frontiers
in Sustainable Food Systems

ORIGINAL RESEARCH
published: 22 November 2021
doi: 10.3389/fsufs.2021.758951

Cassava Production Efficiency in Southern Ethiopia: The Parametric Model Analysis

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Specialty section:
This article was submitted to Waste Management in Agroecosystems, a section of the journal Frontiers in Sustainable Food Systems

Received: 15 August 2021
Accepted: 11 October 2021
Published: 22 November 2021

Citation:
Tafesse A, Mena B, Belay A, Aynekulu E, Recha JW, Osano PM, Darr D, Demissie TD, Endalamaw TB and Solomon D (2021) Cassava Production Efficiency in Southern Ethiopia: The Parametric Model Analysis.
Front. Sustain. Food Syst. 5:758951.
doi: 10.3389/fsufs.2021.758951

Due to capital constraints and land scarcity in developing countries, introducing new technology to boost productivity is difficult. As a result, working to improve cassava production efficiency is the best option available. Cassava is increasingly being used as a food source as well as an industrial raw material in the production of economic goods. This study estimates cassava production efficiency and investigates the causes of inefficiency in southern Ethiopia. Cross-sectional data from 158 households were collected using a systematic questionnaire. The Cobb-Douglas (CDs) stochastic frontier production model was used to calculate production efficiency levels. The computed mean result showed technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE) levels of 74, 90, and 66%, respectively. This demonstrated that existing farm resources could increase average production efficiency by 26, 10, and 34%, respectively. The study found that land size, urea fertilizer application, and cassava planting cut all had a positive and significant effect on cassava production. It was discovered that TE was more important than AE as a source of benefit for EE. Inefficiency effects modeled using the two-limit Tobit model revealed that household head age, level of education, cassava variety, extension contact, rural credit, off-farm activities involvement to generate income, and farm size were the most important factors for improving TE, AE, and EE efficiencies. As a result, policymakers in government should consider these factors when addressing inefficiencies in cassava production. It is especially important to provide appropriate agricultural knowledge through short-term training, to provide farmers with access to formal education, to access improved cassava varieties, and to support agricultural extension services.

Keywords: cassava, Cobb-Douglas, efficiency, stochastic frontier, Tobit

INTRODUCTION

The worldwide production of cassava amounted to 278 million metric tons in 2018, out of which Africa's share was about 61% (FAOSTAT, 2020). Globally, cassava production has increased by 240 million metric tons since 2010 (FAOSTAT, 2020). According to FAO projections, by 2025, about 62% of global cassava production will come from sub-Saharan Africa (FAOSTAT, 2020). In Ethiopia, root crops such as potatoes, sweet potatoes, taro, and cassava covered <2% of the country's total cropping area, and accounted for 23.4, 38.4, and 17.7% of the overall production of root crops, respectively [CSA (Central Statistical Agency), 2018]. Cassava is among the most widely cultivated crops in some districts of Wolaita zone, southern Ethiopia (Kebede et al., 2012; Mulualem et al., 2013; Mulualem and Dagne, 2015; Laekemariam, 2016; Sarka, 2017; Tadesse et al., 2017; Legesse, 2018). It was the first root and tuber crop produced as a food and revenue-generating crop, followed by taro and sweet potato in this zone [Offa District Agricultural and Natural Resource Development Office (ODANRDO), 2018]. The minimum production of cassava in the study area is 20,350 kg/ha [Offa District Agricultural and Natural Resource Development Office (ODANRDO), 2018]. However, under optimal conditions, cassava yields can be about 80 tons per hectare (Howeler et al., 2013; Food and Agricultural Organization (FAO), 2018). In the research area, cassava is consumed as a boiled tuber and processed into flour, which is mixed with cereals such as Teff, barley, and wheat for bread or *enjera*[1] preparation. The recently increasing price of *Teff and other crops* in Ethiopia may be an excellent opportunity to allow increase in cassava production in the country (Biruk, 2013; Mulualem and Dagne, 2015; Louhichi et al., 2019). The Qulle (104/72 Nigeria red) and Kelle (44/72 Nigerian white) are the two most natural cassava varieties in the research region (Tadesse et al., 2013; Mulualem and Dagne, 2015). The two varieties introduced in Ethiopia from Nigeria are characterized by high returns, resistance to diseases, and low toxicity (Anshebo et al., 2004; Tadesse et al., 2013; Parmar et al., 2018). Its carbohydrates richness, availability throughout the year, tolerance to low soil fertility, and resistance to drought, pests, and diseases (Mathende, 2006; Nassar, 2007; Fermont et al., 2008; van Fermont, 2009; Poole, 2010; McQuate, 2011; El-Sharkawy, 2012; Ogunniyi et al., 2012; Tadesse et al., 2017; Ewubare and Ologhadien, 2019; Inegbedion et al., 2020) make cassava an attractive crop, especially to smallholder farmers, who account for the largest share of the country's agricultural production. However, these farmers hardly use modern technology and inputs and hence their cassava productivity is low [Kebede et al., 2012; Laekemariam, 2016; Mustefa et al., 2017; Tadesse et al., 2021] despite significant market opportunities in Ethiopia [Biruk, 2013; Tadesse et al., 2013; Dada, 2016; Offa District Agricultural and Natural Resource Development Office (ODANRDO), 2018; Graffham et al., 2019]. Furthermore, empirical research on cassava economic efficiency (EE) in this specific region that will assist in identifying concrete improvement levers is scarce. Therefore, by using parametric analysis this study estimated the technical, allocative, and economic efficiency of cassava producing households and identified sources of production inefficiency in the Offa district, which is one of the potential production areas in southern Ethiopia's Wolaita Zone.

METHODS

Area Description

Offa district (see **Figure 1**) was selected for this study as a current center of cassava production. It is one of the 16 *districts* in the Wolaita Zone, located in the Southern region of Ethiopia's Offa District Agricultural and Natural Resource Development Office (ODANRDO) (2018). It is about 29 km from the zonal city of Wolaita Sodo on the way to Gofa-Sawula road, 183 km from the regional city Hawassa, and 382 km from the capital city, Addis Abeba. It is geographically located at 370.71′E latitude and 60.83′N longitude. According to Offa District Agricultural and Natural Resource Development Office (ODANRDO) (2018) the district has three major agro-ecological zones: *Qolla* (lowland), *Weynadega* (midland), and *Dega* (highland), which cover 16, 62, and 22% of the total area, respectively. The maximum and minimum temperatures are 34 and 14°C, respectively. The rainfall is bimodal, with the short rainy season (Belg) lasting from mid-February to May and the long rainy season (Kiremt) beginning in June and lasting until October. The annual rainfall ranges from 850 to 1450 mm, with a medium summer rainy season from June to September. From a total area of 38,537 hectares, cultivated land (65.2%), forest land (5.91%), grazing land (13.43%), settlement (10.04%), and other bare lands account for 65.2, 5.91, 13.43, and 10.04%, respectively (5.42%). The district's vegetation is made up of remnant forests, communal forests, homestead plants, and natural vegetation in closed areas. Cereals and pulses such as maize, *teff*, wheat, barley, haricot bean, peas, and root crops such as *enset*, cassava, yam, and sweet potatoes are the most important crops.

Sampling Design and Data Collection

The research employed a cross-sectional survey approach using quantitative primary and secondary data obtained from cassava producers. The data were gathered from 2018/19 cassava season. Farmers who planted cassava in the early season of *Belg* 2018 and harvested from October to December, in the *Meher* season of 2019 were interviewed. The study followed a multi-stage sampling technique. Offa district from Wolaita zone was selected because it is a representative of smallholder cassava production in Ethiopia given its agro-ecological features, producer structure, area coverage, and production potential [Offa District Agricultural and Natural Resource Development Office (ODANRDO), 2018]. Second, from 21 rural *Kebele*[2] Administrations (KAs) in the *district*, 11 *Kebeles* represented cassava production under rain-fed conditions, from which 4 KAs were randomly selected, namely *Warza Dekeya, Galda, Busha,* and *Sere Esho*. Third, the research

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[1] It is a sour fermented flatbread with a little soft texture, by culture of Ethiopia made of teff flour.

[2] The smallest administrative unit in Ethiopia.

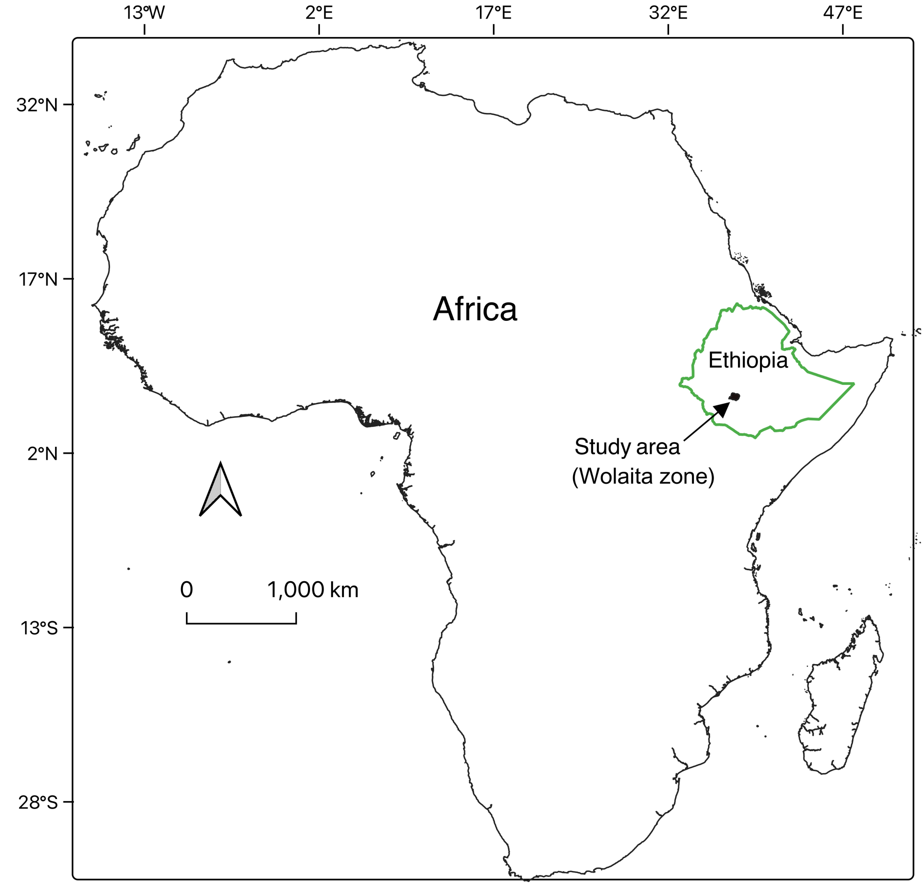

FIGURE 1 | Map of the study area.

purposively identified households producing cassava with the help of *Kebele* development workers. Fourth, based on the list of households that produced cassava during the 2018/19 production season, households that planted at *Belg* 2018 and harvested at *Meher* 2019 were purposively selected. This was necessary to obtain a homogeneous group of respondents for analysis because cassava has a production cycle of 9 months to 2 years as indicated by Jorge (2008), contingent upon the genotype and the ecological conditions. The total sample size was 158 households based on Kothari's (2004) formula (Equation 1). Therefore, 41, 37, 41, and 39 households were selected from *Waraza Dekeya, Galda, Busha,* and *Sere Esho kebeles,* respectively, by using probability proportional to the size of cassava producers (**Table 1**).

$$n = \frac{[Z^2(pq)N]}{e^2(N-1)+Z^2(pq)} = \frac{[1.96^2(0.88 \, * \, 0.12)5400]}{0.05^2(5400-1)+1.96^2(0.88 \, * \, 0.12)} = 158 \qquad (1)$$

where n is the desired sample size, Z is the inverse of the standard cumulative distribution that corresponds to the confidence level with the value of 1.96. N is the total cassava producer's population from which the sample was drawn; q $(1 - P)$, p (this was based on the pre-test survey of research) is the estimated proportion of an attribute present in the population. ∼88% of households in *Kebeles* were estimated to be cassava producers in the 2018/19 season.

TABLE 1 | Distribution of cassava producer households in Kebeles, Offa district.

Sampled *kebeles*	Cassava producers	Sample size
Dekeya	1,409	41
Galda	1,260	37
Busha	1,396	41
Esho	1,335	39
Total	5,400	158

Theoretical and Conceptual Framework

The microeconomics theory of the production function, which converts input into output, serves as a foundation for producing production efficiency. Productivity is defined as "the ratio of the value of total farm outputs to the value of total farm inputs used in farm production" in the production function (Coelli et al., 2005). Measuring a firm's performance in relation to a best practice frontier dates back at least to the 1950s. Koopmans (1951) defines technical efficiency as a firm's ability to maximize output for given inputs. Later, in the late 1950s, Farrell addressed the issue of level of inefficiency. Inefficiency, he proposed, is the observed deviation from a frontier isoquant. To avoid the problems associated with the traditional average productivity measure, he proposed a method that involved plotting inputs per unit output observations as points in a suitable dimension space. It can be estimated by fitting an envelope to the scatter of issues in the input plane, and then comparing other firms to those on the frontier (Farrell, 1957). Production frontier analysis has been widely used to estimate technical efficiency since the work of Aigner et al. (1977) and Meeusen and van Den Broeck (1977). The various approaches to quantifying technical efficiency generally follow the same logic: measuring the difference between observed productivity and theoretical, optimal, or average productivity. The single-output version of technical efficiency measures is defined by Kumbhakar and Lovell (2000) as "… an input-oriented measure of technical efficiency is given by the function and an output-oriented estimate of technical efficiency is given by the process."

In general, output-oriented and input-oriented approaches can be used to measure production efficiencies. The current study used an input-oriented approach. Two analytical measurement approaches can estimate production efficiency; these are "parametric" and non-parametric. Accordingly, the non-parametric methods are Malmquist productivity indices, engineering approach, superlative index numbers, and data envelopment analysis (DEA). The parametric ones are like average production function and stochastic frontier analysis. DEA and stochastic production frontier (SPF) are the two most common methods in various empirical studies on productivity analysis. Although all methods rely on different computational methods and assumptions, it is interesting to note that the results are often not significantly different. Neff et al. (1993), Sharma and Leung (1999), and Mechri (2017) described that estimates derived from DEA are not statistically different from other frontier estimation methods. The choice of a specific frontier model depends on various considerations such as the type of data, the underlying behavioral assumptions of firms, the relevance to consider and extent of noise in the data, and the purpose of the research (Gelaw and Bezabih, 2004; Coelli et al., 2005). Therefore, the parametric approach of SPF econometric model of CD functional form was employed in the current study. It was implemented in the current study for its multiple relative advantages over other non-parametric approaches. The advantages are its consideration of random errors, separating the effect of statistical noise from systematic sources of inefficiency which helps to test hypotheses despite some data inconsistency due to weather variations and developing country settings (Coelli, 1995; Haji, 2008; Michael, 2011; Mustefa et al., 2017; Wollie et al., 2018). By considering that farmers have more control over their inputs than their output, we preferred the input-oriented (IO) approach over the output-oriented (OO) in this study. The production of cassava could be increased in various ways. The new technology, increased use of inputs, and improving resource use efficiency are the main ones. The new technology and advanced production inputs to enhance productivity are complicated due to capital constraints and resource shortage. Thus, the method found best in Ethiopia with limited access to technologies is improving farmers' production efficiency using the current amounts, quality of inputs, and existing technology. Improving agricultural productivity, particularly cassava's, has several benefits. It facilitates the flow of resources from one sector to another, lowers food prices for consumers, and increases the industry's income and competitiveness. The different empirical studies show that various factors influence the production of cassava. The factors include various institutional, demographic, and socio-economic factors that influence technical, allocative, and economic efficiency. The framework discussed in **Figure 2** shows how various factors inter-relate to influence the technical, allocative, and economic efficiency in cassava production among producers.

Analytical Framework

The research used descriptive statistical analysis to summarize the cassava production efficiency of the sampled households. Furthermore, the SPF econometric model of CD functional form was employed to estimate the individual farmer-level TE, AE, and EE of the farmer in the study area. We tested the trans-log and CD functional forms and observed that the data fit the CD form (see **Appendix**). Moreover, we tested the data against econometric problems (heteroscedasticity, multicollinearity, and endogeneity), distributional assumptions for the inefficiency term (X_i), and different hypotheses using the generalized likelihood ratio (LR) prior to running the econometric model (see **Appendix**). The logarithmic form of the SPF function of the CD type is defined in the following equation:

$$\begin{aligned} \ln\, output &= \beta_0 + \beta_1 \ln\, land + \beta_2 \ln\, lobor + \beta_3 \ln\, fert \\ &\quad + \beta_4 \ln\, ox + \beta_5 \ln\, stem + (V_i - U_i) \qquad (2) \\ \varepsilon_i &= V_i - U_i \qquad (3) \end{aligned}$$

$i = 1, 2, 3 ... 153$
where description and measurement of output and input variables utilized by the i^{th} sample farmer is defined in **Table 2**; ln denotes logarithm to base e; $V_i - U_i$ represents the error term (ε); β_0 denotes the constant term to be estimated; $\beta_1 - \beta_5$ are coefficients of the input variables to be estimated; e_i represents the composed error term; V_i is the random error N (0, δ^2v) which is independently and identically distributed as N (0, δ^2v) with a random error that is autonomous of U_i, U_i is the non-negative efficiency measured relative to the stochastic frontier that is i^{th} farmers not attaining the maximum of production (technical inefficiency) and range between zero and one.

The following formula was used to estimate the TE of cassava production for the i^{th} farmer:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{\exp(X_i\beta + V_i - U_i)}{\exp(X_i\beta + V_i)} = \exp(-U) \qquad (4)$$

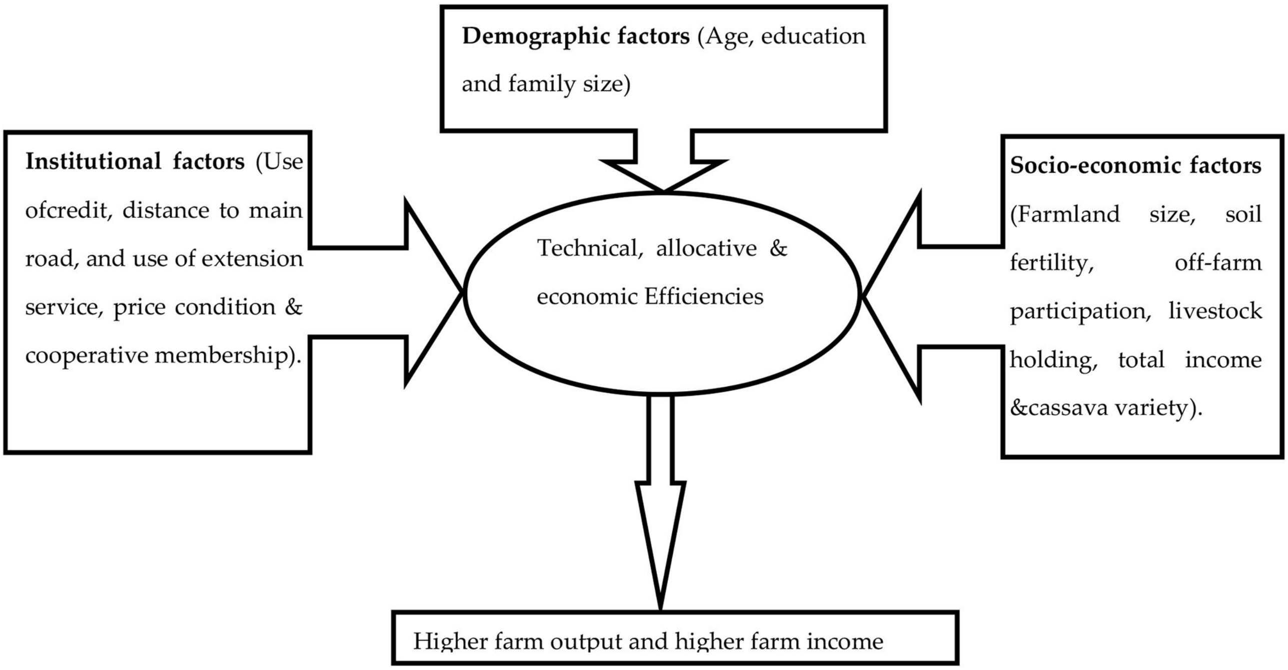

FIGURE 2 | Conceptual framework.

TABLE 2 | The description and measurement of output and input variables utilized.

Output and input variables	Description	Measurement
Lnoutput	Cassava production level of the sample farmers	Quintal
Lnland	Land area used for the production of cassava	Ha
Lnfertlizer	Quantity of urea fertilizer used	Qt/ha
Lnlabor	Quantity of labor used	Man-days
Lnoxen	Number of oxen power used	Oxen days
Lnplanting cut	Number of stems cutting utilized	Numbers

where Yi denoted the observation's actual production and Yi* denoted the frontier production estimation obtained from the stochastic frontier production function. The TEi obtained by predicting TE after stochastic frontier production function estimation [using sfcross command on above output and input variables (**Table 2**)]. The stochastic frontier cost function approach was used to examine allocation and economic efficiency. STATA version 13 was used for the analysis. Assuming the above production function (Equation 2) is self-dual (e.g., Cobb-Douglas), the dual stochastic frontier cost functions model for computing farm level AE and EE is indicated as:

$$C_i = f(Y_i, Z_i, a_i) + \varepsilon_i \qquad (5)$$

where *i* denotes the i^{th} household; C_i denotes the minimum cost to produce Yi as defined in **Table 3**; Y_i denotes cassava output; Z_i denotes the cost of input (**Table 3**); *a* represents parameters of cost function and ε_i denotes the error term that is composed of two elements, $\varepsilon_i = V_i - U_i$; V_i is random error N (0, δ^2v) which is independently and identically distributed; and U_i is the non-negative efficiency. It has positive signs as to Coelli (1995) precede error components due to inefficiencies are always expected to raise costs.

As to Sharma and Leung (1999); the aforementioned cost estimations were used in the current research to compute the AE and EE indices for the i^{th} farmer. The cost inefficiency (CEi) was defined as the ratio of total actual cost (C) to estimated total minimum cost (C*), with a value ranging from one to infinity. As a result, the cost efficiency level was the inverse of it. Allocative efficiency (AE) was used to define cost efficiency. The AE was written as follows: CEi = 1 /AEi. The obtained AEi value ranged between 0 and 1.

$$CE_i = C/C^* = \frac{E(C/u_i, Y_i, P_i)}{E(C/u_i = 0, Y_i, P_i)} = \exp(-u_i) \qquad (6)$$

The formula EEi = TEi*AEi was used to calculate economic efficiency (EE) per individual farmer. Individual farmer i's technical, allocative, and economic inefficiencies are calculated by subtracting one from TEi, AEi, and EEi, respectively.

The production and cost function obtained by using the SPF approach (with sfcross command). The Tobit model (Greene, 2008) was used to identify the source of inefficiencies (as defined in Equation 7). The inefficiency scores are censored from the left

TABLE 3 | Input prices and cassava output value.

Input prices and output value	Description	Measurement	Average value
Land cost	The local average rental land value in the area	ETB[a]/ha	10,000–20,000
Labor cost	Wage rate range	ETB/man-day	60–80
Fertilizer cost	The fertilizer input market values taken from cooperatives and farmers	ETB/kg	25–30
Oxen-day cost	Rental worth of a pair of oxen	Oxen-days	100–120
Cassava planting cut cost	Local purchasing value of cassava stem cuttings	ETB/qt	12–50
Cassava output value	The value of fresh cassava tuber as harvested in quintal	ETB/quintal	140

[a] *It refers Ethiopian Birr, with current exchange rate 1 USD is 42 ETB.*

TABLE 4 | Sources of inefficiency variables and their hypothesized sign.

Variables	Description	Measurement	Hypothesis	Prior researches
Dependent variable				
Inefficiency effect (μ_i)	Levels of inefficiencies ranging from zero to one			
Explanatory variables				
Age	Age of respondent	Years	−/+	Haji, 2008; Nurhussen et al., 2015
Education	The educational level of the household	Years	−	Alene and Hassan, 2006; Debebe et al., 2015; Hassen, 2015
Family size	Number of household family size	Number	+	Gbigbi, 2021
Soil fertility	Soil fertility status	Dummy	−	Tamirat et al., 2017
Farmland size	Farmland size of the respondent	Number	−	Haji, 2008
Off-farm participation	Off-farm participation of households	Dummy	−	Haileselassie, 2005
Livestock holding	Quantity of livestock	TLU	−	Eze and Nwibo, 2014
Credit access	Access to credit	Dummy	−	Adeyemo et al., 2010; Nwike et al., 2017
Extension service	Household's access to extension service	Dummy	−	Michael, 2011
Cassava variety	Use of improved cassava variety (ICV)	Dummy	−	Ospina Patiño et al., 2012; Adofu et al., 2013
Cooperative membership	Household's cooperative membership	Dummy	−	Debebe et al., 2015; Nwike et al., 2017
Total income	Total household income	ETB	−	
Distance to main road	Proximity to the main road	km	+	
Price condition	Cassava farmers' perception on price condition for cassava inputs and output	Dummy	−	Yami et al., 2013

Source, Own review (2019/20).

and right by considering the technical, allocative, and economic inefficiency scores that lay in ranges of 0 and 1.

$$E^* = \delta_0 + \delta_s P_i + V, \frac{V}{P} \approx Normal(0, \delta^2) \tag{7}$$

$E = \max(0, E^*)$
where i denotes the i^{th} household; s represents the number of sources of inefficiency; P_i denotes farm-individual factors of inefficiency; δ represents the parameter to be estimated; and E represents the efficiencies ($E^* = 0$ when $E^* \leq 0$ and $E^* = 1$ when $E^* \geq 1$).

It is expected that the inefficiency effects are individually dispersed, and U_{ij} arises by truncation at zero of the normal distribution (mean U_{ij}, σ^2), where the inefficiency model (U_i), expressed as follows:

$$U_{ij} = \delta_0 + \delta_1 X_{ij} + \delta_2 X_{ij} + \varepsilon_i \tag{8}$$

where U_{ij} denotes the inefficiencies (technical, allocative, and economic) of the i^{th} farmer; and ε_i is the composed error term (V_i − U_i). The inefficiency variables denoted as X_1 to X_{14} include demographic, socio-economic, and institutional variables (**Table 4**).

The research considered the two-stage estimation procedure analyzed using STATA statistical package of version 13. Using the efficiency level and source of inefficiency, the efficiency index was calculated in the first stage, and then regressed on proposed source of inefficiency variables (**Table 1**) determining the efficiency index in the latter stage.

The Sources of Inefficiency

Regardless of the functional form choice, the inputs to be used in the production process are predetermined in the sense that they are the actual inputs for the production of a given output. From the very beginning of the study, the variables selected to enter into the model were area (ha), chemical fertilizer (kg),

TABLE 5 | Estimates of the OLS and SPF CD production function.

Input variables	OLS estimates		ML SPF estimates	
	Coefficient	Std. Err.	Coefficient	Std. Err.
Constant	3.6321***	0.4885	4.1649***	0.3702
Lnland	0.4495***	0.1463	0.5384***	0.1098
Lnlabor	−0.0792	0.0925	0.0402	0.0798
Lnfertilizer	0.0611***	0.0085	0.0531***	0.0070
Lnoxen	0.0330	0.0998	0.0467	0.0883
Lnplanting cut	0.5881***	0.1467	0.3705***	0.1285
Diagnosis statistics				
Adj. R^2	0.7689			
Prob. > F	0.0000			
Sigma square (δ^2)			0.0065***	
Gamma (γ)			70%***	
Log-likelihood	−79.2227		−70.6675	

**** refer to 10, 5, and 1% significance level, respectively.*

TABLE 6 | Maximum likelihood estimates of the parameters of the CD SPF.

Variables	Coefficient	Std. err.
Constant	1.3040***	0.2126
Land cost	0.5389***	0.0462
Labor cost	0.2316***	0.0428
Fertilizer cost	0.0083**	0.0040
Oxen-day cost	0.2053***	0.0395
Cassava planting cut cost	0.0204	0.0391
Cassava output	0.0252	0.0310
Diagnostic statistics		
Sigma square	0.044***	
Gamma (γ)	0.232***	
Log-likelihood	20.3607	

*** and *** refer to 5 and 1% significance levels, respectively.*

TABLE 7 | Summary statistics of efficiency scores.

Parameters	Mean	Std. dev.	Min.	Max.
Technical efficiency (TE)	0.7357	0.1659	0.2009	0.9445
Allocative efficiency (AE)	0.8999	0.0831	0.1838	0.9735
Economic efficiency (EE)	0.6608	0.1609	0.1629	0.8503

labor (man-day), oxen power (oxen-days), pesticide (liter), and planting cut (qt). However, from the sampled farmers almost none used pesticides, while 41 and 86% of the sample households applied DAP and urea fertilizer, respectively. The direct use of these variables in the estimation of the model bias the estimation. To avoid this problem, Coelli (1995) suggested estimating the production frontier by assigning a very small value >0 for farmers who did not apply urea fertilizer. The research assigned a small value of 0.0001 that approaches 0. The variables (DAP fertilizer and pesticides) were excluded from the model. Based on previous empirical studies, the following explanatory variables were expected to determine efficiency differentials among sample households (**Table 4**).

RESULTS AND DISCUSSION

Production and Cost Functions

Among the five variables included in the production function land area, cassava planting cut and fertilizer (urea) had a significant explanation of the difference in cassava output among farmers (**Table 5**). The higher coefficient of land (**Table 4**) indicates high elasticity of output to land (0.538), which suggests that cassava production was moderately sensitive to land area. Thus, a 1% increase in the land area cultivated resulted in a 53.8% increase in cassava output, maintaining other factors constant. The finding on land, fertilizer, and labor were in line with Soukkhamthat and Wong (2016) and Murniati et al. (2021). Similarly, the finding on fertilizer, labor, land, and planting cut are in line with Adeyemo et al. (2010).

The diagnostic statistics of the inefficiency component shows that sigma squared (s^2) was statistically significant at 1% (**Table 5**). It depicts the goodness of fit and the correctness of the distributional form assumed for the composite error term.

The result of the model revealed that the input variables, i.e., land, urea fertilizer, and planting cut, except labor and oxen have a significant effect on the level of cassava output. Hence, the increase of these inputs would increase the output. The result was in line with Eze and Nwibo (2014) and Nwike et al. (2017) who found that an increased use of these inputs will result in an increase in total output of cassava.

The lambda value of 1.511 and the gamma value of 70% show the total difference in output due to the production inefficiency. Further, the sigma square, which is significantly different from zero, suggests that the model is a good fit. The coefficient of multiple determination (R^2) indicates that 76.89% of the total variation in the total outputs was explained by the variables included in the model.

The summation of coefficients shows the production nature is Increasing Returns to Scale (IRS), that is, any extra input may lead to more than a proportionate change in the output illustrating the potential for cassava producers to increase their production. This finding is consistent with the results obtained by Makinde et al. (2015), where the cassava returns to scale was found to be 1.841%, which falls in stage I of the production surface.

Table 6 shows the dual cost function derived analytically from the SPF, which shows the relation of cost of inputs to the total value of cassava. It offers significant input cost variables determining cassava output value. The finding of costs of cassava planting cut, fertilizer, labor, and cassava output amount are consistent with the results obtained by Lanamana and Supardi (2021).

The TE, AE, and EE Scores of Cassava Production

The model result displayed in **Table 7** indicates that cassava farmers had a wide range of variations in efficiencies (TE, AE, and

EE). The mean TE, AE, and EE attained by farmers were 73.57, 89.99, and 66.08%, respectively. These designate that farmers on average could cut inputs (land, labor, fertilizers, oxen power, and planting cut) by 26.43% if they were technically efficient; could save 10.01% of their current cost of inputs by choosing a cost-minimizing input combination; and could reduce the current average cost of production by 33.92% without decreasing cassava output when attaining the potential minimum cost level. The minimum and maximum level of TE among farmers ranged from 20.09 to 94.45%, while the AE and EE ranged from 18.78 to 97.35% and 16.29 to 85.03%, respectively. These results indicate the wide disparity in farmer-specific efficiency levels, in line with the study of Michael (2011). The efficiency scores showed that farmers in the study area were relatively better in the AE of cassava production.

Actual and Potential Level of Cassava Output

The variation between the real and the frontier level of output was obtained by estimating the separate and the average level of frontier output from the SPF model. The average amount of the actual output and the mean value of the potential production was 90.59 qt/ha and 121.75 qt/ha, respectively. **Table 8** shows the existence of technical inefficiency in the study area. The difference in the mean technical efficiency of potential and actual yield per ha shows that, if the sample households used the existing agricultural inputs at an optimal proportional level, a yield increase of 31.16 qt/ha (25.59%) of cassava output could be obtained.

TABLE 8 | The actual and potential level of output.

Variables	Mean	Std. deviation	Minimum	Maximum
Potential production	121.7542	85.4918	16.5850	416.2238
Actual production	90.5949	68.1014	6.00	320.00
Output difference	31.1592	33.6549	3.1342	202.103

Sources of Inefficiencies

Table 9 shows the two-limit Tobit model outputs of the variables determining inefficiencies of cassava producers. The inefficiencies levels obtained from the two-stage estimation approach were regressed on the proposed variables that bring inefficiency deviation among the cassava producer farmers. The same estimation technique was used by Alene and Hassan (2006), Haji (2008), and Wollie et al. (2018).

Age is found to determine the allocative inefficiency of the smallholder farmers in cassava production positively and significantly at 10% significance level. The positive coefficients of age also indicate that the increment in it increases inefficiency. Specifically, the coefficient shows that an increase in age by 1 year increases allocative inefficiency. It indicates that older farmers were less efficient than counterparts. It is possibly due to older farmers having less management skills to effectively minimize costs in farming. This finding is consistent with Adewuyi and Joseph-Adekunle (2013), Ettah and Kuye (2017), Wollie et al. (2018), and Kollie (2020) who showed that the age of the cassava farmer is positively related to cassava production inefficiency.

Education was found to positively and significantly determine both technical and economic inefficiency at a 1 and 5% significance level, respectively. Specifically, the coefficients indicate that an increase by 1 year of education increases technical and economic inefficiency. It indicates that less-educated farmers are more technically and economically

TABLE 9 | Tobit model estimates for sources of inefficiency.

	Technical inefficiency		Allocative inefficiency		Economic inefficiency	
Variables	**Coefficient**	**Std. err**	**Coefficient**	**Std. err**	**Coefficient**	**Std. err**
Age	0.0001	0.0012	0.0014*	0.0007	0.0013	0.0013
Education	0.0093***	0.0036	−0.0012	0.0020	0.0073**	0.0036
Family size	−0.0022	0.0058	−0.0051	0.0033	−0.0065	0.0059
Level of soil fertility	−0.0639***	0.0228	0.0173	0.0132	−0.0425*	0.0230
Farmland size	0.0313	0.0250	0.0144	0.0147	0.0447*	0.0256
Cassava variety	−0.0719***	0.0233	0.0023	0.0136	−0.0648***	0.0237
Off-farm participation	−0.0470*	0.0262	0.0030	0.0153	−0.0426	0.0266
Livestock holding	−0.0209***	0.0073	0.0032	0.0043	−0.0160**	0.0074
Use of credit	−0.0224	0.0225	−0.022*	0.0132	−0.0397*	0.0228
Use of extension service	−0.0877***	0.0238	−0.0254	0.0139	−0.0579**	0.0241
Cooperative membership	−0.0235	0.0235	−0.0173	0.0137	−0.0354	0.0238
Total income	0.0818	0.0530	−0.0457	0.0312	0.0352	0.0538
Distance to the road	0.0132	0.0153	−0.0089	0.0089	0.0049	0.0156
Price condition	−0.0465*	0.0240	−0.0048	0.0140	−0.0472*	0.0244
Constant	0.3902***	0.0929	0.0932*	0.0489	0.4482**	0.0887

, **, and * refer to 10, 5, and 1% significance level, respectively.*

efficient than their counterparts. It might be due to the increased probability of more educated farmers participating in other livelihood options, and hence reducing their time and knowledge input into cassava farming. This result is similar with the results reported by Wollie et al. (2018) from Ethiopia and Ettah and Kuye (2017) from Nigeria, where the cassava farmers' level of education positively contributed to cassava production inefficiency. However, it is not in line with the finding of Adeyemo et al. (2010), Isitor et al. (2017), and Soukkhamthat and Wong (2016) who found that education is negatively determining cassava production inefficiency.

Soil fertility significantly and negatively determined technical and economic inefficiencies at 1 and 10% significance level, respectively. Thus, measures aiming to increase soil fertility will positively affect the efficiency of cassava production. The result was similar to the findings of Musa et al. (2015) and Wollie et al. (2018).

Farmland size positively and significantly determines economic inefficiency at a 10% level of significance. This finding was similar to the *a priori* expectation. The link between efficiency and landholding size has been the subject of much discussion in the literature. While several studies found that small farmland size increases inefficiency due to simple management and intensive resource use in comparison to larger land size, our finding conforms with the results reported by Haji (2008), Debebe et al. (2015), and Tafesse et al. (2020).

The use of improved cassava varieties had a negative and significant influence on cassava output's technical and economic inefficiency at a 1% significant level, in line with prior expectations. In the study area, *Qulle* (104/72 Nigeria red) and *Kelle* (44/72 Nigerian white) were the two most common improved cassava varieties used by farmers because of their high productivity and short-balking time, and better demand in the market. This result is in line with that of Debebe et al. (2015) and Girma et al. (2017).

Off-farm activity participation was negatively and significantly related to technical inefficiency at a 10% significance level. It suggests that farmers involved in off/non-farm activities were more efficient in farming. It could be due to that of more off-farm income means farmers are wealthier and can afford higher-quality input, hence they have higher efficiency. The finding was in line with Nurhussen et al. (2015).

Livestock holding showed a negative and significant difference in technical and economic inefficiency at 1 and 5% significance levels, respectively. It shows that farmers who owned more livestock were technically and economically more efficient than those who owned less livestock. This may be related to the importance of livestock in the cassava production process as a source of working power, fertilizer, and income to procure critical inputs. The result corroborates findings reported by Bizuayehu (2012).

The use of credit shows a negative and significant influence on farmers' allocative and economic inefficiency at a 10% level of significance. As hypothesized, **the use of credit** was related to lower inefficiency levels, as it temporarily solves the shortage of working capital and other production constraints and facilitates the timely purchase of inputs that increase productivity. This is consistent with the findings of Bati (2014) and Nurhussen et al. (2015).

Likewise, farmers with access to **extension services** were less inefficient as hypothesized. The coefficient was negatively associated with technical and economic inefficiency at 1 and 5% significance level, respectively, but positively and significantly at a 10% level to allocative inefficiency. The finding indicated that the use of extension services improves the farmers' technical and economic efficiency that is in line with prior expectations. This finding is consistent with results reported by Haji (2008), Nurhussen et al. (2015), and Teferra et al. (2018), and partially consistent with findings of Dogba et al. (2020). However, it is not in line with Rahman and Awerije (2015).

Price condition was negatively and significantly related to technical and economic inefficiency at a 10% significance level. The price condition was used as a proxy for production cost minimization and profitability, which indicates that producers are not always price takers. The result recognized the fact that a farmer located far from the market incurs more costs to transport farm produce to the market and input to the farm, which in turn increases the sales price for a farmer far from the market. This finding was in line with Alene and Hassan (2006).

CONCLUSION AND POLICY IMPLICATIONS

The research indicated that 73.57% of TE, 89.99% of AE, and 66.08% of the average levels of EE suggest room for a further surge in output without increasing the level and costs of inputs. It suggests that farmers can increase their cassava output on average by 26.43% when they were technically efficient. Moreover, the estimates indicated that the farmers have opportunities to increase their AE and EE by 10.01 and 33.92%, respectively. It implies that using the existing resource base, improved efficiency can still be achieved, and there exists a potential to increase the gross output and reduce costs with the existing level of inputs. The CD SPF and its dual cost functions were valued, and TE, AE, and EE were estimated. The result of the production function showed that all of the factors of production such as land, fertilizer, and cassava planting cut employed in the production model positively and significantly determine cassava output. The production structure was categorized by IRS at a decreasing rate that indicates cassava output of farmers increases over-proportionally with an increase in inputs. The positive elasticity of output concerning land, urea fertilizer, and planting cut revealed that these inputs play an important role in determining the level of output per unit of each input.

In the latter step the relationships between TE, AE, and EE and sources of inefficiencies were examined. Education, farmland size, soil fertility, type of cassava variety, off-farm participation, livestock holding, credit, extension service, and the price condition were significant to determine the level of TE and EE. The model also showed that age, use of credit, and use of extension service were vital factors that significantly determine the allocative inefficiency.

The research indicated that there exists substantial room to boost the level of efficiency of smallholder cassava producers. Improved access to critical input and agri-technologies can improve the current efficiency level and substantially increase production levels. Decision-makers should therefore give due attention to policies that encourage the cassava producers to use existing technologies more efficiently and learn from other farmers in their neighborhood. Our results demonstrate that strengthening education, rural credit, and extension services have the potential to facilitate a more efficient use of available resources for cassava production. Thus, our results accentuate calls to expand knowledge, skills, and information availability through agricultural education programs in schools, farmer training centers, and similar experience-sharing activities. This will require capacitating agricultural advisors by providing incentives, training, advancement of their educational level, definition of non-overlapping and congruous responsibilities, and close supervision. A conducive environment also includes improved credit access for farmers, which can help farmers to cover the cost of production and marketing. Furthermore, in order to help farmers increase their efficiency of cassava production, our findings should encourage the development stakeholders in the area to focus on improving soil fertility through sustainable land and water management practices, to develop mixed livestock-cassava farming systems, and to support farmers in developing off-farm income-generating activities, especially during the off-farming season.

From a national economic point of view, increasing the production of cassava as a potential substitute for *Teff* flour could help in stabilizing the increasing demand for *Teff*, which exceeds the current rates of *Teff* yield improvements. It will also provide new business opportunities for entrepreneurs in the food processing industry through new product development and increased value addition through further processing and commercialization, thereby generating additional employment and tax income. Higher cassava production also possibly provides export opportunities which can increase the country's foreign exchange earnings. Finally, given its relatively modest environmental requirements, which makes cassava production an economically attractive option also on marginal lands, cassava farming can contribute to food production and rehabilitation of barren and degraded lands, which is a national priority in light of an ever increasing total population in Ethiopia.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

AT: conceptualization, investigation, data collection, statistical analysis support, writing—review, and editing. BM: conceptualization, data collection, statistical analysis, and writing—original draft preparation. AB: conceptualization, investigation, analysis support, writing—review, and editing. EA and DD: conceptualization, investigation supervision, writing—review, and editing. JR, PO, TD, and TE: funding acquisition, writing—review, and editing. DS: supervision, funding acquisition, writing—review, and editing. All authors contributed to the article and approved the submitted version.

FUNDING

This research was financially supported through CCAFS-EC Grant Reference: 2000002575 for the project on Building Livelihoods and Resilience to Climate Change in East and West Africa: Agricultural Research for Development (AR4D) for large-scale implementation of Climate-Smart Agriculture. The funds are administered by the International Fund for Agricultural Development (IFAD), Rome, Italy, while the project is implemented by Alliance Bioversity-CIAT. This study was also financially supported through a grant from the World Bank Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) ESA regional project (Grant No. D7540) signed between CIAT and the International Development Association (IDA). The APC was funded by the CGIAR Research Program on Climate Change, Agriculture and Food Security, that is supported by contributors to the CGIAR Trust Fund.

ACKNOWLEDGMENTS

We would like to thank the Wolaita Sodo University, Ethiopia, for administrative and logistical support during data collection.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2021.758951/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.