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Article

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Cogent Business & Management

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Suggested Citation: Mulatu, Gemechu; Gemechu, Tassew (2023) : Technical efficiency of onion production: The case of smallholder farmers in Dallo Mena district, Bale zone, Oromia national regional state, Ethiopia, Cogent Business & Management, ISSN 2331-1975, Taylor & Francis, Abingdon, Vol. 10, Iss. 3, pp. 1-17,
<https://doi.org/10.1080/23311975.2023.2265092>

This Version is available at:

<https://hdl.handle.net/10419/294673>

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To cite this article: Gemechu Mulatu & Tassew Gemechu (2023) Technical efficiency of onion production: The case of smallholder farmers in Dallo Mena district, Bale zone, Oromia national regional state, Ethiopia, Cogent Business & Management, 10:3, 2265092, DOI: [10.1080/23311975.2023.2265092](https://doi.org/10.1080/23311975.2023.2265092)

To link to this article: <https://doi.org/10.1080/23311975.2023.2265092>



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Cogent Business & Management (2023), 10: 2265092



Received: 19 January 2023
Accepted: 26 September 2023

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Reviewing editor:
Peide Liu, Shandong University of Finance and Economics, China

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OPERATIONS MANAGEMENT | RESEARCH ARTICLE

Technical efficiency of onion production: The case of smallholder farmers in Dallo Mena district, Bale zone, Oromia national regional state, Ethiopia

Gemechu Mulatu^{1*} and Tassew Gemechu²

Abstract: This study was intended to identify factors affecting the technical efficiency of onion production by smallholder farmers in Dallo-Manna district of south eastern Ethiopia using cross-sectional data obtained from 183 randomly selected smallholder farmers. Both descriptive statistics and econometric models were used for data analysis. Cobb-Douglas stochastic frontier production function was fitted to predict the technical efficiency of onion-producing farmers. The mean of technical efficiencies of farmers in the study area was 76% and this indicates that there is room for improvement in onion production. The Tobit regression model was fitted to identify factors influencing technical efficiency scores and the result indicated that the technical efficiency of onion production was statistically and significantly influenced by the experience of household head in onion production, education level, family size, livestock holding size, access to market information, number of weeding, training, and extension contact. However, land fragmentation and access to credit services were negatively and statistically significantly affected the level of technical



Gemechu Mulatu

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Gemechu Mulatu Kerorsa [(BA in Economics from Bahir Dar University, 2005); (Msc in Economics/ Development Economics from Adama Science and Technology University, 2010) and (PhD in Agricultural Economics from Haramaya University, 2018)] Research interest: food security, poverty, contract farming, climate change, technical efficiency, welfare, livelihood diversification etc
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PUBLIC INTEREST STATEMENT

Onions are one of the most important vegetables we consume in our day to day diets. Onions add a lot of flavor to dishes and have many health benefits to human being. Therefore, investigation Technical Efficiency of Onion Production in the Case of smallholder farmers is very important. Cobb Douglass production function was fitted to calculate technical efficiency at individual level. The average technical efficiency for the study area was 76%, which indicates that there is a room to increase onion production by 24%. To identify variables which affect the level of technical efficiency onion production, tobit regression was applied and Onion farming experience, education level, family size, and livestock holding size, access to market information, number of weeding, training, and extension were among the variables positively and statistically significantly affected the level of technical efficiency of onion production.

efficiency of onion production. In general, there is a need to intervene in expanding the educational sector, provision of training, and extension services and solving the problem of land fragmentations.

Subjects: Agriculture; Statistics for Business, Finance & Economics; Development Studies; Research Methods in Development Studies; Development Policy; Development Theory; Economics and Development; Economic Forecasting

Keywords: onion production, smallholders, cobb-douglas; technical efficiency; frontier; Ethiopia

1. Introduction

Globally, onion is the most important vegetable consumed with meals every day. It is tasty and adds spices to foods consumed food. With a global production of two million metric tons, onions are a commercially significant crop in all continents and are fourth among the most consumed vegetables after tomato, cabbage, and watermelon (Ddamulira et al., 2019). With its day-to-day increase in demand and low productivity, small-scale farmers strive to increase their production and productivity, which can be achieved by the efficient use of agricultural inputs. The productivity of the small-scale farmers can be enhanced either by improving their production efficiency or by using modern technologies or a combination of both.

In Ethiopia, agricultural sector continues to dominate the economic sectors of Ethiopia. It contributes about 33% of GDP, 82% to export earning, and 69% labor force (EEA Ethiopian Economics Association Economic, 2021). Despite these positive contributions, about 97% of food crops are grown using rain-fed agriculture, small-scale, traditional, and of subsistent nature with limited access to technology and institutional services (Getachew, 2020). Moreover, it is characterized by low productivity, caused by a combination of various constraints, such as demographic, socioeconomic, and institutional, which hinder food and nutrition security and poverty reduction (EEA Ethiopian Economics Association Economic, 2021; Urgessa Tilahun Bekabil, 2014).

Vegetable crops are an important economic activity that ranges from home gardening to commercial farms owned by both public and private enterprises in Ethiopia (ATA Agricultural Transformation Agency, 2016). It is cultivated throughout the country for many purposes (Muluneh, 2019). The farm household consumes about 73% onion of production, 23% sold in the market and 1% is used for seed (CSA Central Statistical Agency, 2021). The same report shows the amount of vegetables consumed at home country is more than cereals and pulses, which is 63.37% and 55.14%, respectively. In terms of the total area and crops under production, vegetable accounted for about 2% and about 1.31% of the total production in quintals, respectively. However, this increment in output could not be attributed to improvement in productivity alone, as there was a simultaneous increase in the size of cultivated land.

In the study area, irrigation expansion has been done to supplement rain-fed agriculture to achieve food self-sufficiency and food security through growing cash crops such as onion, tomato, green pea, cabbage, and others. Due to better market access relative to others, availability of irrigation water and irrigable land many farmers in the study area produce vegetables predominantly onion and tomato. During meher, the main cropping season, farmers in the area are growing onion through a rain-fed farming system. The productivity of onions in Ethiopia (8.89 t ha^{-1}) is far below the world average (19.32 t ha^{-1}) (Gosa et al., 2022). There are numerous reasons for the area's low onion productivity. Due to quality seeds and associated production technologies, lack of storage to increase its shelf life; poor handling of the products, imperfect price information, lack of horizontal coordination among producers, weak market linkage (lack of vertical coordination among chain actors), and lack of quality standards and grades are the major constraints for the marketing process of onion in Ethiopia (Abebe & Agidew Abebe, 2018).

On the other hand, the demand for onion is dramatically increasing in Ethiopia (Teklebrhan et al., 2020). As a result, there is a mismatch between supply and demand for onion in Ethiopia.

Owing the above constraints, it is necessary to study more on the onion production in Ethiopia. To the best of my knowledge of the researcher, there is limited studies were conducted on on factors influencing the technical efficiency of onion production in the study area. Therefore, the overall objective of this study is to assess the level and identify factors affecting the technical efficiency of smallholder farmers' onion producers in Dallo Mana district of Bale Zone, Oromia national regional state, Ethiopia.

2. Literature review

2.1. Efficiency of agricultural production

Productivity and efficiency are both measures of production performance. However, there is a slight difference between them. Theoretically, productivity is the ratio of output(s) that are produced to input(s) that are used. Efficiency, alternatively, is defined as the level of operation that produces the greatest amount of output(s) with the lowest amounts of input(s). Efficiency is the main factor determining productivity. Efficiency score range between 0.00 and 1.00. The maximum score (1.00) represents the highest efficiency while the scores of 0.00–0.99 show a firm's inefficiency, indicating the relative displacement from the frontier (Kea et al., 2016).

2.2. Approaches of measuring production efficiency

Production efficiency is concerned with the relative performance of the process used in transforming inputs into outputs by the farmer. A farmer can increase his/her output via increasing inputs or increasing productivity of inputs and the combination of the two. In microeconomic theory, the production frontier describes the maximum output that may be obtained given inputs and technology. Some inputs may be varied at the discretion of the decision maker, while the other inputs are exogenously fixed, acting as constraints to the production process. Any deviation from the maximal output is considered as technical inefficiency (Armando et al., 2013; Coelli et al., 2005).

In analyzing efficiency, fitting a frontier model performs better than Ordinary Least Square (OLS) regression (Armando et al., 2013; Solomon Bizuayehu Wassie, 2014). This is due to two main reasons; the first one is, the estimation of an average function will give a picture in the shape of technology on an average firm, while the estimation of the frontier function will be more heavily affected by best-performing firm and thus reflect the technology they are using. The second one is that the frontier function represents a best practice technology against which the efficiency of firms within the industry can be measured. It is the second use of frontiers, which leads to wide application of estimating frontier functions.

There are two measures of technical efficiency which are primarily employed in the efficiency literature (Kumbhakar & Tsionas, 2003). These are input-oriented or output-oriented approaches. The former is the ability of a firm to produce a maximal output from a given set of inputs and the latter is the ability of a firm to use as modest inputs as possible for a given level of output. Note that both measures will coincide when the technology exhibits constant returns to scale but are likely to vary otherwise.

2.3. Empirical review

In this sub-section of the literature, recent studies done on efficiency are reviewed. As the current study deals with TE, more weight is given to empirical research on TE done in different parts of the world. Several demographic, socioeconomic, institutional, and natural factors can influence the level of technical efficiency of red onion production. Some of them are stated as follows:

Banani et al. (2013) used the Cobb-Douglas stochastic frontier production function in Indonesia to predict technical efficiency scores and found that experience, age, and education have

significantly influenced the technical efficiency of onion producers. Similarly, Khan (2016) used the Cobb-Douglas stochastic frontier production function to predict household-level technical efficiency score and showed that urea, farmyard manure, irrigation, and pesticides were the major factors that influence changes in onion production while education and farm size were found to have negative and significant effects on the technical inefficiency among the onion producers in Pakistan.

Getahun Mengistu (2014) used the Cobb-Douglas stochastic frontier production function in Ethiopia for efficiency score estimation and indicated that farm size, urea, fertilizer, expenditure on seed, pesticides, and tractor power in the case of irrigators were found to be important factors in increasing the level of onion output. Farm size, off/non-farm occupation, credit, training, irrigation, membership to cooperative, price perception, and family size were found to have positive and significant effects on the technical efficiency of red onion farmers.

Anik et al. (2017) used stochastic production frontier approach to predict technical efficiency and found that extension contact, use of recommended dose of fertilizers, and non-agricultural income were the major determinants of technical efficiency of onion production in Bangladesh.

Using Cobb-Douglas stochastic production frontier function in Nigeria, Grema and Gashua (2014) and in Ethiopia Berhan et al. (2014) reported that farm size, seed, fertilizer herbicide and insecticide, and hired labor were among the factors that influenced onion production.

Omolehin et al. (2019) found that education; farming experience, household size, membership of a cooperative, and access to credit are major socio-economic determinants of technical efficiency under both systems of production in Kano State of Nigeria.

According to Anyatengbey (2020), farm size, seed, labor, fertilizer, access to credit service, age, and water pump were found to influence technical efficiency positively. Maniriho et al. (2020) also applied Cobb-Douglas-type stochastic frontier functions and found that extension contact, use of a recommended dose of fertilizers, and non-agricultural income significantly improve technical efficiency. Efficiency is significantly higher for owner-operators and diversified farms.

Yahaya et al. (2019) using the Cobb-Douglas stochastic frontier production function and found that educational level, years of farming experience and access to extension service positively and significantly influenced the farmers' efficiency. Jemil (2020) also found that family size, experience, gender, access to extension, and credit service have a positive and significant effect on the technical efficiency of onion producers; while age, farm size, and education status has positive and significant effect on the technical efficiency of onion in Somali region, Ethiopia.

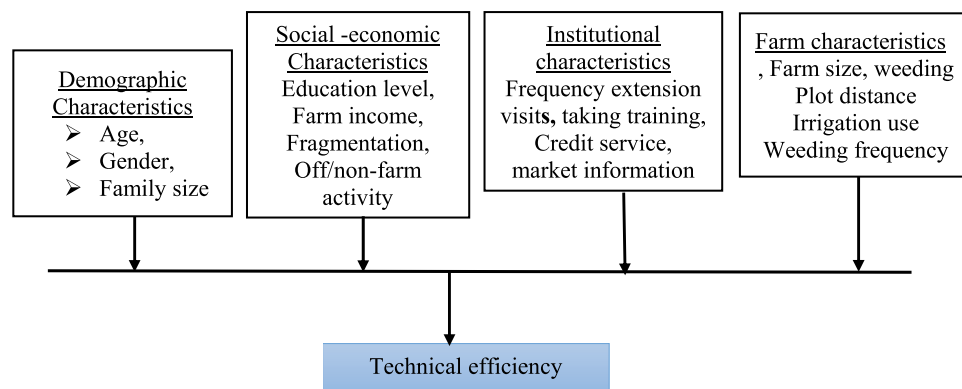
Dagne Koye et al. (2022) applied the stochastic frontier model's maximum likelihood estimates and revealed that plot size, Di Ammonium Phosphate, and oxen have a significant effect on onion output; education, livestock holding, experience, and frequency of watering have a positive and significant effect on technical efficiency, whereas family size and marketing training have a negative and significant effect on technical efficiency.

2.4. Conceptual framework

Technical efficiency of production is influenced by various demographics (education level, family size, gender), socio-economics (on-farm income, experience, landholding size, off/nonfarm income generating activity etc.), institutional characteristics (training, access to credit and extension service, distance to market), and others (weeding frequency (For detail see figure 1 below)). Moreover, technical inputs such as seeds, land, labor, oxen, and inorganic fertilizer are combined to produce the onion output in turn affects technical efficiency of red onion production.

Figure 1. Conceptual framework of technical efficiency of onion.

Source: own design-based literature review.



3. Research methodology

3.1. Description of the study area

Dallo Mena is one the district of Bale Zone Oromia national regional state that is located southeast about 555 km from Addis Ababa (capital city) and 110 km away from the Robe administration town of Bale zone. The total population of the district was about 108,930 of whom 55,193 were men and 53,737 were women. About 14,930 (13.70%) of its population were urban dwellers and 94,000 (86.30%) were rural dwellers.

The major soil type of the woreda is Nitosol which is the dominant soil in the area. Climatically the area characterized by bimodal rainfall with the main rainy season occurring early March through June and the short rain late September through November. The mean annual rainfall is 986.2 mm and the mean annual temperature is 22.5°C (Mengistu & Asfaw, 2016). Topographically, most of this woreda is less than 1500 meters above sea level; Mount Orbo is the highest point. The district has various rivers including the Welmel, Demal, Yadot, Elgo, Erba, Shawe, and the Dayyu Rivers. The district lies between latitudes 5°51'N and 6°45'N and longitudes 39°35'E and 40°30'E (Figure 2).

3.2. Data types and sources

Both primary and secondary data were used as sources of information. Primary data were collected through face-to-face interviews using a structure questionnaire.

3.3. Sampling technique and sample size determination

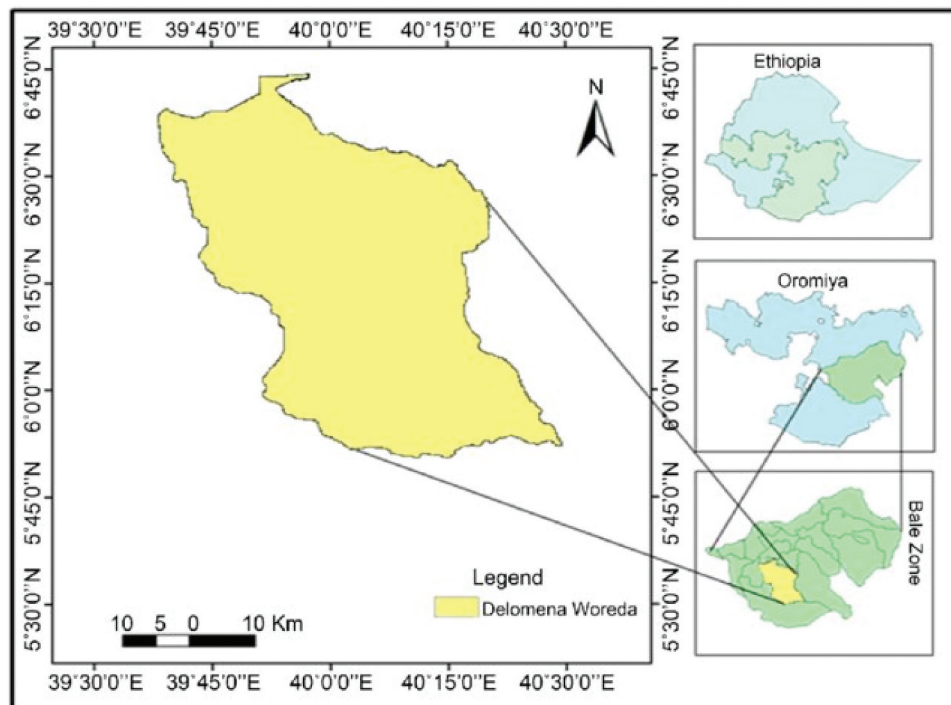
Two two-stage sampling method was applied to select representative sample respondents from the total population. First, from the district, 14 kebeles were identified as potential onion-producing areas due to existence of irrigation. In the second stage, three onion-producing kebeles were identified and selected purposively. These kebeles are namely Haya-Oda, Chiri, and Gomgoma kebeles. Finally, the sample size was determined by Kothari's (2004) sample size formula as follows:

$$n = \frac{Z^2 \cdot p \cdot q}{e^2} = \frac{1.96^2 \cdot (0.22)(0.78)}{0.06^2} = 183$$

where n is the sample size; p is the proportion of the population participating in onion production from total households existing in the district, q = 1-p is a number of the population who do not producer onion in the district, Z = 1.96, e = acceptable error which is 6%. Based on information obtained from bureau of Agriculture of the district, in this study, the proportion of onion producer is 0.22.

Figure 2. Map of the study area.

Source: Mengistu and Asfaw (2016).



3.4. Methods of data analysis

To analyze the collected data and address the objectives of the study, descriptive and econometric methods were employed. Among econometric models' a stochastic production frontier model (SPF) and a Tobit regression model was applied.

To address the objectives of the study, SPF model was selected for its key features that the disturbance variable is composed of two components, a symmetric disturbance and a non-negative. Symmetric parts that capture exogenous shocks and statistical noise (such as measurement error, topography, and weather), which are uncontrolled and exogenous to the farmer contained in every empirical relationship, particularly those based on cross-sectional household survey data. The one-sided component captures deviations from the frontier due to inefficiency. Several recent literatures shows that many productions efficiency studies have used stochastic production frontier model to estimate technical efficiency (Berhan et al., 2014; Grema & Gashua, 2014; Jemil, 2020).

To estimate the level of technical efficiency, the stochastic production frontier model needs a priori specification of the production function such as Cobb Douglas, trans-log functions, and others. In most of the empirical studies of agricultural production analysis, Cobb Douglas and trans-log functions were the most popularly used models from existing production functions. Some researcher argues that the Cobb-Douglas functional form has advantages over the other functional forms in that it provides a comparison between adequate fit of the data and computational feasibility. It is also convenient in interpreting the elasticity of production, and it is very parsimonious concerning degrees of freedom.

In addition, the Cobb-Douglas production function is attractive due to its simplicity and because of the logarithmic nature of the production function, which makes econometric estimation of the parameters a simple matter. The trans-log production function is more complicated to estimate the parameters having serious estimation problems. One of the estimation problems is as the number of variable inputs increases, the number of parameters to be estimated increases rapidly.

Another problem is the additional terms require cross-products of input variables makes the Translog function mathematically difficult to manipulate and thus making a serious multicollinearity problem (Martins et al., 2012). Moreover, the majority of empirical studies done on efficiency in Ethiopia analyzed using Cobb-Douglas frontier function.

Thus, the Cobb-Douglas frontier function was selected for this study. It was specified as follows:

$$Q_i = A X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} \quad (1)$$

Based on our cross-sectional framework, the linearized Cobb-Douglas stochastic production frontier model is written as follows:

$$\ln Q_i = \beta_0 + \sum_{j=1}^6 \beta_j \ln X_{ji} + \varepsilon_i \quad (2)$$

$$\ln Q_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \varepsilon_i \quad (3)$$

where \ln represents the natural logarithm of base e ; j donates the number of inputs used; i donates the i th sample farmer; Q_i represents the actual onion output of the i th sample farmer; X_{ji} denotes j^{th} farm input variables were used in onion production of the i th farmer; β_0 denote intercept and β_i is a vector of unknown parameters to be estimated which represent elasticity of production; ε_i is a composed disturbance term made up of two error elements (V_i and U_i); the symmetric component (V_i) is assumed to be independently and identically distributed as random errors with zero mean and variance $N(0, \sigma^2 V)$ which captures inefficiency as a result of factors beyond control of farmers and U_i proposed to capture inefficiency effects in the production of onion.

This equation (linearized Cobb-Douglas stochastic production function) is estimated by maximum likelihood method. This is because unlike other estimation methods (mostly distribution-free method), it helps us to differentiate inefficiency from statistical error.

A priori to applying this technique is that we assume a particular distribution for the inefficiency component (U_i). There are distributions include the Half-Normal of $U_i \sim N(0, \sigma^2_u)$ (Aigner et al., 1977), the exponential distribution of Meeusen and Van den Broeck (1977), the Truncated-Normal $u \sim N^+(\mu, \sigma^2_u)$, and the Gamma distribution. A likelihood ratio (LR) test is used in this study to choose between the half-normal and the truncated-normal distribution.

Given the independence assumption between u and v , we use the lambda parameterization of Aigner et al. (1977), and the technical efficiency of an individual onion-producing farm household in the study area is defined in terms of the actual output (Q_i) to the corresponding frontier (potential) output (Q_i^*) given the available technology. It is computed using the following formula:

$$TE = \frac{Q_i}{Q_i^*} = \frac{f(X_i; \beta) \exp(U_i - V_i)}{f(X_i; \beta) \exp(V_i)} = \exp(-U_i) \quad (4)$$

In this study, technical efficiency estimate was derived from the stochastic production frontier is regressed using a censored Tobit model on farm-specific explanatory variables that explain variation in efficiency across farms. To find out what factors determine the level of technical of smallholder onion-producing households, probit and logit models can be used. In logit and probit models, the dependent variables are usually binary (Maddala, 2005).

However, when the dependent variable is roughly continuous over strictly positive values but is zero for a nontrivial fraction of the population we usually use the Tobit model. If we run the data using linear model, we would possibly obtain negative fitted values, which leads to negative predictions for mean technical efficiency; this is analogous to the problems with the linear probability models (LPM) for binary outcomes.

Using LPM for estimation resulted in a violation of classical assumption of homoscedasticity. Further, it is often useful to have an estimate of the entire distribution of the dependent variable given the explanatory variables using Tobit model.

Following Green (2005), Tobit regression model is formulated as

$$Y_i = \begin{cases} Y_i^* = X_i' \beta_i + U_i & Y_i^* > 0 \\ 0 & \text{if } Y_i^* = 0 \end{cases} \text{ and } U_i \sim IN(0, \sigma^2) \quad (5)$$

where

Y_i is the level of technical efficiency score of households estimated from Stochastic frontier analysis,

β_i is the vector of parameters

X' is a matrix of explanatory variables consisting of household head characteristics, household-level characteristics, and access to different institutions.

The unconditional expectation of Y given X is

$$E(Y_i|X) = (1 - \Phi(-X_i\beta/\sigma))X_i\beta + \sigma\phi(-X_i\beta/\sigma) \quad (6)$$

The marginal effect or the effect of a change in the k th explanatory variable on the expectation of Y_i given X_i with respect to X is

$$\frac{\partial E[y_i|X_i]}{\partial x_{k,i}} = (1 - \Phi(-X_i\beta/\sigma))\beta_k \quad (7)$$

We use marginal effect, which helps to determine the effect of individual variable effect.

4. Results and discussion

This section consists of both descriptive and econometric results of the study. Econometric results were discussed by supporting with previous researches.

4.1. Descriptive results

The average age of the sample household heads were 40.52 years with a maximum of 79 and minimum of 21 years. The average family size for the sample households were about 5.71 member that was lower than the national average agricultural household size 5.2 persons per household. The average experience in onion production of the sample household heads was 8.05 years with minimum of 2 and maximum of 20 years. The average formal year of schooling of the sample household heads were 2.78 grades with a minimum of 0 and maximum of 12 grades. The average of on-farm income for sample household heads was 110,250.9 birr with a minimum of 2500 and maximum of 756,000 birr per annum. As shown in Table 1 below, the average landholding size of sample household heads was 2.78 hectares with minimum of 1 and a maximum of 7 hectares.

The average livestock holding size of sample household heads were 6.27 in tropical livestock unit with a minimum of 1 and a maximum of 6.45 in tropical livestock unit. The number of training taken by household heads was 2 on average and ranged from taking of no training to six times. The average distance of the onion plot from homestead in walking minutes of sampled households were 40.64 walking in minutes with a minimum of 12 and a maximum of 132 walking in minutes. The average land fragmented of the sampled household was 2.5 plots with a minimum of 1 and a maximum of 6 plots. The number of extensions contact by sample households 11.96 on average and ranging from 4 to 21 visits per annum. The average number of weeding of the sample household heads was 2.71 times with a minimum of 1 and a maximum of 6 times.

Table 1. Sample household characteristics for continues variables

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
Age of household	183	40.52	12.400	21	79
Family size of household	183	5.71	3.29	1	14
Experience in onion production	183	8.049	4.204	2	20
Formal year of schooling	183	2.776	3.042	0	12
On-farm income	183	110250.9	98761.76	2500	756000
Landholding size	183	2.778	1.252	1	7
Livestock-holding size	183	6.517	3.553	1	6.45
Frequency of taking training	183	2.00	1.822	0	6
Distance of onion in walking minutes	183	40.639	23.960	12	132
Land fragmentation	183	2.546	1.118	1	6
Frequency extension contacts	183	11.945	6.367609	4	21
Number of weeding	183	2.705	1.47519	1	6

Source: Own computation from survey data (2021).

Table 2. Sample household characteristics for dummy variables

Variable	Category	Frequency	Percentage (%)
Gender of household	Male	151	82.51%
	Female	17	17.49%
Off/non-farm income	Yes	140	76.50%
	No	43	23.50%
Access to irrigation water	Yes	99	54.10 %
	No	84	45.90%
Access to market information	Yes	115	62.84%
	No	68	37.16%
Access to credit service	Yes	129	70.49%
	No	54	29.51%

Source: Own computation from survey data (2021).

4.2. Sample household characteristics for dummy variables

As survey indicated in Table 2, among the sampled households, about 82.51% were male-headed households and 17.49% were female-headed households in the study area. From the sample household heads, about 76.49% of the sample household heads had participated in off or non-farm activities and 23.50% of them did not participate in off/non-farm income source activities. The survey result indicates that 54.10% of the sample households had access to irrigated water and 45.90% of them do not have access to irrigation water. From the sample, household heads 62.84% had access to market information and 37.16% did not have access to market information. From the sample, household heads 70.49% had access to credit service and 29.51% did not have access to credit service.

of the sample households had access to market information and 37.16% of them did not have access to market information. On the other hand, 70.49% of the sample households had access to credit services and 29.51% of them did not have access to credit services.

4.3. Econometric model results

4.3.1. Stochastic production frontier model results

The Cobb-Douglas functional form of the stochastic frontier model with half-normal distributional assumption of the error terms is selected to estimate the parameters of the model. The parameters were estimated simultaneously with those involved in the model for the inefficiency effects. The coefficients of Cobb-Douglas production function for input variables were interpreted as elasticity of production.

The estimated stochastic production frontier model indicated that input variables such as land size, inorganic fertilizer (Urea and DAP), organic fertilizer (compost and manure), human labor, oxen power, and agro-chemicals (herbicides or pesticides) were found to be positive and significant effect on onion output at 1% probability level in the study area. According Table 3, the quantity of seed used in kilogram was a negative and significant effect on onion output at a 1% significant level. The positive elasticity of inputs implies any intervention that improves the use of that input would give significant improvement in onion output while the negative coefficient of input lower the output of onion.

4.3.2. The elasticity of onion production

The coefficient of production inputs included in the model was summed to 1.88, which indicates that the 1% increase in inputs simultaneously leads to a 1.88% increment in onion production. On the other hand, the sum of input coefficients is greater than one which indicates onion production scores were increasing returns to scale in the study area. This is consistent with the results of Maniriho et al. (2020).

4.4. Technical efficiency scores

As indicated in Table 4, the estimation result indicates that the mean level of technical efficiency of sample households was 0.76, which reveals the existence of a possibility to increase the level of onion output by about 24% by efficient use of the existing resources. On the other hand, 24% of the onion outputs are lost due to the inefficiency of farmers. The mean levels of efficiencies are comparable with the results from other similar studies in different countries. For instance, Banani et al. (2013) found the mean technical efficiency of red onion farming in Indonesia to be 80%, and Getahun Mengistu (2014) found mean efficiency levels onion farmers in east Shewa zone Ethiopia to be 78%.

4.5. Tobit regression results

After measuring the level of technical efficiency scores, it was important to identify the source of inefficiency among smallholder farmer in onion production. The result of Tobit model showed that among the 17 variables including in the model 10 variables (experience of household in onion production, education level, family size, landholding size, on farm income, livestock holding size, frequency of extension contact, and taking training) were found to be statistically significant in affecting the level of technical efficiency (For details see table 1). The results on the determinants of technical efficiency of onion production are presented on Table 5.

4.5.1. Experience in onion production

The model result indicates that experience in onion production was positive and significant effect as expected on technical efficiency of onion producer farmer in the study area. As experience in onion production of household head increase by one year, the technical efficiency of onion producer farmer increases by 0.47% keeping other factors constant. This could be because experience is a proxy for managerial aspects and improves the skill and technical capacity that

Table 3. Maximum likelihood estimates of the Cobb-Douglas SPF with efficiency model

Input variables	Coefficient	Std. Dev.	t-Value	p> t -Value
Ln of DAP applied	0.2967	0.0804	3.69	.000***
Ln of UREA applied	0.0359	0.0708	0.51	.613
Ln of labour used	0.6083	0.1277	4.76	.000***
Ln of onion seeds	−0.3161	0.1282	−2.47	.014***
Ln of oxen power used	0.4693	0.1067	4.44	.000***
Ln of organic fertilizers	0.2365	0.0697	3.39	.001***
Ln of land	0.2521	0.0599	4.21	.000***
Ln of chemicals	0.3004	0.1107	2.71	.007***
Constant term	−0.5130	0.7902	−0.65	.840
Output Elasticity of inputs	1.88			
Wald chi2(8)	425.30			
Sigma_v	0.5997426	0.0314474		
Sigma_u	0.0092925	0.4380804		
Sigma-squared (2)	0.3597775	0.0379643		
Lambda (λ)	0.0154942	0.4416444		
Log-likelihood function	−166.11			
Sample	183			

*, **, ***, significant at 10%, 5% and 1%, significance level, respectively.

Source: Own computation from survey data (2021).

Table 4. Technical efficiency score

Variable	Mean	Std. Dev.	Minimum	Maximum
Technical efficiency score	76.00	0.18	0.28	0.99

Source: Own computation from survey data (2021).

enables to best match inputs and in cost saving aspect so attain higher productivity at minimum cost. On the other hand, the relationship implied that there is an increase in technical efficiency by 0.47%, as one's experience increases by one year. This finding keeps the findings of Dagnew Koye et al. (2022).

4.5.2. Family size

As the model result shows family member has a positive and significant effect on the technical efficiency of onion-producing farmers at 1% level of significance. As family size of household increases by one-man equivalent, the technical efficiency increases by 0.68% score keeping other factors constant. This result implies that an increase in the number of family members could increase the technical efficiency of household in the study area This is because family labor is the main input in crop production and households with more members can perform farming activities effectively and efficiency since crop production in Ethiopia is labor-intensive activity. This result similar with the result of Jemil (2020) and Maniriho et al. (2020) reports the contribution of more family labor in farm activity was important in managing in proper allocation of factors of production optimally.

Table 5. Maximum likelihood estimation of the efficiency effect model

Variables	Coefficient	Std. Err.	t-value
Age of household head	−0.0010	0.0008	−1.35
Experience in onion production	0.0047	0.0021	2.28**
Sex of household head (1=male; 0= female)	0.0269	0.0194	1.39
Family size in numbers	.0068	0.0028	2.40***
Distance to road in kms	−9.9 e-04	4.3e-04	−0.21
Landholding size in hectares	−0.0119	0.0065	−1.82*
Livestock ownership in TLU	0.0043	0.0025	1.69*
Off/non-farm income	0.0103	0.0174	0.59
Education in years of schooling	0.0120	0.0034	3.50***
Frequency of training	0.0093	0.0055	1.69*
Access to saving institutions	−0.0277	0.0166	−1.67*
Access to irrigation water	−0.0140	0.0172	−0.82
Frequency of extension visits	0.0185	0.0028	6.52***
Access to market information	0.0608	0.0152	4.00***
On farm income	−8.31e-08	8.06e-08	−1.03
Land fragmentation	−0.0277	0.0077	−3.62***
Number of weeding	0.0144	0.0073	1.96**
Constant term	0.4762	0.0602	7.90

*, **, ***, significant at 10%, 5% and 1%, significance level, respectively

Source: Own computation from survey data (2021)

4.5.3. Education of household head

The estimated result indicates education level of household head was positive and significant effect on technical efficiency of red onion producing farmers at 1% significant level. This implies that as education level of household heads increases by 1 level of grade, the technical efficiency of onion increases by 1.2% score keeping other factors remain constant. The possible reason is that education enhances their managerial skill, better access to information, and good farm planning. This corroborates the findings of Getahun Mengistu (2014); Khan (2016); Omolehin et al. (2019); Maniriho et al. (2020); Dagnew Koye et al. (2022) and Tamirat et al. (2022) that access to better education enables households to better manage their resources in order to sustain the environment and produce at optimum levels.

4.5.4. Livestock holding size

Number of livestock holding size by households' head in terms of TLU has positive and significant on technical efficiency of onion producing farmers. This implies that as livestock holding size increase by 1 in TLU, the technical efficiency of onion producing farmers by 0.0043. This means households who have large livestock holding size were more efficient than small holding size. This is because livestock in a crop-livestock mixed farming system have various advantage such as it supplies oxen power for ploughing land, provide manure and compost that will be used to maintain soil fertility, and it serves as shock absorber to an unexpected hazard in crop failure as sources of food and income (cash) for the family. Timely ploughing and threshing is decisive in the production of crops thus access of livestock is important to better production. Since all types of

animals and poultry production are considered in this study, livestock competitive effect has dominated its supplementary effect. This result was congruent with the findings of Dagnew Koye et al. (2022) that an increase in livestock holdings improves onion production's technical efficiency.

4.5.5. Frequency of extension contact

The coefficient for the frequency of extension contact has a statistically significant positive relationship with technical efficiency at 1 percent. The positive estimated coefficient for contact with extension workers implies that efficiency increases by 0.262 scores keeping other factors constant as the number of visits made to the farm household by extension workers increase by one at a production period. Advisory service rendered to the farmers in general can help farmers to improve their average performance in the overall farming operation as the service widens the household's knowledge with regard to the use of improved agricultural inputs and agricultural technologies. This keeps the findings of Anik et al. (2017); Omolehin et al. (2019) and Tamirat et al. (2022).

4.5.6. Frequency of taking training

The result shows that frequency of taking training by household head was found to be positively and significantly influence technical efficiency of onion producer farmers in the study area. As frequency of taking training by household head increase by one time, the technical efficiency of onion producing farmers increases by 0.93% keeping other factors constant. This could be related to the advantage of getting technical knowledge and skills related to onion production because of training. This result corporates the findings of Dagnew Koye et al. (2022).

4.5.7. Access to marketing information

As the model, result shows access to market information by household head was found to be positively and significantly influence as expected on technical efficiency of onion producer farmers. As access to market information increase of household head by 1%, technical efficiency of onion producer farmer increases by 6.08%. This implies the better information farmers have the more efficient utilization of inputs which in turn increases the technical efficiency of red onion production.

4.5.8. Access to credit service

the result shows that access to credit service has negative and significant effect on technical efficiency of onion producing farmers. Smallholder farmers due change in weather condition and non-existence of agricultural insurance, they usually fear to receive credits from formal institutions. This result corroborates Omolehin et al. (2019) farmers who are technically inefficient can possibly be more efficient by having access to credit because credit facility may ease the timely acquisition of inputs, thus reducing the inefficiency level of the farmer

4.5.9. Land fragmentation

The model result shows that number of land fragmentation was found to be negative and significant effect on technical efficiency of onion producer farmers at 1% significant level in the study area. The result indicated that a farmer with a greater number of red pepper plots is more technical efficient than a farmer with a smaller number of onion plots. The reason is perhaps as the number of plots operated by the farmer increases; the farmer will be able to distribute labor resources for different activities. Moreover, it might be used as one of the risk minimization strategies of farmers. Farmers may be benefited from fragmented red onion plots in that different plots may represent the reduced risk that different plots provide if the plots are located sufficiently distributed, such that farmers face different degrees of weather-induced variations such as floods and mineral content on the different plots.

4.5.10. Number of weeding

the model result indicates that number of weeding by household head was found to be positive and significant effect as expected on technical efficiency of onion producer farmers. This indicating that there is a positive relationship between onion productivity per hectare and the number of times

weeding is repeated on a given plot. As number of weeding increases by one-time, technical efficiency of farmer increases by 1.44%. This implies that a successful cultivation of onion depends largely on the efficiency of weed control. Weed control during the first 6–8 weeks after planting is crucial, because weeds compete vigorously with the crop for nutrients and water during this period.

5. Conclusions and recommendations

In Ethiopia, onion producer farmers are producing more than ever before, but the demand for the onion has consistently outpaced supply. This requires seeking for a means to increase onion productivity of smallholder farmers. In this context, the measurement of existing efficiency in onion production and identifying the determinant to seeking alternative solutions for this problem becomes paramount important. This study analyzed the level technical efficiencies and factors that explain the variation in efficiency among onion producer farmers in the district of Dallo Mena, Bale zone, Oromia national Regional State.

The study was used both primary and secondary sources of data. Primary data were collected from 183 sample households using semi-structured questionnaires. While secondary data were collected from a published and unpolished source to support primary data. The selection of the study area was purposive, and the selection of onion producing households made randomly. Descriptive statistics and econometric models were applied for data analysis. Descriptive statistics such as mean, standard deviation, percentage, frequency, and table were used. Econometric models like The Cobb-Douglas stochastic frontier production function were used to predict technical efficiency at the household level. The SFA approach was chosen as it best suits single output and multiple-inputs production programs and as it easily disaggregates inefficiency effects in production into non-random and random error components.

The maximum likelihood estimation of the stochastic Cobb-Douglas frontier production function signified important implications on the factor's contribution and productivity increase of onion in the study area. Estimation of the production frontier indicated that among the eight input variables considered in the production function, seven (labor, oxen power, DAP, seed, organic fertilizer, and Agrochemicals) had a significant effect in explaining the variation in onion production among farmers. This implying farmers should use the maximum possible levels of these inputs to enhance onion production. The coefficients of the Cobb-Douglas production function are interpreted as elasticity and summing the individual elasticity yields a scale elasticity of 1.88%. This indicates that farmers are facing increasing returns to scale. The study also indicated that the mean level of technical efficiency was 76.0%. This in turn implies that farmers can increase their onion production on average by 24.0% when they were technically efficient.

Regarding determinants of technical efficiency, the study found that experience, education, family size, livestock holding size, training, extension contact, marketing information and number of weeding contributed significantly and positively to the technical efficiency of onion production, while landholding size, access to credit, and land fragmentation were negatively and significantly influence technical efficiency of the study area.

Improving technical efficiency of smallholder farmers is an important development strategy to achieve food and nutrition security and improve income. The following recommendations were forwarded based on the results obtained from empirical reports.

To make less educated farmers also have better understanding of onion producing and make a decision to produce more, Government, NGO, and other stockholders should give attention to strengthening different educational opportunities like informal education and training in the study area.

To increase technical efficiency of a farmer, there is a need for the government and any other concerned bodies to improve the existing livestock breeding, and traditional mixed farming system in the study area.

Additional effort should be devoted by government to upgrade the skills and knowledge of the development agents so that farmers could gain from the presence of development agents in their kebeles.

In addition to strengthening the existing extension service focusing on practical training provided to farmers, efforts should be made to train farmers for a relatively longer period using the already constructed farmers' training centers and agriculture research demonstration centers. Access to market information has positive and significant effect on technical efficiency of onion producer farmers.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to the containing information that could compromise the privacy of research participants.

Ethical considerations

This article does not contain any studies involving animals performed by any of the authors.

Citation information

Cite this article as: Technical efficiency of onion production: The case of smallholder farmers in Dallo Mena district, Bale zone, Oromia national regional state, Ethiopia, Gemechu Mulatu & Tasew Gemechu, *Cogent Business & Management* (2023), 10: 2265092.

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