livestock ownership, and frequency of extension contact were important factors that affected the

technical, allocative, and economic efficiency of farmers positively.

The study conducted by (Tesema, T, 2021) analyzed the Determinants of allocative and economic efficiency in crop-livestock integration in the western part of Ethiopia evidence from the Horror district. From the results of the data envelopment analysis mean allocative efficiency was (57.0%) and economic efficiency was (38.4%). The efficiency of smallholder farmers is affected by the extension, off-non-farm, and education levels of households positively. While economic efficiency is positively affected by credit use, terrace and extension service positively and distance to the market negatively.

Another study conducted by (Gezahegn, 2022) to estimate the Economic Efficiency of Smallholder Farmers in Teff Production in Libo Kemkem Woreda, South Gondar Zone, Amhara, Ethiopia. Cobb-Douglas production function was fitted using the stochastic production frontier approach to estimate technical, allocative, and economic efficiencies scores, and the Tobit model was used to identify factors affecting the technical, economic, and allocative efficiency of the sampled farmers. The result estimated average values of technical, allocative, and economic efficiencies were 70%, 50%, and 35.47% respectively.

Similarly, the study was conducted on the economic efficiency of sesame production in the Babogambel district Oromia region, Ethiopia by using Cobb Douglass stochastic production function to estimate technical, allocative, and economic efficiency scores, and the Tobit model was used to identify factors affecting the inefficiency of the smallholder farmer. According to the result the average technical, allocative, and economic efficiencies of sample households were 75.16%, 72.95%, and 53.95%, respectively and the non-parametric result revealed that family size, experience, extension contact, soil fertility, and education level affect technical, allocative, and economic efficiency positively, (Fufa. W, 2016)

However, there has not been any study done on the economic efficiency of smallholder grass pea products in the study area as far as Ethiopia. Besides, no research considered the Farming system as an explanatory variable to measure factors influencing household grass pea consumption and implication for lathyrism in the study area, by using the Heckman selection model. Hence, this research used very recent data and the stochastic frontier model so as to fill the existing methodological, time gap and tried to measure the economic efficiency of the farmers with its main determinants in the study area.

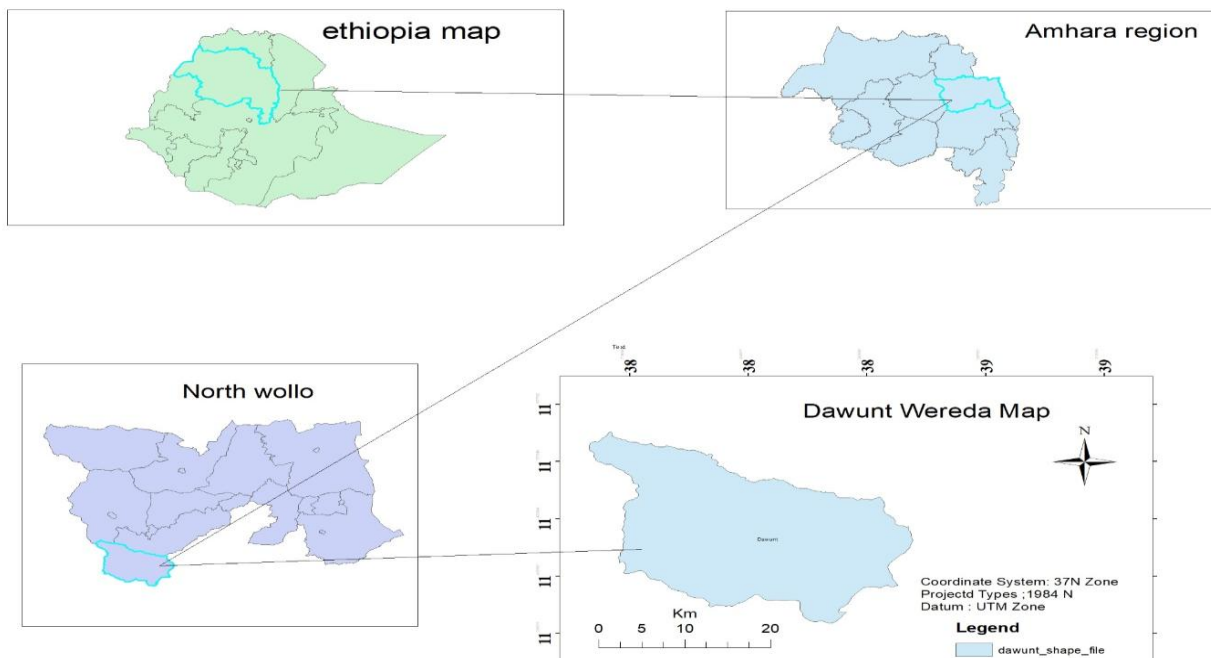
RESEARCH METHODOLOGY

Description of The Study Area

Dawunt district is located in the North Wollo Zone of the Amhara National Regional State of Ethiopia. According to the major landforms in the study area are plateaued. And Beshilo River is the largest river throwing from the district and shortly joins the Abay River. The plateau parts have gained high rainfall during the summer season, Cereals and pulses are the major crop types grown in the Figure 1: Map of the Study area

Dawunt district. Grass pea is the widely cultivated crop in the plateaus of study sites (DWAO, 2022).

The major crops grown in the area are teff, wheat, chickpea, lentils, and grass pea which are mainly rain-fed and the animals that are found in the area are horses, mules, donkeys, goats, and sheep. Horses and mules are used for transportation and farming purposes (DWAO, 2019).



Source: draw from Google earth (2023)

Method of Data Collection

For this study, both primary and secondary data sources will be used. Primary data is collected through personal interviews by employing data collection instruments or questionnaires with a structured interview schedule and key in a format discussion on the 2020/2021 grass pea production period. The primary data incorporated issues on the demographic and other characteristics of farmers, institutional factors, and input types. The secondary data include both published and unpublished documents which would be collected from the Agriculture office, Research Centers, and Central Statistical Agency.

Sampling Technique

In this study, multi-stage sampling techniques will be employed to attain accurate cross-sectional data from sample households in Dawunt Woreda. In the first stage, the Dawunt district is purposefully selected because of

the presence of high-intensity grass pea yield. In the next stage, 4 kebeles² as listed in Table 1 were selected by employing simple random sampling techniques from 12 Kebeles of the district, which have higher potential under the grass pea production base. In the third stage, we selected 360 smallholder farmers out of a total of 3600 smallholder farmers by using a simple random sampling method through the (Yemane, 1967) random sampling formula. Finally, we distributed the total sample for each sample Kebele through the probability proportionality size of each Kebele as follows.

$$n = \frac{N}{1 + N(e^2)} = \frac{3600}{1 + 3600(0.05^2)} = 360$$

Where n= sample size, N=number of people, e= error term and 1= constant

² Local level Administrative units in Ethiopia

Table 1: Sample determination

No.	Kebeles	Total S/farmer	Sample
1	Gersa	900	80
2	Debir	800	75
3	Yekendat	1150	115
4	Fensiha	750	90
	Total	3600	360

Data Analyses

The researcher used descriptive statistics inferential statistics, and econometric methods to interpret the data. Descriptive statistics used to describe farm characteristics in this study are mean, standard deviation, percentage, and frequency.

Econometric Analyses

According to (Asfaw.M.D & Ali. B.M, 2022), there are three types of efficiencies; the first one is Technical efficiency (TE). The technical efficiency lies between zero and one if TE = 1 implies that the smallholder farmer is producing on its production frontier and is said to be technically efficient. 1- TE is therefore the largest proportional reduction in input that can be achieved in the production of the output and if TE= 0 the smallholder farmer is technically inefficient (Msulwa.G.E et al, 2020).

The second is allocative efficiency (AE), which arises when inputs of production are used in a proportion that minimizes the costs of producing a given level of output. Allocative efficiency can also be defined as the average value of total costs of getting a given output using actual factor proportions in a technically efficient manner. Which described that, 0 < AE < 1. Following the same line of reasoning, 1 - AE measures the maximal proportion of cost the technically efficient firm can save technically in a cost-minimizing way AE=1smallholder farmers are allocative efficient, (Tesema T, 2021)

The last one is economic (production) efficiency (EE) defined as the capacity of the smallholder farmer to produce a well-defined amount of cereal yield at a minimum cost for the present value of technology, (Bati, et al, 2017). It is the summation of output efficiency (TE) and price (AE) efficiency. The economic efficiency lies between zero and one if EE = 1 implies that the smallholder farmer was both technically and allocative efficient and is said to be economically efficient, (Aminou.F.A, 2021) and Firs. T.E, 2019).

Stochastic or parametric measurement

The econometric estimation method stochastic frontier approach was employed to estimate the level of economic efficiency score, and the Tobit model was used to identify

the factors that affect the efficiency of the smallholder farmer who produces grass peas.

Economic efficiency is analyzed by employing both the cost frontier and production frontier for estimating farm-specific economic efficiency. According to (Borko.M.P, 2021) when the data on prices at hand and that the farmers minimize costs can estimate the economic characteristics of production technology and predict cost efficiency using a cost frontier and also it states that in the case where there is across-sectional data. Research conducted by (Fufa.W, 2016) also suggests that the corresponding dual cost frontier of the Cobb-Douglas production functional form is a ratio of the minimum cost to the observed cost for a given level of output and prices. Symbolically,

$$C_i = f(\beta, R_i, Q_i) \tag{1}$$

Where: C_i is the observed cost of the i th smallholder farmer, R_i = input price reported by the i th smallholder, Q_i is the total output produced by an i th smallholder which is adjusted for noise v_i .

The frontier gives the minimum cost of producing a specified amount of output (Q) at given prices the minimum cost is derived analytically from the production function, using the methodology.

$$\begin{aligned} \frac{\partial C_i}{\partial R} &= x_i (R_i, Q_i, \beta) \tag{2} \\ \text{Min} \quad \sum_{j=1}^6 \beta_j x_j R_i & \tag{3} \\ \text{Subject to} \quad Q &= \hat{A} \hat{\beta}_i X_i \tag{4} \end{aligned}$$

Where; $\hat{A} = \text{Exp}(\beta_0)$

Output adjusted for stochastic noise (predicted value of yield) in the minimization problem above, the dual cost function can be written as follows

$$C(Q, R) = S Q^{u_i} R^{a_i} \tag{5}$$

Where; $a_i = u_i \beta^u$ $u_i = \sum \beta^u - 1$ and $S = \frac{1}{u_i} (A^u \beta^u)$

The efficient dual cost function can be specified as follows:

$$\ln C_i = \alpha_0 + \sum_{j=1}^n a_j \ln R_{ji} + \alpha_n \ln Q_{ivi} + u_i \tag{6}$$

Where $\ln C_i$ -Denotes the logarithm of the cost of production of the i th firm; R_{ji} Denotes a vector of inputs price, Q refers to adjusted farm output for noise v_i ; α_0 , α_j , and α_n are parameters to be estimated and u_i is the non-negative variables representing economic inefficiency of the i th household, v_i is a symmetric

random variable representing errors and other sources of statistical noise.

$$\ln(CY) = \beta_0 + \beta_1 \ln R \text{ land} + \beta_2 \ln R \text{ seed} + \beta_3 \ln R \text{ labor} + \beta_4 \ln R \text{ oxen} + \beta_5 \ln R \text{ DAP Fertilizer} + \beta_6 Q_{vi} + u_i \dots \dots \dots 7$$

According to (Aigner.D, et al, 1977) the cobb-Douglas function for the model assumes a half-normal distribution for the economic efficiency effects (UI). They expressed the likelihood function using parameterization, where is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. $\lambda = \frac{\sigma_u}{\sigma_v}$). However, (Battese.E.G & Corra. S.G, 1997) proposed that the parameterization, where, $\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$ or $\gamma = \frac{\lambda^2}{1 + \lambda^2}$ be used instead of λ . The reason is that could be any non-negative value that ranges from zero to one and better measures the distance between the frontier output and the observed level of output.

According to (Mutoko M.C, 2015) Value is between zero and one. When it approaches zero, there is no economic inefficiency among the model or most of the present variations are due to random noises that are over the control of smallholder farmers, and approach 1, there is high economic inefficiency from the model or most of the variations are come by technical or economical inefficiency.

Mathematical (DEA) Model

After quantification of economic efficiency measures in SFA, a second stage analysis is a regression of measures on several hypothesized socio-economic and institutional factors affecting the inefficiency of farmers. Economic and efficiency estimates that were derived from stochastic production frontier were regressed using a censored Tobit model on farm-specific explanatory variables that explained variation in efficiency across farms. The rationale behind using the Tobit model is that there are many farms for which an efficiency score is an approach to one and the bounded nature of efficiency is between zero and one, (Gujarati, 2004).

According to (Green, 2003) , the Tobit (Censored Regression) model is specified as:

$$P^* = \sum_{j=1}^N \beta_j Z_j + \mu_i \dots \dots \dots 8$$

Where P_i = inefficiency scores of allocative, technical, and economic inefficiency of the *i*th farm.

β_j = parameters of interest to be estimated, and μ_i error term $u_i \sim N(0, \delta^2)$

Z_{ij} = socio-economic, institutional, and demographic variables that are expected to affect inefficiency scores.

The reduction form of Censored-Tobit regression:

$$P^* = \beta_0 + \beta_1 \text{ credit service} + \beta_2 \text{ education level} + \beta_3 \text{ extension service} + \beta_4 \text{ experience of farm} + \beta_5 \text{ distance from market} + \beta_6 \text{ soil fertility} + \beta_7 \text{ plowing frequency} + \beta_8$$

$$\text{sex of household} + \beta_9 \text{ form of ownership} + \beta_{10} \text{ Farming system} + u_i \dots \dots \dots 9$$

Variables in Economic Efficiency Measurement

OUTPUT (Y): It is the amount of grass pea output that would be attained from the given factor of production in cropping season by the sample farmer through rain-fed farming and measured in kilogram (Wongnaa, 2016)

INPUT: Defined as the factor of production used in the production of Grass Pea namely:

LAND: It is the total area of the plot(s) used for the production of grass peas during the production year by each sample smallholder farmer. During the survey, the data on the size of the land was collected in terms of GEMED (one-fourth of a hectare) which was later converted to a hectare (Solomon.B, 2015).

LABOR: It is the total amount of labor force used for different agronomic practices (plowing, planting, weeding, cultivation, and harvesting) of grass pea products during the production season. It includes both family labor and hired labor.

SEED: It refers to the total qualitative quantity of grass pea seeds in kilograms by each sample farmer.

OXEN: POWER: It is the amount of oxen-power employed for plowing grass pea land preparation to planting and measured in oxen days by each sample farmer.

Fertilizer: Fertilizer is a key input and its application along with other technologies will have a great potential to increase crop productivity. The total amount of DAP fertilizer in (KG) used for grass pea production.

Dependent variable: technical, allocative, and economic inefficiency score of grass pea output (P*) in 2012/13 E.C cropping season.

Independent Variables:

Credit service (credit): this is a dummy variable that represents access to credit service for grass pea production purposes for smallholder farmers. If the farmer has taken credit during the given production season, take variable takes a value of 1, and otherwise 0. This study is supported by (Ali.B.M, 2014).

Education (Education): The education level of smallholder farmers is a continuous variable and necessary for knowledge of how to manage grass pea production barnyards, and educated farmers can understand, the advantages of new technologies more easily than illiterate smallholder farmers. Therefore, smallholder farmers with high education levels were expected to be efficient for grass pea production. This hypothesis is supported by (Gebr, 2022).

Extension contact (Extension): this variable is measured as a continuous variable of the frequency of contacts with extension workers in a production year. Access to extension services as a bridge for the flow of new information and innovation to improve the level of economic efficiency, (Gezahegn, 2022).

Form of ownership (Ownership): it is a dummy variable that assigns the value, 1 if a smallholder participates in grass pea production on rented or shared land and 0 if smallholder farmers participate only on their land in grass pea production. So there is an inverse relation between economic efficiency and form of ownership. .

Farming experience (Experience): It was measured as a continuous variable and the experience of farming had a direct relation to smallholder farmers' grass pea production economic efficiency.

Distance to input and output market (Distance): this is a continuous variable. The smallholder farmers far from the market are not more advantageous for farm inputs, the market price of output, information, transportation, and other costs. An increase in the distance of farmer residence in the market area has an inverse relation to the farm's technical and economic efficiency level (Gebr.K, 2022).

Soil fertility (Fertility): It is considered a discrete variable that takes a value of 2 if a household head perceives his plots as fertile, 1 if a smallholder farmers have semi-fertile land 0 if the smallholder farmer has poor fertile this type of land has very low productivity and cannot produce without the application of any inorganic fertilizer. Since fertile lands under good management provide high yields and reduce the number of input costs than less fertile and poor land, it is assumed to reduce the level of inefficiency of a farmer (Gudeta.M.A, 2020)

Ploughing frequency (Frequency): The frequency of ploughing is a continuous variable that denotes the number of ploughing before sowing. Plowing prevents weed infestation and improves aeration which favors faster and healthier plant growth. The hypothesis was that the farmer who ploughs more frequently is more efficient than one who ploughs land less frequently.

Sex of the household head (Sex): This is a dummy variable that takes a value of one if the household head is male and zero if the household is female. They expected the production of male-headed smallholder farmers higher than that of female-headed smallholder farmers who produced grass peas, (Edosa.T.T, 2018)

Homestead animals (Animal): It is a continuous variable measured in number. It is the amount of livestock used for farming activity. The smallholder farmer agricultural system in the study area depends on livestock mainly oxen, horses, and mules for cultivation. Therefore, it is expected that the larger the number of homestead animals the smallholder farmer, ability to cultivate more land would be increased (Wollie, et al, 2018).

Farming System: It is a dummy variable, which takes the value of 1 farmer who farms a transverse (horizontal) farming style in grass pea production and 0 if a farmer farms a downward farming (vertical) style in wheat and legume production. For a farmer who uses the transverse farming style, the productivity of the grass pea product is very efficient compared to that of the borrowing farm style.

RESULT AND DECISION

In this unit, we described the socio-demographic, personal, natural, and institutional factors that the farmer is employed and econometric analyses of the sample smallholder farmers who produce grass peas.

Descriptive Analysis

As shown in Table 1 below, the intermediate farming experience of a sample smallholder farmer in grass pea production was 24.91 years at a standard deviation level of 11.77751. In the sample, the intermediate education level of literate sample smallholder farmers during the survey period was grade 7 and a standard deviation of 4.740 with a minimum of zero years (illiterate) and a maximum of 15 years. The survey result indicated that 132 smallholder farmers are female-headed in this 42 are hookers the rest are male headed.

As the table shows only smallholder farmers participated in the transverse farming style but the remaining smallholders applied vertical or downward farming style in the study area. Traditionally, more sampled farmers in the Dawunt district farm in the downward farming style. Soil fertility is a natural gift material used to improve the productivity of smallholder farmers by improving the different minerals and that the farmer prospect to employ new and improved output for the standard deviation of 1.06666.

About the sample, 115 smallholder farmers farm very fertile soil type on their farms and are more productive, and 154 smallholder farmers farm medium fertile type of soil locally well known by "Entorma" and the remaining perceived them to be an infertile type of soil.

The number plowing frequency indicates an intensity of land preparation before sowing that helps for proper germination of the seed, improvement of sprouting grains, improves fertility and reduces the usage of

fertilizer it was expected to have a direct impact on productivity.

The survey result signifies that above 70 sample smallholders had no oxen plowed by other livestock such as horses and mules, while the remaining sample smallholders owned several oxen livestock and farmed by oxen livestock.

The distance between the smallholder farmer residences' homes from the market area is located from a minimum of 0.1 kilometers up to the highest value of 6.5kilometersrs its mean and standard deviation of 3.704 and 2.11 respectively. Accordingly, the survey result, on an average sample of smallholder farmers 3.7 kilometers from the market area allocates different inputs to the smallholder farmer residence house

Livestock has various attributes to smallholder farmers in the mixed farming system for agro-economic production, income contribution, and food security, acts as a profile of affluence, and plays a significant role in social status within the community. Farmers in the Dawunt district use oxen, horses, and mules to take different agronomic

practices, out of which plough and threshing were the major ones.

In the study area, any household owned 8-10 Gemmed of land. In general, about the total of 360 samples, smallholder 203 smallholder farmers sow grass pea from their barnyard remain 157 smallholder farmers of sample smallholder sow grass pea rent and share barnyard. According to our survey data sample, the smallholder farmer was visited by extension workers a minimum of 0 times and a maximum of 4 times during the grass pea production year. In general the average extension contact of smallholder farmers from the DA server is 1.9555 times yearly (almost 2 times) and a standard deviation is 1.3633 respectively.

Most of the sample smallholder farmers attain credit service from formal and informal sources to purchase seed inputs, fertilizer input, hired labor, rent oxen power, buy livestock and food items as well as start-up capital for non/off farm participation purposes at a mean of 0.64444 and standard deviation is 0.4793475.

Table 1: Description of in efficiency factor

Variable name	Obs	Mean	Std. Dev.	Min	Max
Experience	360	24.9055	11.7777	4	60
Education	360	7.052778	4.74003	0	15
Sex of head	360	0.633333	0.4883	0	1
Farming system	360	0.6194444	0.4861992	0	1
Farming frequency	360	2.333333	1.089325	1	4
Soil fertility	360	1.066667	0.754559	0	2
distance	360	3.704861	2.110911	0.1	8.5
homestead animal	360	2.855556	1.955272	0	8
Credit	360	0.6444444	0.4793475	0	1
Extension	360	1.955556	1.363357	0	4
Ownership	360	0.4361111	0.4965916	0	1
Off farm Income	360	0.6222222	0.4855064	0	1

Source: own competition (2023)

As shown in Table 2 below, in the study area sample, smallholder farmers engaged in off-farm activity in addition to farming activity is based on the participation of different off/non-farm income sources during the given production year at a mean and standard deviation of 0.6222222 & 0.48550645 respectively.

The minimum level of grass pea seed is 4 kg and the maximum requirement is 87 kg. The average value of seed is 28.4667 kg and the minimum requirement of seed is 4 kg and the maximum requirement is 87 kg. In this production process on average, 13.21042 kg of inorganic fertilizers (DAP) and the minimum fertilizer requirement for grass pea production is 1.25 kg and the maximum usage of fertilized is 42 kg. The minimum land was 0.075 hectares of land and the maximum was 3.75 hectares.

On average farmers put 0.8637907 hectares of their land under grass pea production and the standard deviation was 0.6865114.the average amount of seed planted per hectare was 28.4667 kg of local seed and their standard deviation is 20.87568 kg.

The minimum usage of the labor force was 3 labor force and the maximum was 43 labor force for grass pea production. On average farmers put 12.12222 units of labor force either hired power or family power of their under grass pea production and the standard deviation was 7.097142. Plowing and sowing were mainly done using oxen power horses and mules by hand hoeing. Oxen power is the average value of the farmers put 9.941667 and the standard deviation of grass pea production was 6.147168. The minimum requirement of

oxen power is 2 oxen and the maximum usage of oxen power is 36 oxen power.

On average barnyard is value of the farmers put 0.8637907 and the standard deviation of grass pea production was 0.6865114. The minimum requirement of

barnyard is 0.075 ha and the maximum usage of barnyard is 3.75ha. The average value of fertilizer is 13.21042 kg and standard deviation is 7.784595 the minimum requirement of seed is 1.25 kg and maximum requirement is 42 kg

Table 2: Summary statistics of variables used to estimate the production function

Variable name	Obs	Mean	Std. deviation	Minimum	Maximum
seed	360	28.46667	20.87568	4	87
fertilizer	360	13.21042	7.784595	1.25	42
land	360	0.8637907	0.6865114	0.075	3.75
labor	360	12.12222	7.097142	3	43
oxen	360	9.941667	6.147168	2	36
output	360	821.4833	898.7438	20	4152

Source: from own survey (2023)

Econometrics Analysis

Inferential and other statistical tests

The results for the tests for heteroscedasticity showed that the P values were < 0.05 so the model has no heteroscedasticity problem. The other one is the normality test of the model by using skewness and kurtosis tests. According to (Gujirati, 2004) $\text{Prob} > \chi^2$ value is < 0.05 the model has no normality problem and $\text{Prob} > \chi^2$ value is < 0.05 the model is normally distributed (appendixes 1-2).

Multi-collinearity test for all variables was also done using the Variance Inflation Factor (VIF) and contingency coefficient. The final result test for multicollinearity problems using both methodologies also stated that there is no serious linear problem among explanatory variables (Appendixes 5 and 6).

Goodness or fitness of model: According to the survey that the researcher collected from the sample smallholder the data was checked for the significance of the model by using the one variable t-test ratio for one continuous variable independently to check the fitness and goodness of the SFM and the chi-square test for categorical or dummy variable. The null hypothesis is that the model has not correctly fitted and the alternative hypothesis that implies the model has correctly fitted. The result showed that the values rejected the null hypothesis and accepted the alternative hypothesis because the p value < 0.05 which means the model has correctly fitted (Appendix Table 7-8).

Stochastic Frontier Analysis of Economic Efficiency

Hypotheses testing: The Hypotheses test check whether the economic efficiency levels were better estimated using a stochastic half-normal distribution of u or difficult to estimate the stochastic half-normal distribution (truncated) distribution. If the null

hypothesis is accepted stochastic half-normal distribution is the correct specification distributional assumption and rejecting the null hypothesis stochastic half-normal distribution is not recommended on this mode and use as truncated or other type of specification. The results indicated that the half-normal distribution was suitable for the sample households as the calculated LR value of 3.35 was less than the t-critical value of 11.07 at a 5% significance level with a degree of freedom equal to 5 so we would accept the null hypothesis.

The third hypothesis tested was that all coefficients of the inefficiency factor model correctly determine the inefficiency of a farmer are not correctly specified. In a study conducted by (ADERAJEW, 2018) to test this hypothesis log-likelihood ratio is calculated using the value of the log-likelihood function under the Cobb-Douglas stochastic frontier model. Coefficients of the inefficiency factor of the model simultaneously equal to zero ($H_0: = \delta_1 = \delta_2 \dots = \delta_{12} = 0$), otherwise, ($H_1: = \delta_1 = \delta_2 \dots = \delta_{12} \neq 0$). It means that the explanatory variables in the efficiency effect model do not contribute significantly to the explanation of the inefficiency variation for the grass pea output and against the alternative hypothesis, which states that all parameter coefficients of the inefficiency model are different from zero

The calculated t-value was obtained was 35.70, which is higher than the critical value of 19.68. The result shows that we reject the null hypothesis and accept the alternative hypothesis mean that the explanatory variables in the inefficiency effect model highly contribute significantly to the explanation of efficiency variation for grass pea-producing farmers (Appendix Table 9).

Table 6: Economic efficiency result

Variable name	coefficient	standard error	z value
Ln R seed	-0.1667904***	0.0442973	-3.77
Ln R fertilizer	0.1840628**	0.0916327	0.91
Ln R land	0.8636551***	0.0714461	12.09
Ln R labor	0.0465502	0.0512932	2.01
Ln R oxen	0.813864***	0.090829	8.96
Ln y	0.0342265	0.0992772	0.34
Constant	2.590138***	0.7971757	3.25
Sigma v	0.2046319	0.0235254	
Sigma u	0.5152113	0.03942	
Sigma square	0.3073169	0.035094	
lambda	2.52	0.0576123	
gamma	86.4		
Log-likelihood	-142.7		
return to scale	1.7755		

Source: from own competition (2023)

In the economic frontier function, most of the variables carried the expected positive signs except seed. The coefficients of observed cost of seed, Oxen cost, and cost of land were significant at 1%, while the cost of fertilizer was statistically significant at 5% level coefficients of output (Y^*) adjusted for statistical noise and cost of land were statistically insignificant. The gamma (γ) estimate was 0.864 and was significant at the 1% level indicating that 86.4 % of the variation in minimum cost was caused by economic inefficiency.

The returns to scale analysis were used to measure total factor productivity. (Gezahegn, 2022). The coefficient was calculated to be 1.7755, which is increasing returns to scale. This implies that there is interest for grass pea producers to improve their production because they are in the initial stage of the production function. In other determination, a one percent increase in all inputs proportionally will increase the total production by 1.7755%. Therefore, an increase in all inputs by 1% would increase grass pea production by 1.7755%. This is

Table 3: Summary statistics of efficiency score of sample households

Variables	Obs	Mean	Std. deviation	Min	max
EE	360	0.6634024	0.1680197	0.134055	0.9583228
TE	360	0.7145138	0.1353903	0.1774087	0.9227968
AE	360	0.6981858	0.1170579	0.179374	0.947056

Table 1: Summary of inefficiency score

Source: own survey (2023)

Economic Efficiency (EE)

Experience:-The Experience has a significant and positive significance in 5% of significance levels. Farmers who have stayed long in the venture have learned how to combine scarce resources given the level of technology well, thus increasing the level of

consistent with the results of (Edosa. T.T 2018 and Gudeta, M, A, 2020)

Determinants of the efficiency of Grass pea production

The outcome of the efficiency scores described that there were wide ranges between grass pea producer smallholder farmer TE, AE, and EE. The average economic efficiency (EE) of sample smallholder farmers during the production year was 0.6634024. Economic efficiency among the smallholder farmer ranges from 0.134055 to 0.9583228, with a standard deviation of 0.1680197. The average economic efficiency shows that an economically efficient household can reduce his/her grass pea production cost by 0.365976 (33.66%).

Similarly, the average technical efficiency (TE) and allocative efficiency (AE) of sample households were 0.7145138 and 0.6981858, respectively. Generally, there is a considerable amount of efficiency variation among grass pea producer farmers in all measures of efficiency.

efficiency, adopting different characteristics of grass pea products, land characteristics, sowing weed season, and agricultural inputs (like seed and fertilizer). Therefore, in our study experience of smallholder farmers had a significant and positive effect on improving farmer's

efficiency. This line with, the study by (Shawkat.M & Corp.D, 2015)

Sex:-The sex of the household head has a direct relation and significant impact on the economic efficiency of smallholder farmer grass pea producers at a 1% level which implicated that the male smallholder farmer head was more economically efficient than that female-headed smallholder farmer. This is because females in rural Ethiopia take various responsibilities including fetching water from the far distant river, child caring, and household management but cannot farm, sow, and manage their barnyard. In addition to the above, they added responsibility for farm management tasks that stubborn the burden. Such multiple responsibilities combined with fewer inputs access and ownership would likely lead to more frequent and perhaps severe economic and social shocks that in turn decrease their efficiency. The result is in line with Asfaw.M.D, et al., (2019).

Education:-The literacy status of the household head can be directly controlled by the managerial capability of the farmer and had a positive effect on economic efficiencies of smallholder farmers at a 1% significant level. This describes that educated smallholder farmers are more economically efficient than illiterate smallholder farmers. Hence, literate smallholder farmers always have quickly adopted improved technology, and quickly understand the idea of an agriculture extension service officer. This is in line with the study results of (Bati, M, et al 2017; (Milkessa, 2019; and Edosa. T.T, 2018).

Fertility of land: - It had a positive effect on economic efficiency level at a 1% level of significance respectively. This implies that the smallholder farmers having fertile barnyards were more efficient than the smallholder farmers who had poor fertile land. This may be interlinked with the fact that fertile lands are more productive, and require small amounts of fertilizer which leads to a reduction in cost and time, not affected by

disease, tare, and pest leading to improved efficiency of smallholder farmers. This finding is interlinked to those (Solomon.B, 2015 and Bedasa. Y, 2020).

Credit: In this study, the amount of credit affected the economic efficiency of farmers positively at a 5% level of significance. This implies that credit availability shifts the cash constraint outwards and thus enables farmers to make timely purchases of inputs that they cannot afford. The result is consistent with the findings of (Kamau.P.N, 2019 and Ali, B, M, 2014).

Distance from the market: - It has a negative impact and affects the economic efficiency of farmers at a 1% significance level. The reason that farmers living far from the marketplace makes it difficult to fulfill different imputes easily and convert their production to other crops that reduce the productivity of grass peas. This indicates that as the distance of the market from home increases economic efficiency decreases. This result is related to the findings of (Aderajew, G, 2018 and Gudeta, M A, 2020).

Farming system: - The farming style has a direct relation and significant impact on the economic efficiency of smallholder farmer grass pea producers at a 1% level of significance which implies that the farming style was horizontal (transverse) more economically efficient than those smallholder farmers who farm vertical (downward). Vertical farming has been affected by erosion, weeds, low grass pea production, and water loadings. Because of this transverse farming style has greater grass pea production performance than the smallholder farmer who uses the vertical farming style.

Table 7. Tobit regression for Economic Efficiency (EE),

EE					
Variables	Coefficient	Std. Err	Variables	Coefficient	Std. Err
Constant	0.5601618***	0.0286165	Ownership	-0.010899	0.0096957
Credit	0.0184344**	0.0090964	Experience	0.0006411**	0.0003234
Education	0.0057503***	0.0013163	Off-farm	-0.0015527	0.0073296
Fertility	0.0780589***	0.0089773	Distance	-0.0258639***	0.0037629
Frequency	0.0072068	0.0048655	Livestock	-0.0037033	0.0038714
Sex head	0.0288282***	0.0077876	System	0.0373396***	0.0109152
Extension	0.0028067	0.0040615			
Legend	***=1level	** =5 level		*= 10 level	

Source own competition (2023)

CONCLUSION AND RECOMMENDATION

Conclusion

This finding was conducted on the economic efficiency of grass pea production in the Dawunt district Amhara regional state of Ethiopia. The study area was selected purposively, because of the high level of grass pea production, and a simple random sampling technique was used to select a sample smallholder farmer of 360 grass peas' producer smallholder farmers that correctly describe the population. Both primary and secondary data were used to survive data. The Stochastic frontier model was used to analyze the economic analysis. The study result described that land, DAP, and oxen power are variables that directly affect the production of grass peas, and the amount of local seed significant variable that affects grass pea production negatively. The final result in the average value of EE was 66%. In the second stage, two limits censored Tobit regression was used for EE was regressed as a function of 10 independent variables. Among them, credit access, education level, experience of a farmer, distance from the market, sex of head, soil fertility, and farming system ware affect the economic efficiency of smallholder farmers directly without distance from the market in the study area.

Recommendation and Policy Implications

The outcome of the study indicated that there are various choices to improve the efficiency of grass pea producers to increase grass pea yield.

- Credit service is used to increase economic efficiency directly through resolve financial problems and a smallholder farmer's face in purchasing different inputs in grass pea production. Therefore, the government body should have to adjust different financial institutions at the minimum interest rates, borrow minimum collateral, and support grass pea producer farmers financially to enhance farmers' technical and economic efficiencies..
- Education and Experiences were significant factor that affects positively enhanced economic efficiency. This is because education and experience can increase the farmers' capability to exploit existing technologies and attain higher efficiency level. Hence, investment on education and training should be taken into account as a central ingredient in development strategy to achieve improved production of grass pea productivity
- The study result shows that the residence of smallholder farmers closer to the marketplace is more economic efficient than that of those far from the marketplace. This indicates, that the government should adjust the location of the market and focus on

the development of market and road infrastructure to facilitate market participation based on the farmer's residence.

- Soil Fertility of grass pea barnyard was found to affect the economic efficiency of farmers directly. Therefore, the government body should maintain the fertility of the land, protect against erosion, and usage of natural fertilizers to esteem fertility by creating awareness among the farmers and introducing of creating new innovative technologies that enhance the fertility of the soil so that the efficiency of the farmer increases.
- The results of the study show that households headed by female heads were less economically efficient than households headed by male heads. Because females are too fussed by different homework, have less confidence, are affected by backward culture, and have less time to manage their barnyard. So the government body should give sermonize to a female household leader by supporting innovative technologies to improve their efficiency level in grass pea production.

REFERENCES

- Aderajew, G, & Melkamu, M. (2020). Technical Efficiency of Smallholder Wheat Producers in Simada District of Amhara Region, Ethiopia. *Development Country studies*, 1-24.
- Aigner, D., Lovell, K. C., & Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, 21-31.
- Ali, B. M. (2014). Farm Household Production Efficiency Analysis in Ethiopia: The Case of Dessie Zuria District Ali, Beshir Melkaw MSc Thesis Business Economics .*BEC-80436*.
- Aminou, F. A. (2021). Economic Efficiency of Small Scale Maize Producers in Benin. *African Economic Research Consortium*, 1-33
- Asfaw, M. D., & Ali, K. A. (2022). Review on Economic Efficiency of Vegetable Production in Ethiopia. *Science Publishing Group* : <http://www.sciencepublishinggroup.com/j/advances>, 16.24.
- Bati, M., Ayele, A., Tilahun, M., & Parbathina, R. K. (2017). Studies on Economic Efficiency of Coffee Production in Ilu Abbabor Zone , Oromia Region, Ethiopia. *Journal of Agricultural Economics and Rural Development*, 293-306.
- Battese, E. G., & Corra, S. G. (1997). Stimulation of A Production Frontier Model: With Application To The Pastoral Zone Of Eastern Australia. *Australian Journal of Agricultural and Resource Economics (AJARE)*, 169-179.
- Bedasa, Y. (2020). Bedasa, Y. (2020). Review on Economic Efficiency of Smallholders Farmers in the

- Production of Sesame: The Case of Ethiopia.. <https://doi.org/10.11648/j.jim.20200904.13>, 107-114
- Borko, M. P. (2021). Technical Efficiency of Maize Production in Meskan Woreda of Gurage Zone Technical Efficiency of Maize Production in Meskan Woreda of Gurage Zone. *Academic Research*, 336-342.
- Chiona, S. (2011). *Technical and Allocative Efficiency of Smallholder Maize Farmer in Zambia*. University of Zambia, Lusaka.
- CSA. (2018). Central Statistics Agency. Addis Ababa: Central Statistics Agency.
- CSA. (2020). Report on Farm Management Practices ((Private Peasant Holdings, Meher Season); The Federal Democratic Republic Of Ethiopia Central Statistical Agency.
- Dawit, D. G., Shimels, D., & Pheshendra, S. (2021). Factors influencing household grass pea consumption and Its Implication for lathyrism in Wollo Zone, Ethiopia (www.Elsevier.com, Ed.) *Scientific Africa*, 1-13.
- DAWO. (2022). Annual Report, Woreda Agricultural Office, Kone, South Wollo, Amhara Region, Ethiopia.
- Dixit, G. P., Parihar, A. K., Bohra, A., & Singh, N. P. (2016a). Achievements and prospects of grass pea (*Lathyrus sativus* L.) improvement for sustainable food production. *Crop Journal*.
- DWAO. (2019). *Dawint Woreda Agricultural Office Report*. Kone, South Wollo, Amhara Region, Ethiopia: Woreda Agricultural Office.
- DWAO. (2022). *Dawint Woreda Agricultural Office Report*. Dawint Woreda, South Wollo, Amhara Region, Ethiopia: Dawint Woreda.
- Edosa, T. T. (2018). Edosa, T. T. (2018). Economic Efficiency Of Smallholder Farmers In Maize Production in Gudaya Bila District, Oromia National Regional State, Ethiopia. *World Development*, 1-15.
- Firsa, T. E. (2019). Review on Economic Efficiency of Maize Production in Ethiopia. *Food Science and Quality Management*, 30-36.
- Fufa, W. (2016). Economic Efficiency of Sesame (*Sesamum indicum* L) Production In Babogambel District Of West Wollega Zone, Oromia. *Haramaya University*.
- Gebr, K. (2022). Doption Of Malt Barley þfarmHouseholds Livelihood; The Case Of Basona Worna District , North Shewa Zone.
- Gezahegn. (2022). Economic Efficiency of Smallholder Farmers in Teff Production: A Study in Libo Kemkem Woreda, South Gondar Zone, Amhara, Ethiopia.
- Green. (2003). *Fithe Edition: Econometrics Analysis*. New York University.
- Gudeta, M. A. (2020). Analysis of Technical Efficiency of Lentil Production .
- Gujarati. (2004). *Basic Econometrics. 4th Edition*. McGraw-Hill Companies.
- kamau, P. N. (2019). Kamau, P. N. . Technical, Economic And Allocative Efficiency Among Maize And Rice Farmers Under Different Land-Use Systems In East African Wetlands. <https://doi.org/1037//0033-2909.126.1.78>.
- Meles, T., Alemu, M., Mitiku , A., & Kedir, N. (2019). Economic Efficiency of Smallholder Farmers in Rice Production : The Case of Guraferda Woreda , Southern Nations Nationalities People ' s Region. *International Journal of Agricultural innovation and Research*, 151-167.
- Milkessa. (2019). Economic efficiency of smallholder farmers in wheat production: the case of abuna gindeberet district, western ethiopia.. <https://doi.org/10.15414/raae.2019.22.01.65-75>, 65-75.
- Moges, D. (2018). Measurement of Technical Efficiency and Its Determinants in Wheat Production : The Case of Smallholder Farmers in Wogidi District , South Wollo, Ethiopia. *Food Science and Quality Management*, 86.93.
- Msulwa, B., chamboko, R., Lee, C., Weideman, J., & Nordin, K. (2020). The impact of formal financial services uptake on asset holdings in Kenya: Causal evidence from a propensity score-matching approach. *African Review of Economics and Finance*, 1-23.
- Mutoko, M. C. (2015). Analysis of Economic Efficiency in Smallholder Maize Production in Northwestern Kenya Mwalupaso, G. E., Wang, S., Rahman, S., Alavo, E. P., & Tian, X. (2019). Agricultural Informatization and Technical Efficiency in Maiz Production in Zambia. www.mdpi.com/journal/sustainability, 1-17.
- Shawkat, M., & Corp, D. (2015). Addressing Technical and Economic Efficiencies in Lentil Production : An Assessment to Strengthen Food Policy Option Addressing Technical and Economic Efficiencies in Lentil Production : An Assessment to Strengthen Food Policy option .
- Solomon, B. (2015). *Economic Efficiency of Wheat Seed Production: The Case of Smallholders in Womberma Woreda of West Gojjam Zone. M.Sc. Thesis presented to the School of Graduate Studies of Haramaya University*. Haramaya University, Haramaya.
- Tesema, T. (2021). Determinants of allocative and economic efficiency in crop-livestock. *Helion ;journal homepage: www.cell.com/heliyon*, pp 1-7.
- Wollie, G., Zemedu, L., & Tegegn, B. (2018). Economic efficiency of smallholder farmers in barley production in Meket district , Ethiopia.. <https://doi.org/10.5897/JDAE2018.0960>, 328-338.
- Wongnaa. (2016). Economic Efficiency and Productivity of Maize Farmers in Ghana. <https://doi.org/10.13140/RG.2.2.19830.80962>.
- Yemane, Y. (1967). *Mathematical Formulae for Sample Size Determination*.

Appendixes

Appendix Table 1: Test of heteroscedasticity inefficiency component (Tobit model)

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of te

chi2(1) = 80.07

Prob > chi2 = 0.0000

Appendix Table 2: Test of heteroscedasticity for production function (stochastic frontier)

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of lny

chi2(1) = 52.66

Prob > chi2 = 0.0000

Appendix Table 3: Skewedness kurtosis normality test

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	Prob>chi2
seed	360	0.0000	0.4204	40.09	0.0000
Fertilizer	360	0.0000	0.0000	.	0.0000
land	360	0.0000	0.0008	53.37	0.0000
labor	360	0.6322	0.0000	48.28	0.0000
Oxen	360	0.0000	0.0000	.	0.0000

Source: own survey (2023)

Appendix Table 4 Contingency coefficient table (Tobit model)

	credit	owners~p	offfarm	fertil~y	sexhead	system
credit	1.0000					
ownership	0.4777	1.0000				
offfarm	0.0676	0.0960	1.0000			
fertility	0.5278	0.6507	0.0537	1.0000		
sexhead	0.1963	0.1905	0.0163	0.2283	1.0000	
system	0.5054	0.5393	0.1091	0.6844	0.2723	1.0000

Appendix Table 5: VIF for efficiency component (stochastic frontier)

Variable	VIF	1/VIF
fertilizer	2.61	0.383344
labor	2.34	0.428083
seed	2.03	0.491728
land	1.55	0.646977
oxen	1.05	0.953498
mean VIF	1.91	

Source: own survey (2023)

Appendix Table 6: VIF for inefficiency factor (tobit model)

Variable	VIF	1/VIF
Distance to market	4.88	0.205010
Number of livestock	4.13	0.242423
education	3.02	0.331672
extension contact	2.34	0.427537
plowing frequency	2.28	0.438267
experience of farmer	1.14	0.879816
Mean VIF	2.96	

Source: own survey (2023)

Appendix Table 7: One sample t-test with equal variances (stochastic frontier)

Variable	Obs	Mean	Std. Err.	Std.Dev.	T value	P value
Seed	360	565.65	22.112	419.5467	24.29	0.000
fertilizer	360	133	4.484196	85.08164	26.71	0.000
land	360	5118.651	215.9342	4097.064	23.7	0.000
labor	360	596.8889	11.64965	221.0365	50.16	0.000
oxen	360	2901.111	622.5996	11813	4.643	0.000

Source: from own survey (2023)

Appendix Table 8: Two variable T-test of inefficiency component (tobit model)						
variable	obs	mean	std.err	std dev	t value	p value
education	360	7.052778	0.2498219	4.740038		
extension	360	1.955556	0.0718552	1.363357		
combined	720	4.504167	0.1609472	4.318667	19.6084	0.000
experience	360	24.90556	0.6207292	11.77751		
distance	360	3.704861	0.1112548	2.110911		
combined	720	14.30521	0.5055345	13.56491	33.6188	0.0000
no/oxen	360	2.855556	0.1030519	1.955272		
frequency	360	2.333333	0.0574125	1.089325		
combined	720	2.594444	0.0597408	1.603013	4.4269	0.0000

Source: own computation (2023).

Appendix Table 9: Generalized Likelihood Ratio test of hypotheses for parameters of SPF

Null hypothesis	D/f	LH0	LH1	LR	Critical value (χ^2)	Decision
$H_0: \gamma = 0$	1	-170.5	-142.7	30.00	11.07	Reject H_0
$H_0: \mu = 0$	1	-2567	-2555	3.35	11.07	accept H_0
$H_0: \delta_1 = \delta_2 = \delta_{12} = 0$	11	379.49	379.49	35.70	19.68	Reject H_0

Source: own computation (2022)