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## Research

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# Analysis of Technical Efficiency and Its Potential Determinants among Smallholder Tomato Farmers in Siltie Zone, Southern Ethiopia

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## Abstract

**Background:** In developing world including Ethiopia, agricultural productivity was very low; especially where production is common on fragile lands and characterized by smallholder subsistence farming. One of the main reasons for low productivity is the inability of farmers to fully exploit available technologies and production techniques. Considering this in to account, this study analyzes the technical efficiency and its possible source of inefficiency in smallholder tomato farming in Siltie Zone Southern Ethiopia.

**Methods:** By using three stage sampling, 175 randomly selected smallholder tomato farmers were sampled and stochastic frontier Cobb Douglas production model was applied.

**Results and Conclusion:** The results indicate that the mean technical efficiency among smallholder tomato farmers is 81.7%, implying a potential to increase tomato production by 19.3% with the current level of resources and technology. The study further revealed that output responds positively to increases in technological factors of production. According to estimates of the inefficiency model among various factors sex of household head, frequency of weeding, diseases incidence and type of variety used were found to significantly affect the level of technical efficiency of tomato crop producers. Thus, development policies in the tomato sub sector might focus more on empowering women in resource allocation, adoption of high-yielding and disease-resistant tomato varieties and better management of tomato plantations might reduce technical inefficiency among tomato farmers in the study area.

**Key words:** Technical Efficiency, Tomato, Stochastic Frontier Production Model, Siltie Zone Ethiopia

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## 1. Introduction

Ethiopia is a country with a total population of more than 110 million, of which about 80 percent of the total population is engaged in subsistence farming in rural areas (CSA 2017). Poverty and food insecurity are still prevalent problems in Ethiopia. The causes of food insecurity are various such as extreme weather conditions, environmental degradations, population pressure and policy drawbacks. The economy of the country highly depends on agriculture; a sector that has persistently played a leading part in employment provision, poverty alleviation, food availability, and export earnings. According to National bank of Ethiopia (NBE 2019) agriculture contributes to more than 33.3 percent of the gross domestic product (GDP) and 68 percent employment opportunity. Thus, it is the reason why that policy action in Ethiopia is largely based on influencing the dynamism of the agricultural sector.

Although agricultural sector plays a great role in Ethiopian economy, it is characterized by low productivity due to technological and socioeconomic factors. Mostly the farmers with the same resources are producing different per hectare output, because of management inefficiency inputs, limited use of modern agricultural technologies, traditional farming techniques, weak supportive and infrastructural service delivery such as extension, credit, marketing, road and poor agricultural policies (Abate et al. 2019). To transform the situation, the Ethiopian government has design Growth and Transformation Plan (GTP-I) and (GTP-II) in the 5 years (2011–2015) and (2016–2021) respectively. The center of the plan was enhancing smallholder farmers' agricultural productivity (Davis et al. 2012). According to Asfaw et al. (2010) one of the basic strategies of the Ethiopian government in improving agricultural productivity is to adopt new technologies and use of modern inputs. However, without removing inefficiency in utilization of agricultural inputs, trying to adopt new technology may not bring an expected result.

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important edible and nutritious vegetable crops in the world. It ranks next to potato and sweet potato with respect to world vegetable production but ranks first as a processing crop (Benti et al. 2017; Melese and Samul 2018). It is widely cultivated in tropical, subtropical and temperate climates and the top ten leading tomato producing countries are China, India, Turkey, United State of America, Egypt, Iran, Italy, Spain, Mexico and Brazil (FAOSTAT 2018). As it is a relatively short duration crop and gives a high yield, the crop is economically attractive and the area under

cultivation is increasing from time to time. The current world tomato production reached to more than 182.3 million tons<sup>1</sup> cultivated on more than 4.7 million hectares of land (FAO 2018).

The climatic and soil conditions of Ethiopia are suitable for the production of a wide range of tropical and subtropical fruits and vegetables including tomato. According to FAOSTAT (2018) the annual average tomato production in Ethiopia is estimated to be about 43,816 tons which is harvested from about 7,089 hectares of land. Although Ethiopia has huge potential, yet average productivity of tomato in the country is very low, that is 6.18 tons/ha compared with average productivity of 16, 96.8, 63.9, 43 and 38.3 tons/ha in Africa, America, Europe, Asia and the entire world, respectively (FAOSTAT 2018).

The major causes for low yield and inconsistent production are stated as: shortage of improved input supply, unreliable rainfall distribution (frost), insect pests and diseases, traditional agronomic practices, product perishability, improper post-harvest handling, price drop after harvest, limited infrastructural development and transportation problem leads to decrease in productivity of agricultural produce (James et al. 2010; MoA 2010; Emanu and Nigussie 2011; Ali et al. 2017). Improving smallholders' tomato production would contribute to enhancing food security and alleviating poverty.

Food security continues to be a problem in Ethiopia as it is the situation in a number of Sub-Saharan African countries. One important step towards achieving food security could be increasing productivity through enhancing efficiency in production (Wudineh and Endrias 2016). Productivity entails both technological improvements and technical efficiency (Ogada et al. 2014). Thus, improving the technical efficiency of farmers will lead to an increase in the yield of farmers which will in turn lead to increase in market supply, food security, higher incomes and better standards of living.

According to literature review, there have been various empirical studies conducted to measure technical efficiency in Ethiopia. Some of studies conducted on horticultural crops earlier are: Wussihun et al. (2019) on Analysis of technical efficiency of potato production in Chinga district, Amhara regional state; Abate et al. (2019) on Technical efficiency of smallholder farmers in red pepper production in North Gondar Zone; Weldegiorgis et al. (2018) on Resources use efficiency of irrigated tomato production of smallholder farmers in Hintalo-Wajerat district of the South-Eastern Zone of Tigray region in Northern Ethiopia; Dube et al.

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<sup>1</sup> 1 ton is equals to 10 quintals

(2018) on Technical efficiency and profitability of potato production by smallholder farmers in Bale Zone of Ethiopia; Tiruneh et al. (2017) on Technical efficiency determinants of potato production in Welmera district, Oromia. Even though several studies have been conducted on technical efficiency of crops including tomato in Ethiopia, technical efficiency of tomato farming is still inappreciable and very little is known whether smallholder tomato producers are efficient or not in Siltie Zone. Moreover, all those findings might not be applicable to the case of tomato production in Siltie Zone Southern Ethiopia due to the diverse agro-ecological zone, differences in the product produced, and differences in technology adoption. Moreover, as to the best of the author's knowledge and belief, there were no similar studies undertaken in the study area. Therefore, this study was investigated to fill this gap with the aim of analyzing technical efficiency of tomato production and its determinant factors in Siltie Zone Southern Ethiopia.

## **2. Research Methodology**

### **2.1. Descriptions of the Study Area**

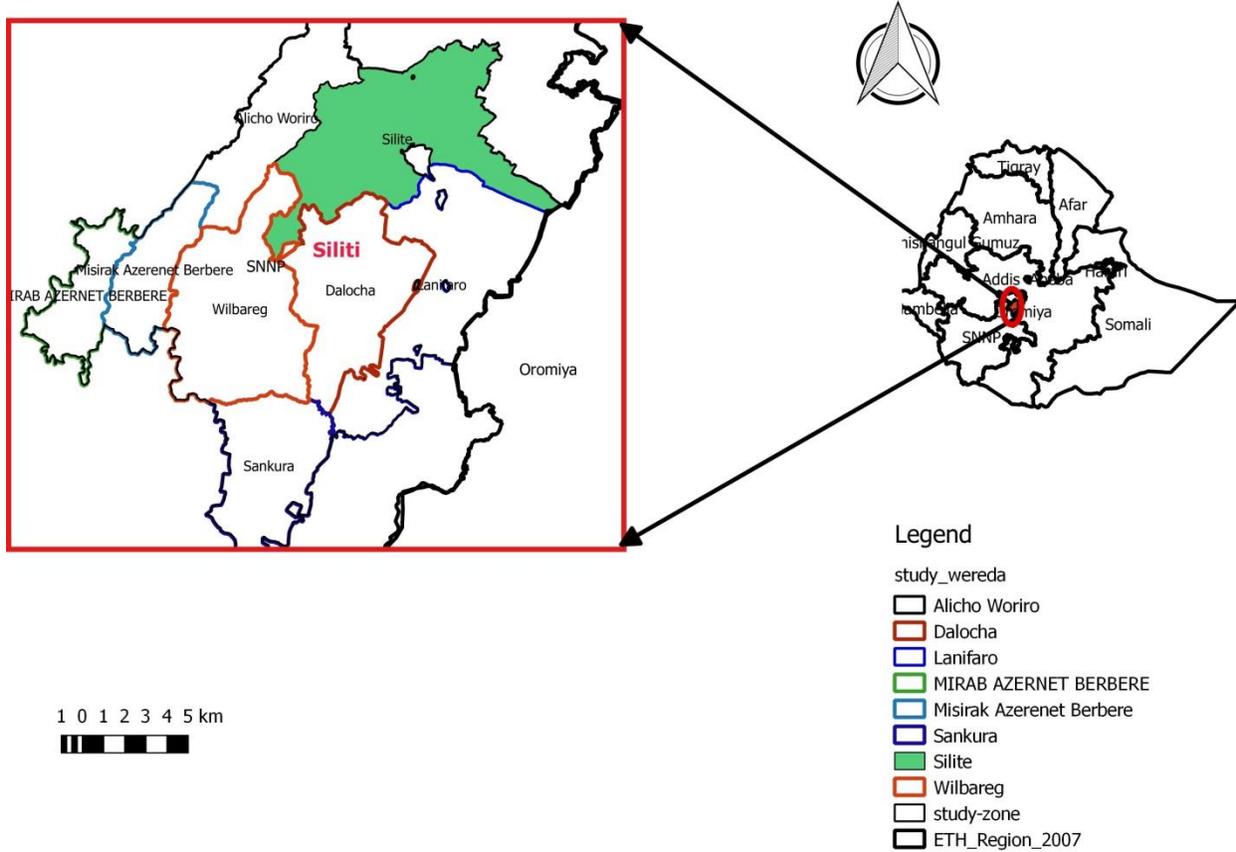
The study was conducted in Siltie Zone, Southern Ethiopia. Siltie administrative zone has a total area of 3000 sq. km and for administrative purpose; it is structured in to ten districts and one urban town. These include Silti, Misrak Silti, Dalocha, Lanfro, Sankurra, Hulbareg, Mito, Misrak Hazernet, Mirab Hazernet, and Alichu. Worabe town is the administrative center of the zone which is found 173 kms from Addis Ababa. The land scape of the zone is fairly level and found in northern part of South Nations, Nationalities and People Region (SNNPR) and located in North West of Alaba Zone, North East of Hadiya Zone, West of Oromia and South, South East and South West of Gurage Zone.

The zone can be classified into three major climatic zones on the basis of altitude, rainfall and temperature: 20.6% Dega, 74.4% Woina-Dega and 5% Kolla of the total area of the region. Mean annual temperature is between 12 - 26 C<sup>o</sup>. The rainfall is between 700 and 1818 mm. Agriculture is the main economic activity and the zone has varied ecological zones that range from lowland to highland, which makes possible the cultivation of various crop (SZBoA 2019)..

The main economic source of livelihood is based on both crop production and livestock raising. Crops which are grown for food consumption as well as for income source in the area are *enset*, wheat, barley, maize, bean, pea, haricot bean, beetroot, potato, tomato, paper, onion, garlic, cabbage, and some other garden spices. Further, oxen and sheep fattening for holidays of

the year is very common serving as an alternative source of income generating strategy of farmers in Siltie Zone.

**Fig. 1** Map of study area. *Source:* Own developing using satellite data (2019)



## 2.2. Data Types and Methods of Data Collection

The data set for this study obtained from both primary and secondary data sources which are qualitative and quantitative in their nature. The primary data were collected from structured sample of 175 smallholder tomato farmers' interviews. Structured sample household head interviews employed to generate household level data on the household demographics, assets ownership, tomato production inputs, infrastructural facility and service delivery. Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and Observations were also employed to triangulate and support the primary data which obtained from the sample household head interviews. Secondary methods of data collection were reviewing published and unpublished research journals, books and thesis; and assessing different records and reports of agriculture and rural development office on production and productivity of tomato.

### 2.3. Sampling Technique and Sample Size

To select representative sample size from tomato producers, a three stage sampling technique was used. In the selection process district agricultural office experts were consulted. In the first stage, two districts were selected purposively based on tomato crop production potential. The selected districts were Silti and Misrak Silti. In the second stage, three *kebeles* from each district were selected purposively based on agro-ecology and potential of production. In the third stage, according to the number of total households in each *kebele*, proportionate to size technique was applied to determine sample households size from each *kebele*. The sample frame of the study was the list of households obtained in each *kebele* of agricultural office. Finally, 175 sample sizes from producers were selected by using systematic random sampling technique and interviewed for the study (Table 1). For this study to obtain a representative sample size, for cross-sectional household survey sample size determination formula developed by Kothari (2004) was used as follows:

$$n = \frac{Z^2 pq}{e^2} \dots \dots \dots (1)$$

Where;  $n$  = Sample size;  $Z$  = confidence level ( $\alpha = 0.05$ , thus,  $Z = 1.96$ );  $p$  = proportion of the population containing the major interest,  $q = 1-p$  and  $e$  = allowable error (0.07). Hence,  $Z = 1.96$ ;

$$n = \frac{Z^2 pq}{e^2} = \frac{1.96^2(0.5)(0.5)}{0.07^2} = 175$$

**Table 1 Sample distribution. Source: Silti and Misrak Silti Districts Agricultural Office (2019)**

District/Woreda	Name of <i>Kebeles</i>	Total HH	Sampled HH
Silti	Ajira	860	36
	Dobana bati	623	26
	Shalewasho	712	29
	Sub total	2195	91
Misrak Silti	Sadagora	755	31
	Balo karso	746	31
	Chumbuli sada	535	22
	Sub total	2036	84
	Grand total	4231	175

## 2.4. Method of Data Analysis

The collected data was analyzed using descriptive statistics tools like mean, standard deviation, percentage and tabular presentation to describe demographic, technological and socio-economic variables for smallholder tomato producers. Moreover, to analyze technical efficiency stochastic frontier Cobb Douglas production function was applied by using STATA 13.

### Econometric Model Specifications

In this study, the stochastic frontier production method was adopted to estimate the technical efficiency of smallholder tomato production. This model is appropriate for two reasons: (a) Agricultural production in general depends on climatic conditions and is affected by shocks; hence the need to identify and separate this (Abebe 2014) and (b) stochastic frontier models specify noise separately from efficiency score and can test hypotheses since a functional form is specified. The outstanding advantage of this model is that it contains an inefficiency component which is used statistically to test for the degree of technical inefficiency of households (Abebe 2014; Haji and Andersson 2006; Malinga et al. 2015; Okoye et al. 2016; Wudineh and Endrias 2016) and also less sensitive to outliers (Kavoi et al. 2016). Its main weakness however lies in its assumption of an explicit functional form for technology and frequency for the distribution of the inefficiency terms (Haji and Andersson 2006). The stochastic production frontier was independently proposed by Aigner et al. (1977) and Mueesen and Broeck (1977). The stochastic frontier model can be generally represented as:

$$Y_i = f(X_i \beta) \exp (V_i - U_i) \dots \dots \dots (2)$$

Where  $i = 1, 2, 3 \dots 175$ ,  $X_i$  = vector of input quantities used by the  $i^{\text{th}}$  farm

$Y_i$  = output of the  $i^{\text{th}}$  farm,  $\beta$  = vector parameters to be estimated,  $V_i - U_i$  = composite error term,  $V_i$  denotes the random error not under the control of the farmers, assumed to be independently and identically distributed as  $N(0, \sigma v_i^2)$  and independently of  $U_i$  which is the non-negative random variable associated with technical inefficiency in the production (Battese and Coelli, 1995).

The technical efficiency (TE) of an individual farm is specified in terms of ( $Y^*$ ), conditioned on the level of inputs used by the farm. It is mathematically expressed as

$$TE = Y_i / Y^*$$

$$TE = f(X_i \beta) \exp (V_i - U_i) \dots \dots \dots (3)$$

$$f(X_i; \beta) \exp(V_i) \dots \dots \dots (4)$$

$$TE = \exp(-U_i) \dots \dots \dots (5)$$

Any farmer who is fully technically efficient will have a value of one and farmers with values lying between zero and below one are said to be technically inefficient. The frontier production function is estimated by the maximum likelihood estimation technique which yield estimators for  $\beta$  and  $\gamma$ , where  $\gamma = \frac{\sigma u^2}{\sigma^2}$  and  $\sigma^2 = \sigma u^2 + \sigma v^2$ . The parameter  $\gamma$  represents total variation of output from the frontier that is attributed to technical inefficiency and it lies between zero and one that is  $0 < \gamma < 1$ .

For the investigation of the technical efficiency and factors affecting the efficiency of smallholder tomato farms in the Siltie Zone, a Cobb-Douglas production function was adopted. Despite its well-known limitation, the Cobb-Douglas functional form was used. It has been argued by Binam et al. (2005) that the Cobb-Douglas production function provides an adequate representation of any given production technology. In addition, it is efficient for multiple input modeling and provides an efficient way of handling multicollinearity, heteroscedasticity and correlation (Kavoi et al. 2016). The following Cobb-Douglas stochastic frontier production is specified:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + V_i - U_i \dots \dots \dots (6)$$

Where

- Y is the value of tomato output measured in quintal;
- X<sub>1</sub> is land allotted for tomato (ha),
- X<sub>2</sub> is the total labour (family and hired) in man days,
- X<sub>3</sub> is the fertilizer (quintal),
- X<sub>4</sub> is the pesticide used (liter),
- X<sub>5</sub> is the seedling quantity (number),
- X<sub>6</sub> is irrigation (number).

The inefficiency model based on Battese and Coelli (1995) is specified as:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} \dots (7)$$

Where

- Z<sub>1</sub> = SexHH, Z<sub>2</sub> = AgeHH, Z<sub>3</sub> = Education level, Z<sub>4</sub> = Family size, Z<sub>5</sub> = Weeding frequency,
- Z<sub>6</sub> = Disease incidence, Z<sub>7</sub> = Credit, Z<sub>8</sub> = Extension contact, Z<sub>9</sub> = Experience, Z<sub>10</sub> = Type of variety used, Z<sub>11</sub> = Livestock (TLU)

### **3. Result and Discussions**

#### **3.1. Descriptive Statistics of Tomato Farmers in the Study Area**

The household and socioeconomic characteristics of the various sampled tomato farmers in the Silti and Misrak Silti districts are provided in Table 2. According to the survey, the average household head had a mean education of 4.26 year of schooling. The average household education ranged from 0 to 15 years portraying that some households had attained no education. This is pretty low and indicative of low education levels among tomato growing households in the study area. The mean age of the respondents was 41.36 years while the mean experience in growing tomatoes was 5.04 years implying most of the farmers in the study area were moderately experienced in growing tomatoes.

The mean household size in adult equivalency was 3.76 persons per family with family labour and hired labour totalling an average of 5.97 adult equivalents look for conversion factor in appendix 1. The mean cultivated area employed for tomato production was 0.23 hectare which ranged from 0.063 to 0.75 hectares. Average fertilizer use per hectare of tomato production was 0.76 quintal. The recommended dose for Nitrogen, phosphorus and potassium (NPK) in tomato production are 1quintal, 1.9 quintal and 1.9 quintal respectively, summing up to 4.8 quintal per acre of NPK (Najjuma et al. 2016). Compared to the mean fertilizer usage in the study area, farmers are using below the recommended dosage.

With the use of all the mentioned inputs, the mean tomato output was 35.01 quintal. The mean weeding frequency was 1.748 per the production season. It ranges from 0 to 4. Another important factor for tomato production is application of pesticide. As the result portrays, the mean pesticide usage was 5.31 liter. Regarding to the ownership of some assets, the mean livestock owning capacity was 3.90 TLU.

For the categorical variables, 155 of the respondents were males, giving a percentage of 88.57%. This clearly shows that tomato production is usually carried out by males. This is justifiable because most of the activities involved are very labour intensive. Incidence of disease and pests in the given production season were a severe problem for tomato producers. Accordingly, 70.29% of the respondents observe disease occurrence in their tomato field. Lastly, from the sampled respondents around half of them were using improved tomato from agricultural office and different cooperatives.

**Table 2 Descriptive statistics for households and tomato productivity variables. Source: Field survey results (2019/2020).**

<b>Variables</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Min</b>	<b>Max</b>
Age	41.36	8.946	25	72
Family size in adult equivalency	3.760	1.150	1.2	6.6
Labour(both family and hired)	5.971	2.312	4	14
Education in year of schooling	4.268	3.255	0	15
Area of cultivation in (ha)	0.231	0.117	0.063	.75
Actual yield in quintal	35.01	19.27	5	90
Weeding frequency	1.748	0.738	0	4
Tomato farming Experience	5.04	2.702	1	16
Fertilizer in quintal	0.76	0.309	0.35	1.75
Pesticide in Litre	5.31	4.89	.75	25
Livestock in TLU	3.90	1.501	0	9.97
Seedling in number	1314.86	668.59	400	4800
Irrigation in number	13.53	4.64	5	25
<b>Variables</b>	<b>Label</b>	<b>Freq</b>	<b>Percent</b>	
Sex	1= Male	155	88.57	
	0 = Female	20	11.43	
Prevalence  of disease	1 = Yes	123	70.29	
	0 = No	52	29.71	
Type of variety planted	1 = Improved	88	50.29	
	0 = local	87	49.71	

### **3.2. Stochastic Production Frontier Function**

The stochastic frontier production function was applied using the maximum likelihood estimation procedure using STATA computer program. Before proceeding to model estimation, tests were made for all assumption of stochastic frontier approach. First, a test was made for multicollinearity among the continuous and categorical explanatory variables using the variance inflation factor (VIF) and contingency coefficient (CC), respectively, and the values of VIF and CC for all variables entered into the model were below 10 and 0.75, respectively, which indicate

that there is no severe problem of multicollinearity among the explanatory variables appendix 2 and appendix 3.

Second, it is necessary to detect the presence of inefficiency in the production function for the sample households. This is made in order to decide whether the traditional average production function (OLS) best fits the data set as compared to the stochastic frontier Analysis (SFA). The test was carried out by estimating the stochastic frontier production function and conducting a likelihood ratio test assuming the null hypothesis of no technical inefficiency ( $H_0: = 0$ ). The likelihood ratio test statistics is calculated to be  $LR = -2(LH_0 - LH_1) = -2(-11.123 - (26.23)) = 74.7$ . This value exceeds the critical  $\chi^2$  value of 12.59 at 5% level of significance (Table 3). Thus, the null hypothesis must be rejected indicating that there is statistically significant inefficiency in the data. Hence, stochastic frontier production function was an adequate representation of the data.

**Table 3 Log Likelihood Test Ratio for Hypothesis Testing of Technical Inefficiency. Source: Model result (2019/2020)**

LH <sub>0</sub> (restricted)	Gamma equal to 0	-11.12
LH <sub>1</sub> (unrestricted)	Gamma not equal to 0	26.227
Degree of freedom	No of Para specify to zero in Null Hypo	6
$\chi^2$ Calculated	$\chi = -2[LH_0 - LH_1]$	74.70
$\chi^2$ Tabulated	5% level of sign, at 6 degree of freedom	12.59

The results of maximum likelihood estimates of variance parameters explain that variance parameter such as gamma that is the ratio of  $\sigma^2 u$  to the  $\sigma^2$  ( $\sigma^2 u / \sigma^2$ ) has value of (0.817) which shows that out of total variation in production 81.7 percent variation is due to technical inefficiency  $U_i$  while remaining 19.3 percent is due to the uncertainty  $V_i$ . Both sigma  $u(\sigma u)$  and sigma  $v(\sigma v)$  were statistically significant at the 1% level of probability, indicating a perfect goodness of fit with the Cobb- Douglas stochastic frontier model as well as the correctness of the specified distributional assumption of the composite error term (Table 4).

**Table 4 Maximum Likelihood Estimates of the Variance Parameters. Source: model result (2019/2020)**

Variance	Parameters	Coefficients	Std. Err.
sigma_v	$\sigma v$	0.1578	0.0234
sigma_u	$\sigma u$	0.3335	0.0415
sigma2	$\sigma^2$	.1361	0.0233
Lambda	$\lambda$	2.113	0.0599
Gamma	$\gamma$	0.817	-

Table 5 shows the maximum likelihood estimates obtained from the Cobb-Douglas stochastic frontier for tomato production. The study revealed that the area of tomato cultivation, total labours (both family and hired), fertilizer applied, pesticide used, quantity of tomato seedling used and irrigation frequency per a given production season are important determinants of tomato production. The variables were positive and statistically significant at 1% and 5% level of probability. This is highly expected and matches with *a priori* expectations.

**Table 5 Maximum likelihood estimates of the stochastic production function. Source: Field survey results (2019/2020).**

Variables	SFA model			OLS model	
	Parameters	Coefficients	Std. Err	Coefficients	Std. Err
Ln Area	$\beta_1$	0.2009***	0.052	0.129**	0.058
Ln labour	$\beta_2$	0.239***	0.054	0.336***	0.076
Ln Fertilizer	$\beta_3$	0.126**	0.058	0.291***	0.080
Ln pesticide	$\beta_4$	0.071***	0.024	0.087**	0.034
Ln Seedling	$\beta_5$	0.410***	0.051	0.414***	0.059
Ln Irrigation	$\beta_6$	0.124**	0.060	0.246***	0.075
Constant term	$\beta_0$	0.260	0.387		
RTS	$\beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 = 1.17$				
Log likelihood function		26.227		-11.123	
No. of obs		175		175	

Notes: \*\*\*, \*\*, denote the level of significance at 1 and 5 percent, respectively

A percent increase in the quantity of area of cultivation, labour, fertilizer applied, seedling used, pesticide and irrigation frequency will increase tomato output by 20.09 %, 23.9%, 12.6%, 41%, 7.1% and 12.4% respectively. Furthermore, the constant coefficient indicates that total output is 0.26 when area for tomato cultivation, fertilizer, seedling quantity, labour, irrigation frequency and pesticide used are kept constant.

The results further indicate that all inputs used in the production function are inelastic, implying that a 1 percent increase in every input will lead to a less than 1 percent increase in tomato output. Among all six input variables considered in our model, seedling appeared to be the most important factor of production that has the highest effect on tomato output with production elasticity equal to 0.41. This implies that a 1 percent increase in the quantity of improved seedling increases the level of tomato output by about 0.41 percent, *ceteris paribus*. The significant and positive sign of seedling variable also indicated that a moderate increase in population of tomato on the field will increase the yield provided that, the farm is not overpopulated beyond the recommended tomato carrying capacity that will lead to competition for nutrients which will lower the yield. This result is consistent with Pretty et al. (2011), Zalkuw et al. (2014) and Chiona et al. (2014).

The following highest elasticity was for quantity of labor used, with production elasticity equal to 0.239. This implies that amount of labor used for tomato production plays a significant positive impact on raising the tomato production level, as a 1 percent increase in the quantity of labor in adult equivalency leads to an estimated 0.239 percent increase in tomato output, *ceteris paribus*. This finding is consistent with our expectations, and concurs with other existing studies that found a significant positive effect of labor on the crop output, such as Pretty et al. (2011), Fatima and Khan (2015), Weldegiorgis et al. (2018), Ngango et al. (2019), Abate et al. (2019)

Fertilizer input is also sensitive toward tomato production, as a 1 percent increase in fertilizer will boost the production of tomato by 0.126 percent, *ceteris paribus*. This result conforms to prior expectation of the positive effect of fertilizer use on tomato output; it is also consistent with studies by Theriault and Serra (2014) and Abate et al. (2019). Likewise, land is an alternative input variable that can improve tomato production. We found that land size was associated with an elasticity coefficient of 0.20, implying that a 1 percent increase in the area under tomato plantation will lead to a 0.20 percent increase in tomato production. This finding

conforms to prior expectations, and concurs with Pretty et al. (2011), Zalkuw et al. (2014), Fatima and Khan (2015), Ngango et al. (2019).

Finally, the elasticity coefficients associated with pesticide and irrigation inputs were found to be 0.071 and 0.124 respectively, implying that a 1 percent increase in the amount of pesticide in litre for tomato production will lead to a 0.071 percent increase in tomato production while holding other inputs constant. On the other hand, 1 percent increase in frequency of irrigation for tomato production will lead to a 0.124 percent increase in tomato production. This result is consistent with the findings of Khan et al. (2010) and Ngango et al. (2019).

The sum of all partial production elasticities (i.e., scale elasticity) equaled 1.17, indicating the presence of an increasing returns to scale (IRS) in tomato production. IRS implies that a proportional increase in all factors of production results in a more than proportional increase in tomato output.

### 3.3. Factors Influencing Technical Efficiency

The presence or absence of technical inefficiency was tested in the study using the important parameters of the log likelihood in the half normal model.

**Table 6 Technical Inefficiency effects Function. Source: Field survey results (2019/2020).**

Variable	Parameters	Coefficients	Std.Err	Z	P value
Constant	$\delta_0$	-3.731	2.633	-1.42	0.156
Sex of HH	$\delta_1$	-0.976**	0.458	-2.13	0.033
Agesqrt	$\delta_2$	0.386	0.365	1.06	0.291
Education	$\delta_3$	0.076	0.069	1.11	0.267
Family size	$\delta_4$	0.123	0.162	0.76	0.446
Weeding frequency	$\delta_5$	-0.931***	0.284	-3.27	0.001
Disease Incidence	$\delta_6$	2.332**	0.837	2.79	0.005
Credit	$\delta_7$	0.279	0.507	0.55	0.581
Extension contact	$\delta_8$	-0.022	0.051	-0.43	0.668
Experience	$\delta_9$	-0.115	0.072	-1.60	0.110
Type of variety	$\delta_{10}$	-0.975***	0.409	-2.38	0.017
Livestock	$\delta_{11}$	-0.167	0.118	-1.41	0.158

Notes: \*\*\*, \*\*, \* denote the level of significance at 1, 5, and 10 percent, respectively

If  $\lambda=0$ , then, there were no effects of technical inefficiency and all deviations from the frontier were due to noise. The estimated value of  $\lambda=2.113$  significantly differed from zero. As a result, we fail to reject the null hypothesis. To analyze the factors having an impact on the technical efficiency of tomato production, an inefficiency model was implicitly specified. The inefficiency parameters shown in Table 6 relate to farm-specific characteristics and the farmer's socio-economic position. The parameters of important determinants of inefficiency were discussed as follows.

**SexHH:** The sex of household head coefficient is estimated to be negative and statistically significant at 5%, which implies that male farmers are relatively more efficient in tomato production. This is due to planting, weeding, staking, harvesting and other tomato management operations are labour-intensive. Female farmers also have relatively less access to productive resources. The result could also be explained by the imbalance in resource's access by gender. In literature, allocation of resources to poor women has a bigger impact on production and productivity; hence our result could imply the relatively low efficiency of women-headed tomato farmers could be due to lack of access to productive resources. This finding is in line with Mango et al. (2015).

**Frequency of weeding:** The coefficient for the frequency of weeding is estimated to be negative and statistically significant at the 1% level. This indicates that more frequent weeding and proper management of tomato tend to increase technical efficiency, as weeding and proper management including tying the tomato plant to stake stuck in the ground provide support to plant in order to grow upward and produce more. This finding is in line with Mango et al. (2015).

**Disease Incidence:** The coefficient of the incidence of disease and pest infestation in a given production season was positive and significant at the 5% level of probability. This implies that the more prevalence of disease and pest infestation, the lower will be the farmers' technical efficiency. This is expected as occurrence of disease could affect smallholders' tomato farm productivity. This result is consistent with Emam (2011) and Gemechis et al. (2012)

**Tvariety:** The use of an improved variety of tomato crop was also found to significantly improve the level of farmers' TE. Specifically, in the study area, farmers who produced improved variety were more technically efficient than their counterparts, who still had low yielding local tomato varieties. This finding supports Pretty et al. (2011) and Chiona et al. (2014)

and who acknowledged the importance of modern and upgraded crop varieties in improving productivity and efficiency in Rwanda and Zambia respectively.

#### 2.4. Distribution of TE Scores and Yield Gap due to Inefficiency of Tomato Farmers

The model output presented in table 7 indicates that farmers in the study area were relatively good in TE. The mean TE was found to be 81.7%. This implies that in the short run there are opportunities for reducing tomato production inputs by 19.3% and performing the practice of technically efficient farmer in the locality. Or the mean of TE indicates that if sample households operated at full efficiency level, they would increase their output by 19.3% using the existing resources and level of technology. This mean score is in line with a similar study conducted by Ngango et al. (2019) who observed a mean technical efficiency level of 82% amongst coffee growers in the Rwanda.

**Table 7 Distribution of TE scores. Source: Model results of survey data (2019/2020).**

Range of TE(%)	Number of farmers	% of farmers in TE interval
< 50	11	6.29
50-59	4	2.29
60-69	18	10.29
70-79	27	15.43
80-89	53	30.29
90-99	62	35.43
Total	175	100
Mean TE (%)	81.7	
Standard deviation	0.148	
Minimum TE (%)	25	
Maximum TE (%)	97.7	

As indicated in the table technical efficiency ranges from 0.25 to 0.977. For average efficient farmers in the area, to achieve the technical efficiency level of the most efficient farmers could only bring  $(0.977 - 0.817/0.977)$  16.37 percent increase in production. The least efficient farmers can increase the production of  $(0.977-0.25/0.97)$  74.3 percent to achieve the required technical efficiency of the most efficient farmers. However, a gap still exists between

the efficiency of the least technically efficient farmer 25 percent and that of the mean technical efficiency. This suggests that considerable amount of productivity is lost due to inefficiency. According to table 7 results of technical efficiency score distribution, we found that about 35.43 percent of tomato farmers in the sample have a TE ranging from 90 to 100 percent.

**Table 8 Tomato yield gap due to technical inefficiency. Source: Model results of survey data (2019/2020).**

Variable	Mean	Std.Dev.	Min	Max
Actual yield(quintal/ha)	35	19.26	5	90
Potential/frontier yield(quintal/ha)	41.19	18.68	13.8	95.12
TE estimates	81.78	14.8	25	97.7
Yield gap/loss(quintal/ha)	6.18	4.7	1.02	37.23

Knowing the individual farmers technical efficiency and actual output in tomato production enables to determine the potential level of tomato output farmers produce through efficient use of existing inputs and technology. The potential tomato output was estimated for sample tomato producer farmers by dividing the actual individual level of tomato output by the predicted technical efficiency scores from stochastic frontier model. After calculating potential tomato output, the yield gap of tomato was estimated. Yield gap is estimated by the difference between technically full efficient yield and observed yield.

As observed from table 8 mean technical inefficiency was 19.3% which caused 6.18 quintal yield gap of tomato on average with mean value of the actual output and the potential output of 35.01 quintal and 41.19 quintal, respectively. This shows that sample households in study area were producing on average 6.18 quintal lower tomato output than their potential yield. In other words, the result indicated that in the short run there is a potential to increase tomato output on average by 6.18 quintal at the existing input use and technology through improving technical efficiency of farmers. Under the existing practices there is a room to increase tomato yield following the best-practiced farms in the study area. This study is in line with Abate et al. (2019).

#### **4. Conclusions and Recommendations**

Stochastic frontier Cobb Douglas production function was used to measure the mean technical efficiency of the farmers by using parametric approach. This study applied a sample of 175

tomato farmers operating in the Siltie Zone Southern Ethiopia in order to derive their TE scores, and then investigated the factors that influence TE of tomato farmers in the study area. The mean level of TE among tomato farmers in the study area was estimated at 81.7 percent. From a technical standpoint, this implies that there is a potential to increase tomato production by about 19.3% with the current levels of inputs and farm technologies available in the area through the reduction of technical inefficiency. The analysis of partial production elasticities and returns to scale revealed that all inputs used in the production function are inelastic, that is, a 1 percent increase in each input will lead to a less than 1 percent increase in tomato output. In addition, we found that tomato production was more responsive to seedling, followed by labour, land, fertilizer, irrigation and pesticide. The returns to scale (RTS) coefficient was found to be 1.17, which implies that farmers in the area experience IRS in tomato production. In other words, this suggests that a proportional increase in all factors of production results in a more than proportional increase in tomato output. Our results further revealed that sex, prevalence of disease and pests, improved variety of tomato seedling and weeding frequency significantly improved tomato producers' TE.

On the basis of the results of the study, the following policy implications are proposed. The main focus should be put on training and encouraging farmers to adopt improved and disease resistant varieties. In addition, proper tomato crop management through the help of extension services should be strengthened and should target all farmers in all locations. This will improve the farmers' managerial skills, thus resulting in higher technical efficiency. The government should empower women farmers by ensuring that they are not marginalized in productivity-enhancing inputs like facilitating credit access, extension contact and equal access for training in any aspect of production and marketing.

In the study area tomato crop is cultivated through irrigation system. The very good opportunity for the study area is that underground water is found in not more than five meter depth and availability of small Abbaya Lake in Misrak Silti Wereda. It is possible to dig a borehole at smallholder level in their farm. However, their main problem is borehole slide. This is due to the nature of the soil. On the other hand, if the irrigation project over this lake be implemented, the smallholders around the lake can be efficient in their tomato and other vegetable production as well. Thus, government and other concerned organizations should have to assist smallholders' regarding to this irrigation problem in the study area. The findings further

suggest that research and development is needed to develop and release improved tomato varieties. Finally these findings may not generalize the whole situation of TE among tomato farmers across Ethiopia. Hence, future research must consider a larger sample of farmers that covers all Ethiopia.

### **Abbreviations**

CC: Contingency coefficient; CSA: Central statistical authority; FAO: Food and Agricultural organization; FGDs: Focus group discussions; GDP: Gross domestic product; GTP: Growth and Transformation Plan; HH: Household head; KII: Key informant interview; In: natural logarithm; LR: Log likelihood ratio; MLE: Maximum likelihood estimator; NBE: National bank of Ethiopia; NPK: Nitrogen, Phosphorus and Potassium; OLS: Ordinary least square; RTS: Return to scale; SFA: stochastic frontier analysis; SNNPR: South Nations, Nationalities and People Region; SZBoA: Siltie Zone Bureau of Agriculture; TE: Technical efficiency; TLU: Tropical livestock unit; VIF: Variance inflation factor.

### **Conflict of Interest**

The authors have not declared any conflict of interest.

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### **Authors' contributions**

DEC, GET and BET were carried out “Analysis of Technical Efficiency and Its Potential Determinants among Small-Scale Tomato Farmers in Siltie Zone, Southern Ethiopia”. All authors have participated in proposal development, data collection and final manuscript approval.

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## APPENDICES

### Appendix 1. Conversion factor used to compute adult equivalent

Age group year	Male	Female
< 10	0.6	0.6
10-13	0.9	0.8
14-16	1	0.75
17-50	1	0.75
>50	1	0.75

Source: Storcket *al.*, 1991

### Appendix 2

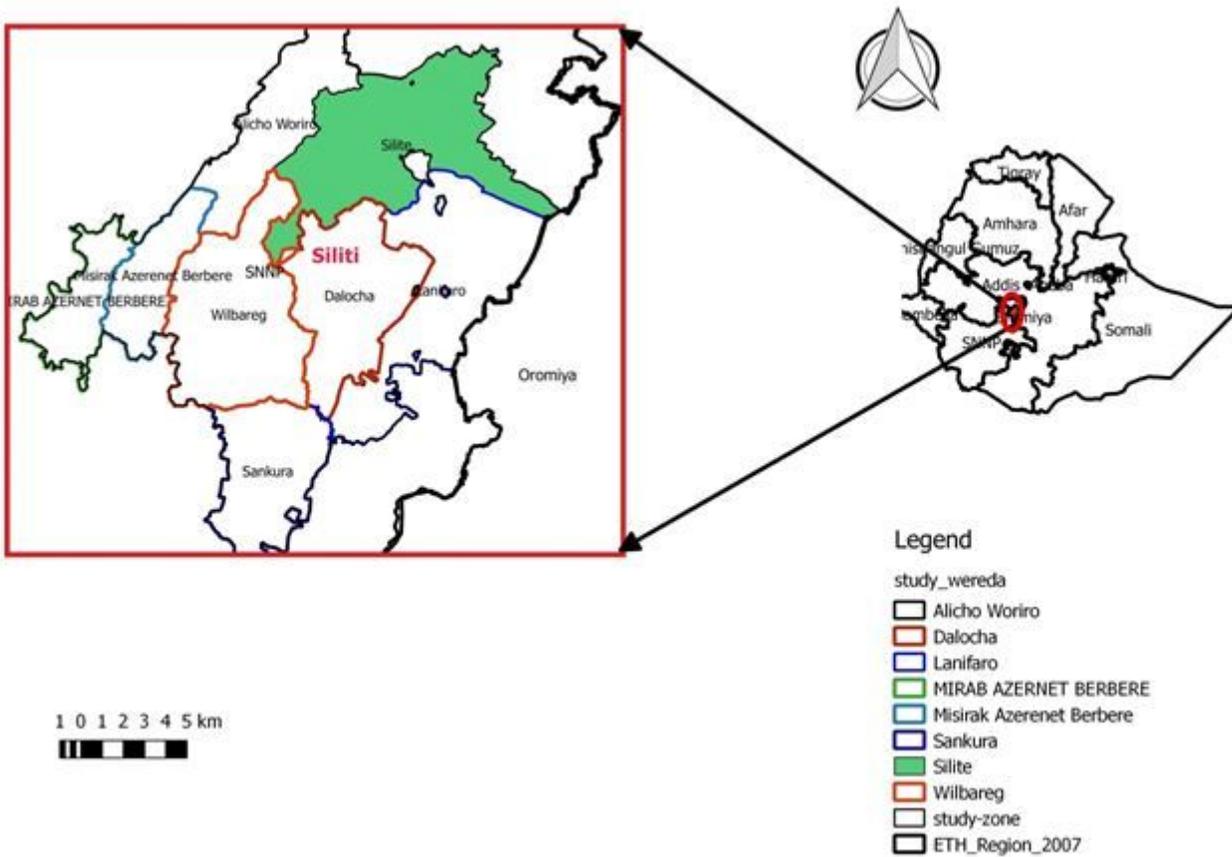
Variable	VIF	1/VIF
LnFertilizer	2.39	0.419234
LnSeedling	2.05	0.488342
LnPesticide	2.00	0.499197
LnArea	1.85	0.539530
LnIrrigation	1.80	0.555531
LnLabour	1.78	0.560230

Variable	VIF	1/VIF
Extcontact	1.91	0.523159
Productivity	1.70	0.588433
Agesqrt	1.70	0.589037
Ltomato	1.61	0.620049
Education	1.34	0.747473
Fsize	1.33	0.750427
Texperience	1.33	0.753805
Marktdistance	1.17	0.854991
Livestock	1.13	0.886791
Mean VIF	1.47	

### Appendix 3

	SexHH	Diseft	Credit	Tvariety
SexHH	1.0000			
Diseft	-0.1550	1.0000		
Credit	0.1874	-0.5022	1.0000	
Tvariety	0.1098	-0.3214	0.3253	1.0000

# Figures



**Figure 1**

Map of study area. Source: Own developing using satellite data (2019) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.