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Technical Efficiency of Irrigated Onion and Tomato Production in the Central Rift Valley of Ethiopia

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Abstract

We estimated the technical efficiency of smallholder vegetable (onion and tomato) producers in the Central Rift valley of Ethiopia using a stochastic production frontier model. A multi-stage sampling procedure was employed to select 258 smallholder farmers producing onion (183) and tomato (75) in the 2018/19 growing season. The stochastic production frontier model was used to estimate the production frontier and identify the determinants of technical efficiency and technical efficiency levels of farmers. The results show that the technical efficiency of smallholder farmers in the area was about 73.4% and 59% for onion and tomato, respectively, showing 26.6% and 41% inefficiency levels in the same order. This result shows that there is a room to increase the yield of onion and tomato using existing technologies. Labor, fertilizer, agrochemicals, farm size, and cost of seeds/seedlings were the major factors that influenced changes in onion and tomato output. Education level of the household head, farming experiences, extension contact, off-farm income, and ownership of irrigation facilities have shown significant and positive impacts on the level of efficiency. We recommended that tomato growers should use pesticides with appropriate doses. More prominently, efficient resource use (e.g., labor, fertilizer, land, and seed), cost reduction, and profit maximization goals should be promoted so that farmers can benefit from the enhanced efficiency of onion and tomato production.

Keywords: Central Rift Valley, vegetable production, smallholder farmers, stochastic production frontier, technical efficiency

Introduction

Agriculture is a principal economic sector and the engine of growth to transform the overall economic development in Ethiopia. The sector provides employment opportunities to more than 73% of the total population, generates about 70% of the foreign exchange earnings of the country and 70% raw materials for the industries in the country (UNDP, 2018). Ethiopian agriculture requires substantial transformation to sustain economic growth, reduce poverty and ensure food security. However, the sector is dominated by smallholder subsistence agriculture and largely rain fed (FAO, 2021). Enhancing agricultural productivity is desirable to address these tasks and irrigation is one pillar to contribute to agricultural transformation. Irrigation enables smallholders to adopt more diversified cropping patterns and support their low-value subsistence production system by producing high-value market-oriented production (Hagos *et al.*, 2017).

Agricultural productivity is a measure of efficiency since the aggregate productivity of an economic system is proportional to the efficiency of production of the components within the systems (Battese and Coelli, 1995). Technical efficiency shows the ability of farms producing the maximum level of output for given quantities of the set of inputs or producing a given level of output using the set of inputs. Technical inefficiency indicates that more output can be produced from a given quantities of inputs or fewer quantities of inputs can be used to produce a given output levels. Such insights are vital for designing effective policy programs to reduce resource wastage and increase farm output. Further, potential resource productivity means getting the maximum output from the minimum possible set of inputs. Stochastic frontier (SF) models have been widely used to measure the technical efficiency of farms or farm households (Kumbhakar *et al.,* 2014).

The rest of the paper is organized as follows: the next section provides brief background information about onion and tomato production in the context of production efficiency. Then, a brief methodology is presented for the study. The sections that follow present the main results and discussion. Finally, we conclude with key policy recommendations aimed at improving the vegetable production efficiency in the study areas and beyond.

Background

Vegetables are the most important source of cash income for resource-poor smallholder farmers, (World Vegetable Centre, 2013). In addition to cash income, the sector also plays vital roles in nutrition and health, poverty alleviation, food security, income generation, and foreign currency earnings through export trade while also attracting direct foreign investment in Ethiopia (Ethiopian Investment Agency, 2012). Furthermore, vegetable production is an important economic activity for private farms in Ethiopia (Rahiel and Gebresilasie, 2018). These crops can be cultivated throughout the year both under irrigation and rain fed conditions in different parts of the country (Belay et al., 2015). The national average area of onion did not show a marked change over time (FAOSTAT, 2020 while the average yield has been showing a decreasing trends (Figure A1).

Tomato is also an important vegetable like onion in Ethiopia. The crop is produced mainly in northern and the Central Rift Valley (CRV) of Ethiopia. Currently, tomatoe is one of the export crops of the country. Tomato offers better economic returns to many farmers in Ethiopia especially when it is grown during the summer season. However, the productivity of tomatoes varies depending on the cultural, and management practices employed as well as the varieties used for production. Despite the importance of tomatoes, production and productivity are declining over time (Figure A2).

An empirical investigation of farm efficiency helps to determine the level to which it is possible to raise output given the existing technology thereby improve productivity through efficiency. Information about the overall efficiency of vegetable production and its determinants in the study areas (which supply to most parts of the country) is important to ensure he maximum possible output with no additional input. An evaluation of the ecnomic performance of the market-driven farm products, particularly vegetables, is relevant because the impact of factor and product market performances might be considerable, and these crops are produced under intensive cropping practices. Moreover, inputs are costly and vegetables are vulnerable to poor weather conditions and diseases. Our key results indicate that there is a substantial level of production inefficiency in vegetable production in the study areas, which needs targeted policy interventions to reduce the observed productivity gap. Therefore, this study analyzes production efficiency and document the level of technical efficiency of small-scale irrigated vegetable production in the CRV of Ethiopia.

Methodology

Description of the Study Area

The study was conducted in the Central Rift Valley (CRV) of Ethiopia. The region lies between 38°81 E and 39°8 E, and between 7°10 N and 8°30 N. The altitude of the region ranges from 1600 meters above sea level in the lowlands to about 3000 meters above sea level at the edge of the rift valley. The CRV is located in Oromia and Southern Nations, Nationalities and Peoples (SNNP) administrative regions of Ethiopia. The study area has a bimodal rainfall distribution, which is characterized by a short rainy season (Belg) in March and April and the long rainy season (Kiremt), which begins in May/June, and ends in September/October. The region receives an average annual rainfall of about 855 mm, which varies across altitudes, and the average temperatures vary between 14.6 °C and 30.1 °C (Getnet, 2015). The area is known for its high irrigation potential and is one of the producers and suppliers of horticultural crops in the country. These vegetable crops are mainly produced using irrigation.

Sampling Procedure and Sample size determination

A multi-stage random sampling technique was used to select the respondent farmers. In the first stage, vegetable growing areas namely Dugda, Adami Tullu Jido Kombolcha, Bora, and Adama districts were selected based on the potential of onion and tomato production. The second stage involved the selection of two to four kebeles randomly from each district. At the final stage, a simple random sampling procedure was used to select a total of 258 respondents (183 onion and 75 tomato producers) based on the proportion of vegetable farmers in each of the selected *kebeles*. The sampling frame was a list of vegetable farmers obtained from the *kebele* level Bureau of Agriculture (BoA), Farmer Training Center (FTC) and vegetable farmers' association.

Data Collection Methods

The study uses primary data collected from the sampled vegetable farmers in the CRV of Ethiopia during the 2018/19 production season. The data were collected through structured questionnaires. Enumerators were carefully selected and trained on how to administer the questionnaire including pre-testing before conducting the actual survey.

Method of Data Analysis

Both descriptive and econometric methods were used for data analyses. The descriptive methods include means, standard deviation, frequencies, and percentage distributions. A parametric or econometric stochastic production frontier method was used to analyze the technical efficiency of vegetable (onion and tomato) producers. The SF model has two parts, the deterministic production technology part and the stochastic part that consists of inefficiency and random noise. Technical efficiency estimates are sensitive to assumptions implied by different SF models and how farm household heterogeneity is treated (Kumbhakar et al., 2014). The stochastic frontier approach was selected because it can capture measurement error and other statistical noise influencing the shape and position of the production frontier. The stochastic production frontier model can be specified as follows:

$$Y_i = f(x'\beta) - U_i + V_i \text{, given that } i = 1, 2 \ldots n \qquad (1)$$

Where, Y_i represents the onion or tomato output level of the i^{th} farmer; X is a (1 X k) vector of farm inputs used in onion or tomato production; β is a (k X 1) vector of parameters to be estimated, V_i is a random error (variation in onion and tomato output) associated with random factors not under the control of the farmer, while U_i represents the inefficiency effects. A formal likelihood ratio test is done to determine the functional form that fits the data. The Cobb-Douglas functional form used to specify the stochastic production frontier despite its well-known limitations compared to other flexible functional forms[1], such as the translog and

[1]The first-order coefficients of the Cobb-Douglas production function are elasticities. The likelihood ratio test also shows that the Cobb-Douglas form fits our data.

quadratic forms. The Cobb-Douglas production function gives better estimates when some of the basic assumptions are violated and fits a range of datasets (Miller, 2008). Thus, to estimate a Cobb-Douglas production function, the input and output data were converted into logarithms before the analysis (Battese and Coelli, 1995). The estimated explicit equation for the stochastic function is expressed as:

$$LnY_i = \beta_0 + \beta_1 lnX_{1i} + \beta_2 lnX_{2i} + \beta_3 lnX_{3i} + \beta_4 lnX_{4i} + \beta_5 lnX_{5i} + V_i - U_i \ldots\ldots (2)$$

where:

Y_i = quantity of output of the i^{th} farmer (kg);
X_1 - X_5 = jointly refers to production inputs,
β_0= constant
$\beta_1 - \beta_5$ = estimated parameters;
i =1, 2, 3…....n, (number of farmers)

V_i = random variable assumed to be independently and identically distributed as $N(0, \sigma^2 v)$ and independent of U_i that represents the stochastic effect outside the farmer's control; U_i = one-sided error ($U_i \geq 0$) efficiency component that represents technical inefficiency in production and assumed to be independently and identically distributed at truncation (at zero) of the normal distribution with mean, Z_i σ and variance σ_u^2 $(Z_i\sigma, \sigma^2 u)$. The U_i was estimated as:

$$U_i = \delta_0 + \delta_1 lnZ_{1i} + \delta_2 lnZ_{2i} + \delta_3 lnZ_{3i} + \delta_4 lnZ_{4i} + \delta_5 lnZ_{5i} + \delta_6 lnZ_{6i} + \delta_7 lnZ_{7i} + W_i \ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots (3)$$

where:

U_i = Technical inefficiency
$Z_1 - Z_7$ = socioeconomic variables that determine inefficiency
δ_0 = constant
δ_1 - δ_8 = vector of unknown parameters to be estimated.

W_i = random variable defined by the truncation of the normal distribution with zero mean and variance σ^2 such that the point of truncation is $Z_i\sigma_i$, i.e., $W_i \geq - Z_i \sigma$. The inefficiency component of the stochastic production frontier function comprised socioeconomic variables that were expected to be the determinants of technical inefficiency[2]. The technical efficiency of the ith sample farmer, denoted by TE_i was expressed as:

$$
\begin{aligned}
TE_i &= \exp(-U_i) \\
&= y_i / f(X_i \beta) \exp(V_i) \\
&= y_i / y^* \quad \ldots\ldots (4)
\end{aligned}
$$

where:

y = observed output

y *= frontier output

If $y_i = y_i^*$ then TE_i = 1, reflecting 100% technically efficient. The difference between y_i and y* is embedded in U_i. If $U_i = 0$, it implies that production lies on the stochastic production frontier, the farm obtains its maximum attainable outputs given its level of inputs. If $U_i > 0$, production lies below the frontier, which is an indication of inefficiency. The Maximum Likelihood Estimate (MLE) of the parameters of the model defined by equations (2) and (3) and the farmer specific TE defined in equation (4) were estimated using Stata version 14. The technical efficiencies were estimated using a predictor that is based on the conditional expectation of exp($-U_i$). In the process, the variance parameters σ^2u and σ^2v are expressed in terms of parametrization as:

$$\sigma^2 = (\sigma^2 u + \sigma^2 v) \quad \ldots\ldots (5)$$

$$\gamma = \sigma^2 u / \sigma^2 v \quad \ldots\ldots (6)$$

where: γ = total variation in output from the frontier which is attributed to technical inefficiency. The value of γ ranges between zero and one. When γ equals zero, variation in output is due to factors outside the farmer's control. A value close to one indicates that a random component of the inefficiency has a significant contribution to the analysis of the production.

[2]Technical efficiency could also depend on environmental characteristics such as soil types and soil fertility. However, we do not have such data in our sample to capture these variables in the model and estimated efficiency levels should be interpreted with caution.

Results and Discussion

Demographic and Socioeconomic Characteristics of Respondents

Descriptive statistics of the socio-economic characteristics of the respondents are presented in Table 1. The average number of years of schooling (education) among sample household heads was seven years. It implies that most of the farmers had very few years of schooling. The age of the farmer was expected to affect his/her labor productivity and output. These results imply that farmers in the area are relatively young, a condition that may contribute to their overall efficiency in vegetable production. The average household size of the farmers was five persons and ranging from one to 17 persons. This indicates that farmers have family labor for onion and tomato production, which is labor-intensive. The age of the sample farmers ranged between 20 to 82 years with an average of 34 years.

Furthermore, the average experience of farmers in irrigation farming activities is 16 years. This implies that the sample farmers have good experience in onion and tomato production. This should enhance farmers' productivity/efficiency since experienced farmers can use inputs efficiently and use improved agronomic practices as well as pest and disease management in their fields. The respondents' average annual off-farm income was about 13,111 Ethiopian Birr (ETB). It is highly likely that farmers use their income to finance their farm operations leading to enhanced production efficiency.

Table 1. Summary Statistics of the households' heads in the study area.

Variable description	Mean	Std. Dev	Minimum	Maximum
Age	34	10.79	20	82
Education (years of schooling)	7.27	3.71	0	20
Household size	5.41	2.95	1	17
Experience in irrigation farming	16.06	9.921	3	65
Area of operated irrigated land (Ha)	1.41	0.64	0.13	30
Area of operated rain-fed land (Ha)	1.27	0.303	0.25	7.5
Off-farm income (in 1000 ETB)	13.11	7.13	.00	108

Source: field survey 2019

Descriptive Statistics of the Output and Input Variables

Descriptive statistics of the variables used in the production function estimation is presented in Table 2. The mean labor usage for onion and tomato enterprises was 1145 and 1367 person-days, respectively. Smallholder onion and tomato farmers cultivate an average farm size of 0.85 and 1.3 hectares, respectively. Onion producers applied, on average, 923 kilograms of fertilizer, 25 liters of agrochemicals (pesticides, fungicides, and herbicides), and incurred cost of onion seed/seedlings of 6383 ETB resulting in an average of 21941 kilograms of onion output. On average, 1241 kilograms of fertilizer, 37 liters of agrochemicals (pesticides, fungicides, and herbicides), and incurred 14509 ETB cost for tomato seeds to produce tomato. Using these inputs, on average, sample farmers produced about 42718 kilograms of tomato.

Table 2: Summary Statistics of Variable used in the Stochastic Frontier Model

Variables	Onion		Tomato	
	Mean	Std. Dev	Mean	Std. Dev
Output (kg)	21941.3	12434.5	42718	13165.2
Labor (person-days)	1144.7	9238.4	1367.3	1076.6
Quantity of fertilizer (kg)	922.7	192.6	1240.7	631.07
Quantity index of pesticides	25.1	18.5	37.2	25.6
Cost of seeds/Seedlings (ETB)	6383	5410	14509	10124
Farm size (ha)	0.85	0.08	1.3	1.2

Source: field survey 2019

Determinants of Technical Efficiency of Onion and Tomato

Table 3 shows the variance parameters of the production function represented by Sigma-squared (σ^2) and Gamma (γ) and significant at the 1% level. This indicates the goodness of fit, and correctness of the distributional form of the composite error term in the model. The results of the maximum likelihood estimates of the stochastic production frontier function indicate that gamma (γ) which is the ratio of the variance of technical inefficiency effects (U_i) to the variance of random errors (V_i) was 0.98 and 0.70 for onion and tomato, respectively. These results imply that many variations in outputs are due to technical inefficiency justifying that the use of stochastic frontier is appropriate over the deterministic frontier. The Lambda is also greater than one (λ = 1.31 and 2.14 for onion and tomato, respectively).

The study also revealed that the output of onion was most responsive to labor, followed by fertilizer, farm size, cost of seed and seedlings, and agro-chemicals. The results of the estimated parameters revealed that all the coefficients of inputs except the agrochemicals used for tomato, confirm a priori expectation of positive signs. The positive coefficient of labor, fertilizer, agro-chemical, farm size and cost of seeds and seedlings implies that as each of these variables increase, the vegetable output also increases, ceteris paribus. The coefficients of labor for onion and tomato were found to be positive and significant at 1% and 10% levels for onion and tomato, respectively. A 1% increase in the person-days of labor increases the output of onion and tomato by 0.36% and 0.30%, respectively. These results agree with the findings of previous studies (Okon et al., 2017). In addition, a 1% increase in fertilizer rate increases the output of onion and tomato by 0.17 and 0.39 %, respectively.

An increase of pesticides applied increases the output of onion by 0.14% but decreases the output of tomatoes by 0.12%. The implication is that agrochemical contributes positively to the onion output in the study area, unlike the tomato output. Nevertheless, the negative sign of agro-chemicals for the case of tomato might be a situation of excessive and, hence, inefficient use of insecticides, herbicides, and fungicides in the production of tomato in the area. The coefficient of cost of seed and seedlings was also found to be positive and statistically significant at the 1% level. The farm size under onion and tomato cultivation had a coefficient estimated to be positive and statistically significant at 1% indicating that an increase in the area under onion and tomato cultivation would lead to an increase in outputs.

Table 3: Estimates of Parameters of the Stochastic Production Frontier and the Inefficiency Model

Variables	Onion			Tomato		
Stochastic Frontier	Coefficients	Std. Err.	P> Z	Coefficients	Std. Err.	P> Z
Intercept	7.186***	1.60	0.000	7.653***	1.96	0.000
Ln Labor	0.359***	0.06	0.001	0. 295*	0.13	0.066
Ln Fertilizer	0. 174**	0.17	0.048	0.384**	0.18	0.029
Ln Agro-chemicals	0.137*	0.15	0.093	-0.128	0.07	0.421
Ln Cost of seed/Seedlings	0. 169**	0.08	0.044	0.179***	0.09	0.018
Ln Farm size	0.250***	0.13	0.000	0.264***	0.19	0.000
Inefficiency Model						
Education	-0.110**	0.07	0.011	-0.044**	0.05	0.045
Household size	0.1797	0.09	0.492	0.009*	0.04	0.074
Farm experience	-0.036*	0.69	0.055	-0.021**	0.04	0.067
Extension contact	-0.295*	0.72	0.047	-0.422**	0.66	0.019
Irrigation facility	-0.708***	0.05	0.009	-0.219*	0.75	0.080
Owner plot (dummy)	-0.048***	0.44	0.001	-0.013**	0.10	0.044
Off-farm income	-0.528***	0.59	0.003	-0.243**	0.54	0.045
Variance parameters						
$\sigma^2 = (\delta u^2 + \delta v^2)$	0.550***			0.870***		
$\gamma = (\delta u^2 / \delta^2)$	0.983***			0.698***		
$\lambda = (\delta u / \delta v)$	1.312			2.143		
Log-likelihood function	-170.89			-62.29		
Mean Technical Efficiency	73.4			59		

Note: ***, **, * *are 1%, 5% and 10% significant level, respectively.*
Source: Survey data 2019

The estimate of inefficiency variables is also presented in Table 3. The negative sign on the estimated parameters is an indication that the variables had negative effects in explaining technical inefficiency or positively contribute to improving technical efficiency. The coefficient for the level of education was negative and significant at a 5% level for both onion and tomato enterprises. The result indicates that increasing the level of formal education by a unit leads to a 0.11 and 0.044% increment of technical efficiency for onion and tomato, respectively. The influence of farming experience was found to be significant at 10 and 5% levels for onion and tomato, respectively. Therefore, an increase in years of farming would lead to a technical efficiency improvement by 0.036 and 0.021% for onion and tomato, respectively. The result is in line with the findings of Ayinde et al. (2017) indicating that experienced farmers were more efficient in farm productivity than farmers without experience.

Farmers are more efficient on owned plots than on leased (rented and sharecropped) plots. The values of the coefficients of the owner's dummy variables were -0.048, and -0.013 for onion and tomato, respectively. The coefficients of off-farm income were negative and significant at a 1% level. This means that an increase in off-farm income would lead to a reduction in technical inefficiency. The implication is that respondents could have more funds at their disposal to purchase more inputs required to produce vegetables.

Technical Efficiency Level for Irrigated Vegetable Producers

The result obtained from the analysis of the level of technical efficiency for onion and tomato enterprises is presented in Table 4. The result revealed that the mean levels of technical efficiency among the respondents were 73.4 and 59% for onion and tomato enterprises, respectively. This means that an average smallholder farmer in CRV of Ethiopia could increase output by 26.6 and 41% for the enterprises to reach the production frontier (100%), respectively, using the same level of inputs and technology. In terms of the distribution of the estimated technical efficiency, onion producers had higher levels of technical efficiency on average than tomato producers did.

Table 4: Distribution of technical efficiency levels of smallholder vegetable growers

Technical Efficiency Level	Onion		Tomato	
	Frequency (F)	% of farmers	Frequency (F)	% of farmers
< 50	15	7.7	17	27
50 - 60	9	4.6	8	12.7
61 - 70	24	12.4	14	22.2
71 - 80	70	36.2	15	23.8
81 - 90	73	37.6	8	12.7
>90	3	1.5	1	1.6
Mean TE	73.4		59	
Std. Deviation	9.3		23.8	
Minimum TE	25.3		16.2	
Maximum TE	91.9		88.9	

Source: Survey data 2019

Returns to Scale

The return to scale (RTS) analysis, which serves as a measure of total resource productivity, is given in Table 5. The production function can be used to estimate the magnitude of the return-to-scale. Constant return-to-scale only holds if the sum of all partial elasticity is equal to one. If the sum is less than one, the function has a decreasing return-to-scale: If more than one, as in the case of onion output, an increasing return-to-scale exists. Therefore, an increase in all inputs by one percent increases onion and tomato output by 1.089 and 0.994 percent, respectively. This indicates that onion farmers are operating in stage one of the production surfaces which is the output that can still be increased by using more of the inputs. It was further shown that all the input elasticities were inelastic for tomato production; a one percent increase in each input results in a less than one percent increase in tomato yield, where resources and production are believed to be efficient.

Table 5: Elasticities and returns to scale of the parameters of a stochastic frontier estimates

Variables	Elasticities	
Stochastic Production Frontier	Onion	Tomato
Ln Labor	0.359	0. 295
Ln Fertilizer	0.174	0.384
Ln Agro-chemicals	0.137	-0.128
Ln Cost of seed/seedlings	0.169	0.179
Ln Farm size	0.250	0.264
Returns to scale (RTS)	**1.089**	**0.994**

Source: field survey 2019

Production and Marketing Constraints of Onion and Tomato

Production and marketing constraints can significantly reduce the technical efficiency of farm households. Table 6 shows the prioritization of production constraints in onion and tomato farming. The most limiting factor to produce onion and tomato were high production cost followed by a low output price especially at the farm gate level. The first prioritized limiting factor in onion and tomato production were high input prices, especially the cost of agro-chemicals, fertilizers, the cost of seeds, and seedlings. Like other crops, output price declines sharply during the peak harvesting season, and farmers are forced to sell their produce at very low prices. Unavailability of quality of improved seed was ranked as the third constraint in onion and tomato production. Other important constraints in an ascending order include lack of expertise about pesticides and their application, lack of extension services, susceptibility to pest and disease, and lack of access to capital.

Table 6. Prioritizations of Production Constraints in Onion and Tomato Production

Constraints	Frequency	Percent (%)	Ranking
Unavailability of quality of improved seed	35	13.5	3
High production costs	97	37.6	1
Low price of output	48	18.6	2
Lack of access to capital	9	4	7
Susceptible to pest and disease	17	6.6	6
Lack of extension services	24	9.5	5
Lack of know-how about pesticides and application	28	10.2	4

Source: field survey 2019

Marketing constraints in onion and tomato production results are detailed in Table 7. Interference of brokers, price fluctuation of the products, and low price of produce are the top three critical marketing constraints based on information provided by onion and tomato growers. Interference of agents and high variability in output price cause fluctuation in outputs from year to year. Again, this problem reveals an inefficient marketing system and poor market information to vegetable growers. During the period of a short supply of vegetables, output prices rise substantially, which could motivate farmers to increase their production. Other market constraints in an ascending order include low bargaining power, lack of market information, poor market linkage, and lack of transport facilities in the study areas.

Table 7. Prioritizations of marketing constraints in Onion and Tomato Production

Constraints	Frequency	Percent (%)	Ranking
Price fluctuation	56	21.7	2
Low bargaining power	28	11	4
Interference of agents	92	35.5	1
Low price of produces	46	18	3
Lack of market information	24	9.3	5
Poor market linkage	8	3	6
Lack of transport facility	4	1.5	7

Source: field survey 2019

Conclusions and Recommendations

The study analyzes technical efficiency and determinants of technical (in) efficiency for smallholder onion and tomato producers in the Central Rift Valley of Ethiopia using a stochastic frontier production model. The study also analyzed production and market constraints of onion and tomato production that can reduce producers' technical efficiency. The mean technical efficiency for the small-scale onion and tomato farmers in the study area were 73.4 and 59 %, respectively. The result implies that there are potentials for improving the technical efficiency of these farmers substantially with the available technology. We concluded that substantial inefficiency exists in irrigated vegetable production of the study area. The percentage of technical inefficiency is estimated at 27 and 41 % for onion and tomato, respectively. The average returns-to-scale of onion and tomato is 1.08 and 0.99, respectively, implying that farmers are operating under constant returns to scale. This indicates that the outputs can be increased only by proportionally/simultaneously increasing all inputs for given production technology.

Among socioeconomic variables estimated in the inefficiency model, formal education, extension contact, irrigation facilities and off-farm income had a negative relationship with the inefficiency effects. The most limiting factors in onion and tomato production are also high input prices of agrochemicals, fertilizers, cost of seeds and seedlings and the problem reveals an inefficient marketing system and interference of agents and high variability in output price causes in price fluctuation of production outputs.

More efforts should be made to improve access to extension services on onion and tomato production. It requires tailored practical training to improve farmers' production efficiency on horticultural crops production in general and particularly, onion and tomato. Here, the policy implication is that extension programs should target adult household members in addition to the household head, modernizing the agricultural extension system to be knowledge-intensive, and promoting irrigation technologies. Generally, the government should promote enabling agricultural institutions and farm inputs to enhance farmers' technical efficiencies in vegetable production.

More importantly, efficient uses of resources (land, labor, fertilizer, and seed) could lead to cost reduction and profit maximization so that farmers benefit from an accelerated increase in efficiency of irrigated onion and tomato production. Inputs should also be made available to farmers at an affordable and cheaper price to increase the output and profit of the vegetable farmers.

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Appendix

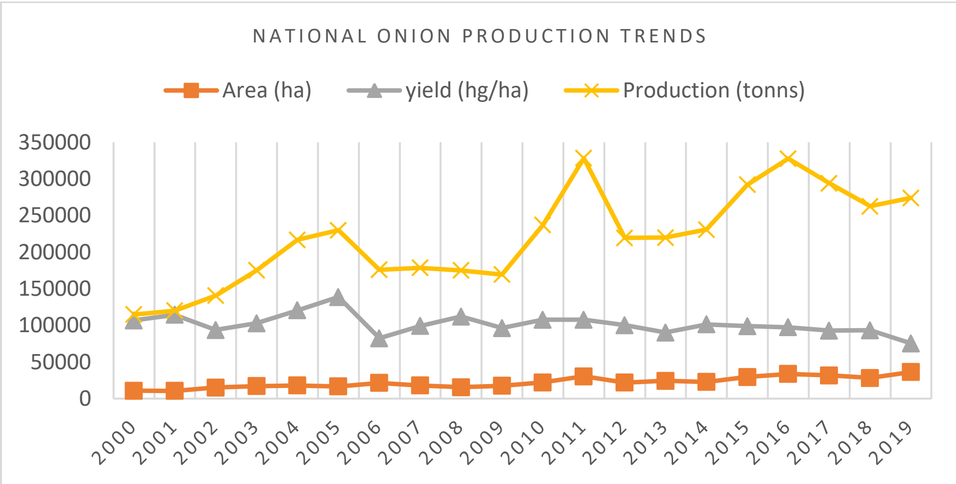

Figure A1. National Onion area, yield, production trends in Ethiopia, 2000–2019
Source: FAOSTAT (2020)

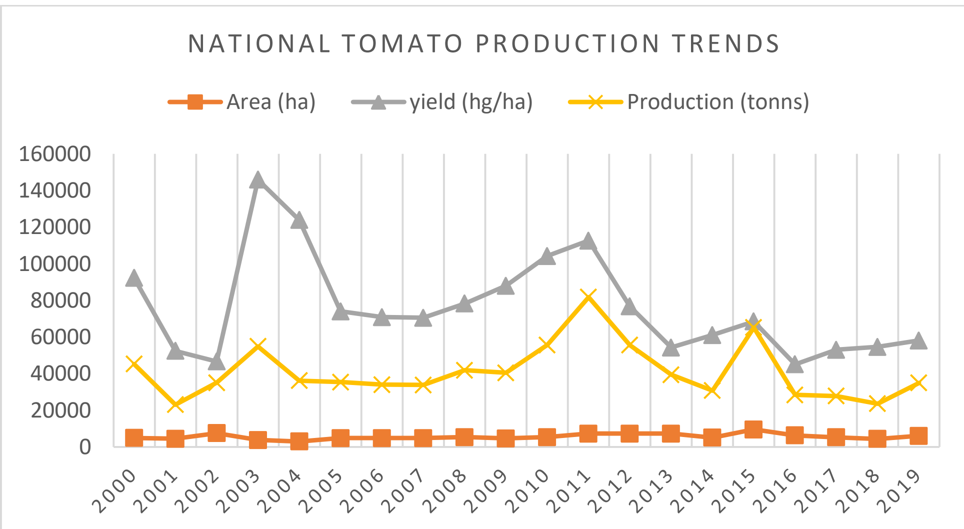

Figure A2. National Tomato area, yield, production trends in Ethiopia, 2000–2019
Source: FAOSTAT (2020)