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RESEARCH PAPER

Analysis of Tomato and Onion Production Efficiency in Ejersa Lafo District of West Shewa Zone, Oromia National Regional State, Ethiopia

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Abstract

Increasing productivity and efficiency in agricultural production could be seen as an important step towards attaining food security. Hence, the study was conducted to identify factors affecting tomato and onion production efficiency in the Ejersa Lafo district of West Shewa zone, Oromia using cross-sectional data obtained from 145 randomly selected sample farm households, which was analyzed using data envelopment analysis and an econometric (Tobit) model. Accordingly, the average TE, AE, and EE of sampled households are 66.2%, 55.4%, and 36.7%, respectively. The tobit model confirmed that family size, total cultivated land and frequency of ploughing positively and significantly affected TE, while distance to the nearest market had a negative and significant effect on TE and the number of livestock owned. Frequency of ploughing and extension contact affected AE significantly and positively, while EE was significantly and positively affected by education level, family size, total cultivated land, frequency of ploughing and access to credit services. However, the distance to the nearest market significantly and negatively affected the EE level of tomato and onion producers. Based on the results gained, the study recommends that improving the above problem can increase farmers' economic efficiency in the study area.

Keywords: *Tomato, Onion, Efficiency, DEA, Tobit, Ejersa Lafo, Ethiopia*

Introduction

Africa is still producing too few products and its productivity has been largely stagnant (AGRA, 2020). In Ethiopia, agriculture is the mainstay of the economy and is still expected to play a dominant role in the years to come. The sector plays a substantial role in the lives and livelihoods of most Ethiopians. It accounts for over 35.8% of the country's GDP and 79% of the national export earnings were obtained from this sector (CIA, 2019). This means that the performance of the country's whole economy is heavily reliant on agricultural growth. The sector is also thought to be the key to both poverty alleviation and the realization of transformative growth in Ethiopia. This together placed the sector at the center of development and policy interventions (FDRE, 2020).

According to Nimona (2017), commercial and smallholder farmers in Ethiopia grow a variety of vegetable and root crops as a source of income and food in various agro-ecological zones. Vegetable production accounts for roughly 1.67% of all farmlands and 2.23 percent of overall crop volume at the national level (CSA, 2018/19). It is an efficient strategy to alleviate poverty, pay attention to customer health and well-being, and provide farmers, customers, and agro-manufacturing with modern market opportunities (Hailu and Fan, 2017; Cochrane and Bekele, 2018; Rikitu et al., 2019).

Tomatoes are one of the most widely grown vegetable crops on the planet. After potatoes and sweet potatoes, it is the world's third largest vegetable crop, and it ranks first among all vegetables as a processed crop (Agrisnet, 2010). Ethiopia produced 22,788 tons of tomatoes in the 2015 cropping season from a harvested area of 3,677 ha, making it the world's 84th largest tomato producer (CSA, 2015). Tomatoes are Ethiopia's fourth most popular vegetable after Ethiopian cabbage, red pepper, and green pepper (5.45%). It produces 6.2 tons per acre on average across the country (Desalegn et al., 2016).

Onions are grown all over the world for their numerous health advantages. Onion output in the world totals 742.51 million tons per year, covering around 4.3 million hectares of land. Africa accounted for 570,000 hectares of the total cultivated land (FAOSTAT, 2019). Ethiopia's onion cultivated area and yield, according to CSA (2018/19), were 28,185.71 hectares and 2,624,782.85 tons, respectively. Although onion production is improving, Ethiopian productivity is low when compared to other African countries. Ethiopia's productivity is 9.31 tons per hectare, compared to Oromia's 7.56 tons per hectare and the Ejersa Lafo district's 4.7 tons per hectare (ELDANRO, 2021). Due to a lack of access to modern agricultural technologies, Ethiopia is heavily influenced by food security concerns. Smallholder farmer productivity and profitability are extremely low in the country, and rural productivity growth has barely kept pace with population expansion. Despite this, farmers are discouraged from increasing production due to a lack of agricultural technology.

Analyzing efficiency levels can help you understand the components of the efficiency system and solutions for enhancing efficiency (Sisay et al., 2015). It's worth emphasizing that more efficient resource use leads to increased production. Farmers' efficiency improvements resulted in higher yields, food security, and higher living standards. As a result, growing agricultural products could boost revenues while reducing price volatility. Most of the time farmers in the research area interested in increasing production due to their economic efficiency returns. Given the limited resources available to farmers, raising tomato and onion output for food security necessitates efficient use of current resources.

As a result, the study was performed to investigate the problem and knowledge gap faced by farmers in tomato and onion production, compare the severity of the problems faced by producers, identify some selected farmer characteristics, and investigate the relationship between the selected farmer characteristics and the problems encountered in tomato and onion production efficiency in the study area.

Materials and methods

Description of Study Areas

Ejersa Lafo was selected due to the potential vegetable production exists in the district. It is one of the 22 districts that make up the West Shewa zone. The district was located 70 kilometers west of Ethiopia's capital city, Finfine, and 47 kilometers east of Ambo, a zonal town. The district's current administrative structure consisted of 17 rural and 3 urban kebeles. The district had a population of 61,141 people, with 33,604 men and 27,537 females (ELDAO, 2021).

Types and Sources of Data

The research was approached using primary and secondary data sources, which have qualitative and quantitative nature.

Sampling Techniques and Sample Size Determination

To obtain a representative sample, two-stage sampling approaches were used. In the first step, three kebeles were chosen at random from a total of seven prospective vegetable-producing kebeles in the district's midland agro-ecological zone/area. In the second stage, sample vegetable farmers were chosen from each of the three kebeles using a probability proportional to size (PPS) method. The sample size was calculated using the Taro (1967) formula and simple random sampling (SRS) methods, yielding 145 sample households. The sample size was calculated using the following formula:

n = N/(1+N 〖(e)〗 ^2)=2090/(1+2090 〖(0.08)〗 ^2)=145------------------------------------- (1)

Where: n = Sample size, N = Total number of vegetable producers in studied kebeles, e = level of precision which is 8% (since, the producers have homogeneity characteristics) and 1 is for designates probability of the event occurring. Yamane's formula was used because of its homogenous type of population in the study area and known population and 8% of precision level was applied for the purpose of managing all samples in terms of the available resource that the researchers have including cost, time, etc.

Table 1: Sample households of the three *kebeles*

Name of Kebeles	**Vegetable producing HHs**			**Sample household heads**		
	Male	Female	Total	Male	Female	Total samples
Chalalaka Bobe	593	210	803	41	15	56
Jamjam L/ Batu	645	102	747	45	7	52
Kala Embortu	380	160	540	26	11	37
Total	1,618	472	2,090	112	33	145

Source: Own computation based on the district data (2021)

Methods of Data Collection

The primary data was acquired from sample households using a semi-structured questionnaire, a checklist from a focus group discussion, and a key informant. Policy and institutional elements, socioeconomic factors, demographic traits, and market factors are all included in the questionnaire. Farmers, DAs, and district agricultural experts provided primary data. Secondary data was used to supplement primary data, such as reports from line ministries, journals, books and CSA national policies, zone and district reports.

Methods of Data Collection

Descriptive Statistics

Demographic, socioeconomic, agricultural, and institutional characteristics of producers in the research region were described using descriptive statistics such as mean, minimum, maximum, percentages, frequencies, and standard deviation. In addition, descriptive statistics were used to depict the inputs, expenses, and outputs of production across sample households.

Econometric Analysis

The goal of this study was to analyze the elements that influence tomato and onion producer efficiency, as well as the sources of inefficiency. The Tobit analysis approach was used to achieve this goal. Because the approach is designed to deal with estimation bias related to censoring, it is more efficient and beneficial in avoiding biased estimations. Furthermore, when the dependent variable is constrained to a range between 0 and 1, the model is more appropriate (Greene, 2003).

According to Farrell's seminal study from 1957, there are two widely used methodologies for assessing production efficiency. They are the stochastic production frontier (SPF) and data envelopment analysis (DEA) techniques (the model was independently projected by Meeusen and Broeck (1977). TE, AE, and EE are studied using data envelopment analysis. A farm's efficiency is determined by comparing its input/output performance to that of all other farms in the sample (Fraser and Cordina, 1999).

To investigate the technical and allocative efficiency, data envelopment analysis was presented as the following. Suppose the number of decision making unit (DMU) is n. Tj-th DMU is characterized as DMUj (j=l, 2…n). The input vector of DMUj is Xj= (X1j, X2j…Xmj) T, and the output vector is Yj= (Y1j, Y2j…Yrj) T. Here, m is the number of input, r is the number of output. The corresponding weight coefficient is V= (V1, V2…Vm) and U= (U1, U2…Ur) respectively. Also suppose Xij is the i-th input value of the j-th DMU, Ykj is the k-th output value of the j-th DMU. Vi, Uk is the weight coefficient of the i-th and the k- th index respectively. Then the corresponding appraisal efficiency index of the j-th DMU is:

$$H_i = \frac{u^T y_j}{V^T x_j} = \frac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}} \text{----------------------} (3)$$

The EE score for a given field n is obtained by first solving the following cost-minimizing Linear Programming (LP) model:

$$MC_n = min_{\lambda i x_{nj}^*} \sum_{j=1}^{J} p_{nj} x_{nj}^*$$

Subject to:

$$\sum_{i=1}^{j} \lambda_i x_{ij} = x_{nj}^* \leq 0$$

$$\sum_{i=1}^{1} \lambda_i = 1$$

$$\lambda_i \geq 0$$

Where mc_n = the minimum total cost for field

$n; p_{nj}$ = the price for input j on field n; and

x_{nj}^* = the cost-minimizing level of input j on.

Selecting the appropriate weight coefficients V and U to allow H i1. A high hj suggests that the DMU can use less input to produce more outputs. A Tobit regression model was used to determine the relationship between socioeconomic and institutional characteristics and the derived efficiency indices. Because the efficiency scores were twice truncated at 0 and 1, and the scores feiled within the range of 0 to 1, this model was chosen. This Tobit model's functional form is:

$$y^* = \beta_0 \sum \beta_m x_{jm} + \mu \text{-----------------------} (4)$$

Where yi* representing the non-observed efficiency latent variable scores of farm j, β = a vector of unknown parameters, Xjm = a vector of explanatory variables m (m = 1, 2... k) for farm j and μ_i = an error term that is independently and normally distributed with mean zero and variance σ2 denoting y_i as the observed variables,

$$y_i = \begin{cases} 1 \;\; if \;\; y_i^* \geq 1 \\ y_i^* \;\; if \;\; 0 < y_i^* < 1 \\ 0 \;\; if \;\; y_i^* \leq 1 \end{cases} \text{-----------------------}(5)$$

In the Equation (4, 3), the distribution of the dependent variable is not normally distributed rather its value varies between 0 and 1. Therefore, the maximum likelihood estimation which can yield the consistent estimates for unknown parameters vector for it has been used than the ordinary least square (OLS) estimation which gives biased estimates (Maddala, 1986).

Results and discussion

Descriptive Statistical Results

Major Vegetable Grown and Area Coverage

The farming system of the district is mixed crop-livestock where crops play the major role in the farmers' income; animals are kept for complementary purpose and to meet farmers cash needs. Table 3 shows that the land allocated for vegetable and root crops by sample households which is on average 0.20 ha for tomato followed by onion (0.14 ha) and green pepper (0.10 ha). Cabbage (0.07 ha) and potato (0.05 ha) were the most frequently sown vegetable and root crops during 2020/21 production year in the sampled area.

The average production of main vegetables is also shown in kilograms in the survey results. Given the differences in productivity among vegetables, sample households received an average of 8776.77 kg of tomato and 3415.86 kg of onion, as shown in Table 2. The typical home received 3260.57 kg of green pepper, 1210.54 kg of cabbage, and 1829.35 kg of potato, respectively. During the survey period, key informants and focus group discussions revealed that the production of major vegetables was reduced in the 2020/21 production season due to a variety of factors including disease and insects, high prices for improved seed, water shortages, and cold, as compared to the previous years' experience.

Table 2: Area coverage and production of major vegetable grown by sampled households

Type of vegetable	Area coverage (ha)		Production (kg)	
	Mean	Std. Dev.	Mean	Std. Dev.
Tomato	0.20	0.35	8776.77	15022.57
Onion	0.14	0.24	3415.86	5977.76
Green pepper	0.10	0.13	3260.57	4391.83
Cabbage	0.07	0.12	1210.54	2886.31
Potato	0.05	0.11	1829.35	3928.81

Source: Own computation (2021)

Description of Production Function and Variables

Six input variables were used to estimate the production function for this investigation. Table 3 reveals that in the 2020/21 production season, the average tomato and onion produced in the research region were roughly 8776.77 and 3415.86 kg, respectively, with a standard deviation of 15022.57 and 5977.76 among the tested farmers, indicating a considerable disparity in output between the households. Table 4 shows that the average land holding for tomato and onion production was about 0.34 ha, with a standard deviation of 0.52 and a range of 0 to 2 ha. Farmers in the research area are small-scale and have family-managed and operated farm plots, as seen by the average land allotted to tomato and onion production.

Tomato and onion production used an average of 2.33 man-equivalents, with a standard deviation of 3.10. This demonstrates that the sample household's production was labor-intensive. The average number of oxen utilized for labor was 1.26 pairs. Oxen ownership influences land preparation and management. Farmers with more oxen per ha employ more labor and have greater oxen draft power, implying that oxen and labor are complementary. Ploughing activities also increase as oxen ownership increases. The average amount of chemical fertilizer utilized, on the other hand, was 3.18 qt. However, as the expert stated, the suggested fertilizer rate is 4 qt per ha. This indicates that farmers did not apply fertilizer at the recommended rate. This study is in line with (Rikitu et al., 2019).

Furthermore, the farmers in the research area used an average seed rate of 1.45 kg. However, according to expert descriptions, the suggested seed rates in the extension packages for tomato and onion are 1.5–1.75 and 1.5–2 kg per hectare, respectively. This indicates that the amount of tomato and onion seeds utilized by the sampled farmers was less than what the extension service suggested. On average, 1.25

liters of insecticide were applied. This also implies that farmers used pesticides (herbicides, fungicides, and insecticides) at a lower rate than recommended due to the high cost of insecticides (ELDANRO, 2021).

Table 3: Summary statistics of production input variables

Variables	Mean	Std. Dev.	Min	Max
Output (Y) (kg)	12192.63	19150.37	0	77600
Tomato yield (TMTYLD) (kg)	8776.77	15022.57	0	64800
Onion yield (ONNYLD) (kg)	3415.86	5977.76	0	25600
Total land (LND) (ha)	0.34	0.52	0	2
Total labour (LAB) (ME)	2.33	3.10	0	9.1
Total seed (SEED) (kg)	1.45	2.39	0	10
Fertilizers (CHEMFERT) (qt)	3.18	4.87	0	18
Total oxen (OXEN) (pair oxen)	1.26	1.10	0	4
Total pesticides (PSTCD): (lit)	1.25	1.86	0	7

Source: Own computation (2021)

Description of Variables Used in Cost Function

Similar to the production function, the average and standard deviation of each variable used in the cost function are summarized and presented below in Table 5. The average total cost of birr 24585.28 was required to produce 12192.63 kg of tomato and onion output. Among the various factors of production, the cost of seed accounted for the highest share (9,843.45 birr) and the cost of oxen accounted for 418.41 birr, which was the smallest cost.

Table 4: Summary statistics of production cost variables

Variables	Mean	Std. Dev.	Min	Max
Cost of production (CSTY) (birr)	24585.28	37945.12	0	138550
Cost of land (CSTLND) (birr)	6177.93	9791.95	0	36000
Cost of labour (CSTLAB) (birr)	2098.48	3101.25	0	10800
Cost of seed (CSTSEED) (birr)	9843.45	15422.16	0	56000
Fert. cost (CSTCHEMFERT) (birr)	5419.90	8428.86	0	31500
Cost of oxen (CSTOXEN) (birr)	418.41	591.28	0	1800
Pesticides (CSTPSTCD) (birr)	627.10	986.56	0	4500

Source: Own computation (2021)

Demographic and Socio-economic Characteristics of Sampled Households

The mean, minimum, maximum, and standard deviation of family size, age, livestock size, and education status of sampled households are presented in Table 5 below. The sampled household's average family size was 3.39, with a minimum of 2 and a maximum of 6. Family size has a dual purpose: it provides more family labor, which reduces pesticide use, particularly herbicides, and increases consumption. During the survey period, the average age of the sample homes was 37.21 years, with a minimum of 23 and a maximum of 51. This means that the majority of the sample households were younger (middle-aged) farmers in their productive years.

Due to the mixed farming system, livestock plays a significant role as a source of income in the research area. Furthermore, households with a larger livestock herd may have fewer issues with purchasing farming inputs such as seed and fertilizer. The cattle, oxen, bulls, horses, donkeys, calves, sheep, goats, heifers, and hens are among the livestock managed by the tested household. Oxen power is an important input in the agricultural production process, functioning as a source of draft power, among other things. The average livestock holding of the research area's sampled farmers was 9.48 TLU (Table 5).

Education is a tool for improving farming systems by allowing new technologies and techniques to be adopted. Furthermore, through knowledge improving acquisition and decision-making abilities, it would assist households in producing higher output using existing resources more efficiently. Finally, the survey result shows, the average educational level of sampled households was around 7.10 years old, with a minimum of 1 and a maximum of 12 years of schooling.

Table 5: Age, education level, family size and livestock holding of sampled household.

Variables	Mean	Std. Dev.	Min	Max
Age of sample HH (year)	37.21	8.89	23	51
Educational level of sample HH (school year)	7.10	2.66	1	12
Total family size of sample HH (number)	3.39	1.23	2	6
Livestock owned of sample HH (TLU)	9.48	2.47	5.19	16.31

Source: Own computation (2021)

Wealth, Physical, Institutional and Farm Characteristics of Sampled HHs

The following tables show the lowest, maximum, mean, and standard deviation of farm size, distance from the nearest market, frequency of extension contact, and ploughing of sampled families (Table 6). The average size of the sampled household's total cultivated land was 1.47 hectares, excluding land used for tomato and onion production. According to the survey results, households in the study region have bigger land sizes than the national average of Ethiopian farmers, which is 1.2 ha (Chanie, 2011). According to the survey results, the average walking distance to the nearest market from the farmer's home was 0.70 hours, while the minimum and maximum walking distances to the nearest market from their homes were 0.25 hours and 1.25 hours, respectively.

Extension services are commonly used to disseminate new and better farming techniques. Extension agents are the primary suppliers of agricultural knowledge to farmers. Farmers are more aware of the use of new technology as a result of increased contact with extension agents, which helps them enhance agricultural production and productivity. Extension agents contact farms at various times; some farmers are contacted more frequently, while others have a much lower likelihood of being reached at all. According to the survey results, extension agents contacted sample households an average of 5.12 times during the 2020/21 production season in the study region.

The number of ploughs indicates the intensity of land preparation that helps for appropriate germination of seed, which is expected to have a direct impact on yield. Sample households were ploughing their vegetables (tomato and onion) fields on average 3.47 times, with a minimum of 2 and a maximum of 5.

Table 6: Farm size, extension contact, frequency of ploughing and distance from market

Variables	Mean	Std. Dev.	Min	Max
Total cultivated land (ha)	1.47	1.04	0.25	4
Distance from the nearest market (hour)	0.70	0.31	0.25	1.25
Frequency of extension contact (number)	5.12	2.13	2	9
Frequency of ploughing (number)	3.47	1.09	2	5

Source: Own computation (2021)

Problems of Tomato and Onion Production

Diseases and insects, expensive pricing of improved seeds, weeds, pesticides, inadequate soil fertility, and a lack of rainfall (water for irrigation) were all cited by the households in the survey. When the problems were ranked in order of frequency, disease and insects, high prices of improved seed, high prices of pesticides, lack of rainfall (water), weeds, low soil fertility, and other issues accounted for 106, 52, 45, 28, 17, 11, and 8 respectively. Disease and insects were identified as the greatest challenges to vegetable (tomato and onion) production in the survey (Table 7).

Table 7: Major problems of vegetables (tomato and onion) production

Types of problem	**Sample HHs who identified the problems**		
	Frequency	Percent	Rank
Disease and insects	106	73.1	1
High price of improved seed	52	35.9	2
High price of pesticide	45	31	3
Shortage of rainfall (water)	28	19.3	4
Weeds	17	11.7	5
Low fertility of soil	11	7.6	6
Others	8	5.5	7

Note: Percentage cannot be added to 100 due to multiple responses
Source: Own computation (2021)

Econometric Result

Specific explanatory variables of household characteristics and their relationship with tomato and onion production efficiency were discussed in the preceding descriptive statistical results. However, only examining the relationships and associations between these variables is insufficient to summarize and draw significant conclusions. As a result, the findings and discussion from the econometric model on factors impacting technical, allocative, and economic efficiencies of vegetable growers, as well as the cause of inefficiency, are shown below.

This section evaluates tomato and onion production efficiency in terms of TE, AE, and EE. Keeping in mind the widely accepted method for performing DEA in efficiency analysis, it was decided to execute different input and output to avoid the possibility of encountering issues connected to beneficial structural misspecifications. The output variables were vegetable production, which was measured in kilograms of tomato and onion collected. Land, labor, oxen, seed, chemical fertilizer, and pesticides were all used as inputs.

Potential difficulties with the DEA approach employed in the estimation of relative efficiency of decision making unit (DMU) were tested for, such as sample size and outliers, which can have a significant impact on efficiency ratings. The efficiency of tomato and onion production was calculated using the Data Envelopment Analysis Program (DEAP) version 2.1. Even if the data obtained had a zero value, it is difficult to use zero in DEAP; therefore, to overcome this challenge, we used the (Battese, 1992; George, 1997) method of replacing a small number, i.e., 0.01 instead of 0.

Noise (even symmetrical noise with zero mean) such as measurement mistake might cause major issues because DEA is an intense factor technique. To ensure the robustness of the productivity outcomes, testing for the affectability of DEA effectiveness ratings to enter yield abnormalities are required. The Z score and box plot technique were mostly used to confirm that the data was generally appropriate. Furthermore, we used, among other things, the method used by to confirm the robustness of the DEA model's effectiveness following effects on input-output abnormalities (Yildirim and Birant, 2017). Following the DEA issues were treated using each of the perceptions producing techniques, all fully productive homestead farms were excluded and DEA concerns were resolved.

According to the results of the data envelopment analysis package, the average TE of the households was 66.2 percent, meaning that farm households are producing 33.8 percent less of the possible output given their current level of technological know-how and input consumption. The efficiency ratings in each input orientation (input reduction) and output orientation (output maximization) are similar under the assumption of constant returns to scale (CRS) (output maximization). As a result, if we kept input constant and measured efficiency along an output-growing path, the efficiency rating would also show that outputs improved by 33.8 percent to become efficient.

The mean allocative efficiency and economic efficiency showed that there was a significant difference in the level of inefficiency in the production process. As the DEA result indicated, the mean AE of farm households was 55.4 percent. This indicates that the AE of farm households showed a 44.6 percent growth in output by improving AE with current technology. According to DEA data, the average EE of farm households was 36.7 percent. This result indicated that if the typical farm household in the pattern ended up with the EE degree of his/her most efficient complement, then the typical farm household would have to experience a 63.3 percent increase in output by employing the winning strategy. Result suggests the existence of large technical, allocative, and economic inefficiencies in vegetable production amongst smallholder farmers within the study area.

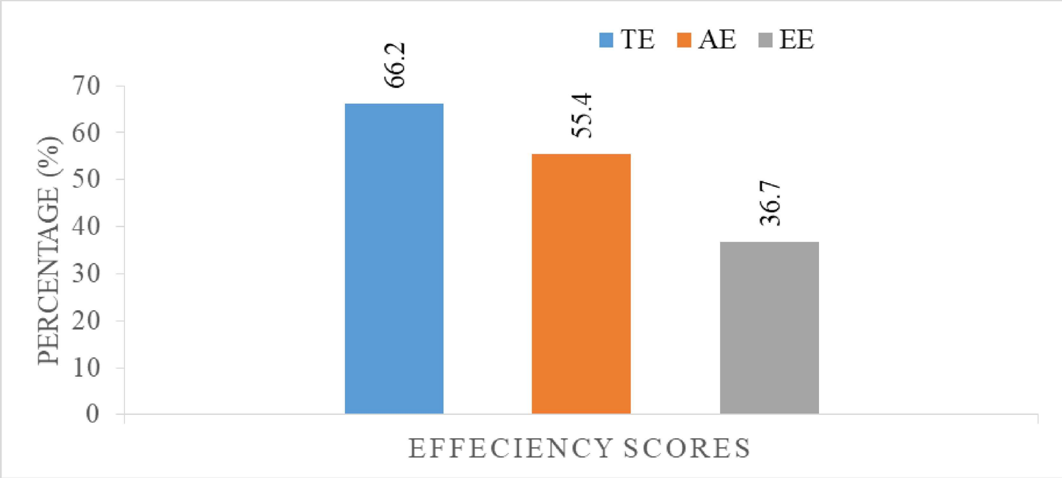

Figure 1: The mean TE, AE and EE scores of sampled households
Source: Researcher sketch (2021)

Assessment of Sources of Inefficiency

Once identifying each efficiency level, finding out the source of inefficiency in farm households is the primary objective of the study. To see this, the technical, allocative, and economic inefficiency of the sampled household was analyzed using the Tobit model given in Table 8. To illustrate this, socio-economic, demographic, and institutional factors that affect the tomato and onion production efficiency of households were observed. Before explaining the model, multicollinearity tests for continuous variables were carried out, and the mean VIF was 1.83, with a maximum VIF of 2.87. This shows that there is no serious problem with multicollinearity in the data set. For interpretation purposes, the marginal effects of explanatory variables from the Tobit regression model were used. In other words, the derived values for the significant explanatory variables indicated that the effects of a unit change in those variables on the expected unconditional value of TE, AE, and EE were conditional on being between 0 and 1, and the probability of being between 0 and 1.

The Tobit model result showed that family size of households, total cultivated land, frequency of ploughing, and distance from home to the nearest market were significantly affected by TE, while family size of households, total number of livestock owned, frequency of ploughing, extension contact, and access to credit services were factors affecting the AE of the sampled households. Finally, the EE of the sampled households was affected by the education level of household heads, family size, total cultivated land, frequency of ploughing, distance from home to the nearest market and access to credit services.

As Tobit output in Table 8 shows, education affected the economic inefficiency of tomato and onion producers negatively at a 1% significance level. The negative marginal effect of economic inefficiency shows that an increase in education by one year increases the economic efficiency of tomato and onion producers by 6.1%, keeping other variables constant. This shows that farmers that are more educated tend to be more efficient in agricultural production than the less educated in the study area. This is due to the fact that better educated household heads can understand agricultural instructions easily, have a higher tendency to adopt improved agricultural technologies, have better access to information and are able to apply technical skills imparted to them than less educated ones. Educated farmers also respond more readily to new, cost-effective technology and have relatively better capacity for optimal allocation of inputs. In line with t0126\is study, research done by Tefera et al. (2018) and Degefa et al. (2020) explains that the more educated the farmer is, the more technically, allocatively, and economically efficient he/she becomes. Thus, the level of education of household heads emerges as an important factor in enhancing the efficiency of tomato and onion production in the study area. But the findings of Wollie et al. (2018) and Rikitu et al. (2019) contradict this result. According to their results, farmers with higher education levels may pay less attention to agricultural activities and give more opportunity by investing their time and knowledge in non-agricultural activities.

Family size had a positive effect on allocative inefficiency and a negative effect on technical and economic inefficiency of tomato and onion producer sample households at 10%, 5%, and 1%, respectively. The marginal effect of allocative inefficiency shows that an a one more increase in family size decreases allocative efficiency by 9.8%, whereas the marginal effects of technical and economic inefficiency indicate an increase in family size increases technical and economic efficiency by 10.1% and 29.1%, respectively, citrus paribus. The positive marginal effect of allocative inefficiency implies that larger family households were faced with the challenges of attending to many family needs, which reduced the magnitude of resources allocated to farming activities (Haji, 2008; Nwachukwu and Onyenweaku, 2016). While the negative sign of technical and economic inefficiency shows that farmers with a large number of family members might be able to use appropriate input combinations due to the fact that the family is the main source of labour supply and it might be important in the production of vegetables, as labour was a significant factor of production. Hence, the result was consistent with that found by Degefa et al. (2020).

Total cultivated land had a negative effect on the technical and economic inefficiency of the tomato and onion farms, and it was significant at the 1% significance level for both efficiencies. The negative marginal effect of technical and economic inefficiency indicated that a one-hectare increase in land size increases technical and economic efficiency by 17.4% and 35.3%, respectively, other things being constant. According to empirical results from Rikitu et al. (2019) and Adeoye (2020), farmers with a larger area of cultivated land have the capacity to use compatible technologies and allocate the maximum available resources (inputs) that could increase the efficiency of the farmers. Larger farms enjoy economies of scale and are relatively more efficient than small-scale farms.

The result indicated that there was a negative and significant impact of livestock size on allocative inefficiency at a 1% significant level. The negative marginal effect of allocative inefficiency indicated that an increase in livestock size increases the allocative efficiency of tomato and onion producers by 9.2%, keeping other variables constant. This is why livestock can support crop production in many ways; they could be a source of cash and manure that is used to maintain soil fertility. It also serves as a shock absorber for an unexpected hazard in crop failure. The researchers, Mustefa et al. (2017), Tefera et al. (2018), and Wollie et al. (2018), confirm the considerable contribution of livestock in reducing the current cost of inputs in tomato and onion production. Given the importance of livestock in the crop production system as a source of draft power, food, income, and inputs, the model result seems logical to affect AE positively as expected.

The frequency of ploughing had a negative effect on technical, allocative, and economic inefficiency at 10%, 5%, and 5% significant levels, respectively. The negative marginal effect of technical, allocative, and economic inefficiency revealed that an increase in the number of ploughing increases TE, AE, and EE by 6.7%, 10.3%, and 9.7%, respectively, citrus paribus. Based on the negative marginal effect of technical, allocative, and economic inefficiency, farmers can conclude that increasing the number of ploughings up to the recommended times increases tomato and onion productivity. Because timely and properly ploughed land is used in order to make the soil compatible with crop growth. This implies that farmers with the number of ploughs were more efficient in tomato and onion production than those with the lower or above the number of ploughs described by the expert, which has its own disadvantages.

As Table 8 identified, extension contact affected the allocative inefficiency of tomato and onion production negatively at a 1% significant level. The negative marginal effect indicated that an increase in the number of extension contacts increases AE by 6.4%, keeping other variables constant. This is consistent with the prior expectation that those farmers who had had more frequency of extension contact were more AE than those with less frequency of extension contact with development workers. This suggests that more frequency of extension contact could lead to improvements in resource allocation, facilitate the practical use of modern techniques, improve agricultural production practices and use inputs in the right way. This is in line with previous studies by Tefera et al. (2018), Rikitu et al., 2019 and Degefa, et al. (2020), who found that extension agents provide farmers with new information on improved agricultural technologies, better farm management practices, and other factors that increase their tomato and onion production efficiencies. But contrary to this, the studies found that extension contact positively affects inefficiency due to the fact that extension workers are only interested in maximizing output level and do not have new skills and information to support the farmers (Mustefa et al., 2017).

At 10% and 5%, respectively, credit had a negative effect on economic inefficiency and a positive effect on allocative inefficiency of the tomato and onion producer households. The marginal effect indicates that an increase in a given amount of birr increases EE by 16.9% while it decreases AE by 21.8%, other things being constant. The negative marginal effect of economic inefficiency shows that credit increases a farmer's efficiency as it temporarily solves the shortage of working capital. Studies done by Mustefa et al. (2017) and Tefera et al. (2018) found similar results. The positive marginal sign of allocative inefficiency reveals that access to credit negatively affects efficiency due to the improper or unwise use of credit, lack of advice on how to use credit, and lack of follow-up for what purpose they use it. Furthermore, producers who took credit may be resource poor and unable to produce tomatoes and onions in the same quantities as resource-rich producers. This result is consistent with Hailu and Fana (2017).

Table 8: Tobit model for sources of inefficiency analysis

Variables	Technical inefficiency		Allocative inefficiency		Economic inefficiency	
	Marginal effect	Std. Err	Marginal effect	Std. Err	Marginal effect	Std. Err
Sex of household head	0.073	0.090	-0.124	0.099	0.140	0.097
Age of household head	-0.007	0.005	-0.002	0.006	-0.002	0.006
Education level	0.014	0.017	0.007	0.018	- 0.061***	0.019
Family size	-0.101**	0.050	0.098*	0.055	-0.291***	0.055
Total cultivated land	-0.174***	0.062	0.057	0.067	-0.353***	0.069
Off/non-farm activities	0.038	0.081	0.088	0.089	-0.058	0.086
No. of livestock owned	-0.031	0.024	-0.092***	0.027	-0.030	0.026
Fertility status of land	0.083	0.147	0.035	0.159	0.248	0.161
Frequency of ploughing	-0.067*	0.038	-0.103**	0.043	-0.097**	0.041
Distance to the market	0.004*	0.002	0.001	0.002	0.010***	0.002
Extension contact	0.005	0.020	-0.064***	0.023	0.013	0.022
Access to credit services	-0.054	0.084	0.218**	0.092	-0.169*	0.092

Note: ***, ** and * indicate the level of significance at 1, 5 and 10 percent, respectively.

Source: Own surveyed data (2021)

Conclusion and recommendations

An important conclusion coming from the analysis is that tomato and onion producers in the study area were not operating at full TE, AE, and EE levels, which implies that there is an opportunity for producers to increase output at existing levels of inputs and minimize cost without compromising yield with present technologies. Results of the production function revealed that land, labour, oxen, seed, chemical fertilizer, and pesticides were the most important inputs for the cultivation of tomato and onion in the study district. On the other hand, factors that affect the efficiency of the sampled farmers were identified to help different stakeholders increase the current level of efficiency in tomato and onion production by using the Tobit regression model. Family size, total cultivated land and frequency of ploughing were significantly and positively affected by TE. This implies that farmers who are and had more family size, cultivated land, and frequency of ploughing had more TE than the others, while the number of livestock owned, frequency of ploughing, and extension contact had a significant positive effect on AE among farmers. So, this shows that farmers who own these explanatory variables are more allocatively efficient than their counterparts.

Total cultivated land was positively associated with both TE and EE. This indicates that farmers who had more cultivated land had more TE and EE than sample farmers who had less cultivated land. Moreover, education level, family size, frequency of ploughing, and access to credit services positively affect the EE level of tomato and onion producers in the district. This implies that farmers who had more education level, family size, frequency of ploughing, and access to credit services were more economically efficient than the others. Generally, the investigation found that production can be enhanced by increasing the use of inputs. The suggestion is that there will be a significant increase in production level or a decrease in the cost of production if foreword and allocation of agricultural technologies are joined with improving the existing level of efficiency. Therefore, the government and any concerned body should focus on frequency of ploughing, extension contact, access to credit services and education level to improve tomato and onion production economic efficiency.

Acknowledgement and Declaration

We sincerely thank each and every person and organization who helped make the publishing of this study report possible. We hereby declare that the work contained in this Article is entirely original to us and was not previously submitted to this or any other journals for publication. We are responsible for carrying out the procedures in accordance with the journals Committee on the Use of Human Subjects in Teaching and Research guidelines. We have read the most recent version of the journals research ethical policies and we tried to identify all potential risks associated with this article that might occur during its conduct, and we have gotten the necessary ethical and/or safety permission (where applicable).

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