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Technical Efficiency of Moringa Production: A case Study in Wolaita and Gamo Zones, Southern Ethiopia

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Abstract

Moringa has been becoming among vastly growing and trading commodities in different parts of Ethiopia for its multiple benefits. However, empirical researches analyzing its productivity at smallholder farmer level were missing. This study aimed to fill the existing gap with a cross-sectional survey study on sampled 117 Moringa producer farmers from southern Ethiopia. The Stochastic Frontier Model was used to estimate the level and factors determining the technical efficiency of Moringa production. The collected data fitted Cobb-Douglas production function with inputs, labor and the numbers of trees positively and significantly determined the output of Moringa. An estimated level of efficiency shows farmers have the possibility to increase Moringa output by 47.81% with existing inputs and technology. The land, off-farm activities, access to road, credit, and irrigation were significant factors affecting the technical efficiency of Moringa. It requires policies and development actions to perform on mechanisms to advance the production of Moringa. Hence, any development direction to enhance Moringa production should consider households with limited access to land and irrigation. Furthermore, the development of road infrastructure is required to increase agricultural productivity. In sum, modern credit institutions, as well as facilities, found essential to improve the livelihood of Moringa producers in the area.

Keywords: technical efficiency, stochastic frontier model, Moringa, Ethiopia

1. Introduction

In Ethiopia, Kelemu, Kindu, and Yetneberk (2012) indicated that in the previous periods Moringa has been existed without giving benefits other than just serving as a shade tree. It has been produced for a long period of time but its productivity remained low. Its production remained below the required level that is only limited to smallholder farmers, and unscientific (Seifu, 2015). The Ethiopian public health institute additionally mentioned the various challenges persisting including its productivity issues (Ethiopia Public Health Institute (EPHI), 2014). However, despite its production is traditional and the productivity still remained low, recently, it has gained public attention and produced at a different level. It has become one of the vastly growing and traded commodities in different parts of the country for its benefits. The consumption of its leaves both in powder or dried form has been mounting; production is expanding and new businesses are flourishing. The private sectors including the small and informal businesses are dominating the emerging markets. Many investors have involved in establishing value chains for their production (EPHI, 2014).

Hence, it is highly required to implement the theories and approaches of economics to the area of agroforestry commodities. However, there are limited numbers of economic studies in this area. The studies by Alene, Manyong and Gockowski (2006), Azeez *et al.* (2013), Binam, Sylla, Diarra, and Nyambi (2003), Getachew and Temesgen (2016); Lindara, Johnsen, and Gunatilake (2006), Mercer, Cubbage and Frey (2014), Ngango and Kim (2019) and Sekhar, Venkatesan and Vidhyavathi (2018) are among the few empirical studies that tried to examine the efficiency of agroforestry commodities such as Moringa, Coffee and others. Particularly Azeez *et al.* (2013) and Sekhar *et al.* (2018) studied the profitability of Moringa production; the productivity of the factors involved in Moringa production and efficiency analysis in Nigeria and India, respectively.

In general, an efficiency study may help in providing the evidence-based outcome to make decisions about the introduction of important interventions/activities and discourage the use of inefficient interventions/activities. Thus, the current study mainly focuses on the production of this agroforestry commodity, Moringa as a single output. The analysis of productivity and efficiency of existing unscientific and inefficient production techniques of Moringa will have a great implication to improve the sector. The study has tried to answer the following research questions; what is the existing level of efficiency of Moringa producing farmers? Is there any possibility of improvement in the level of efficiency? What are the main causes of the existing level of inefficiency? What are the main possible solutions to improve the existing level of inefficiency?

2. Research Methodology

2.1 Description of the Study Area

Wolaita and Gamo Gofa zones are two adjacent zones among the 13 zones in the Southern Nations Nationalities and Peoples Regional (SNNPR) state of Ethiopia where Moringa is extensively produced (Edwards, Tadesse, Demissew and Hedberg, 2000). *Moringa Stenopetalla* grows in these areas at a wide range of altitudes that range from 500 to 1800m above sea level (a.s.l). But its upper altitude range can also extend to 2100 m a.s.l if trees are sheltered from the wind and heavy rain (Bosch, 2004). Wolaita Sodo is an administrative center of the Wolaita zone. The administrative center of Gamo Gofa is Arba Minch. Wolaita and Gamo zones are located in between 350 - 500 km south of Addis Ababa on the Sodo Gamo Gofa main road. Wolaita zone is subdivided into 12 districts. The zone has a total area of 4512 km^2, administratively divided into 12 districts (locally termed *woredas*). Based on the 2007 census conducted by the Central Statistical Agency of Ethiopia, the total population of the zone is nearly 2,473,190. Gamo Gofa zone has a total area of 18,010.99 km^2, administratively divided into 18 districts (locally termed *woredas*). Based on the 2007 census conducted by the Central Statistical Agency (CSA) of Ethiopia (2007), the zone has a total population of 1,593,104. Figure 1 below demonstrates the study area setting.

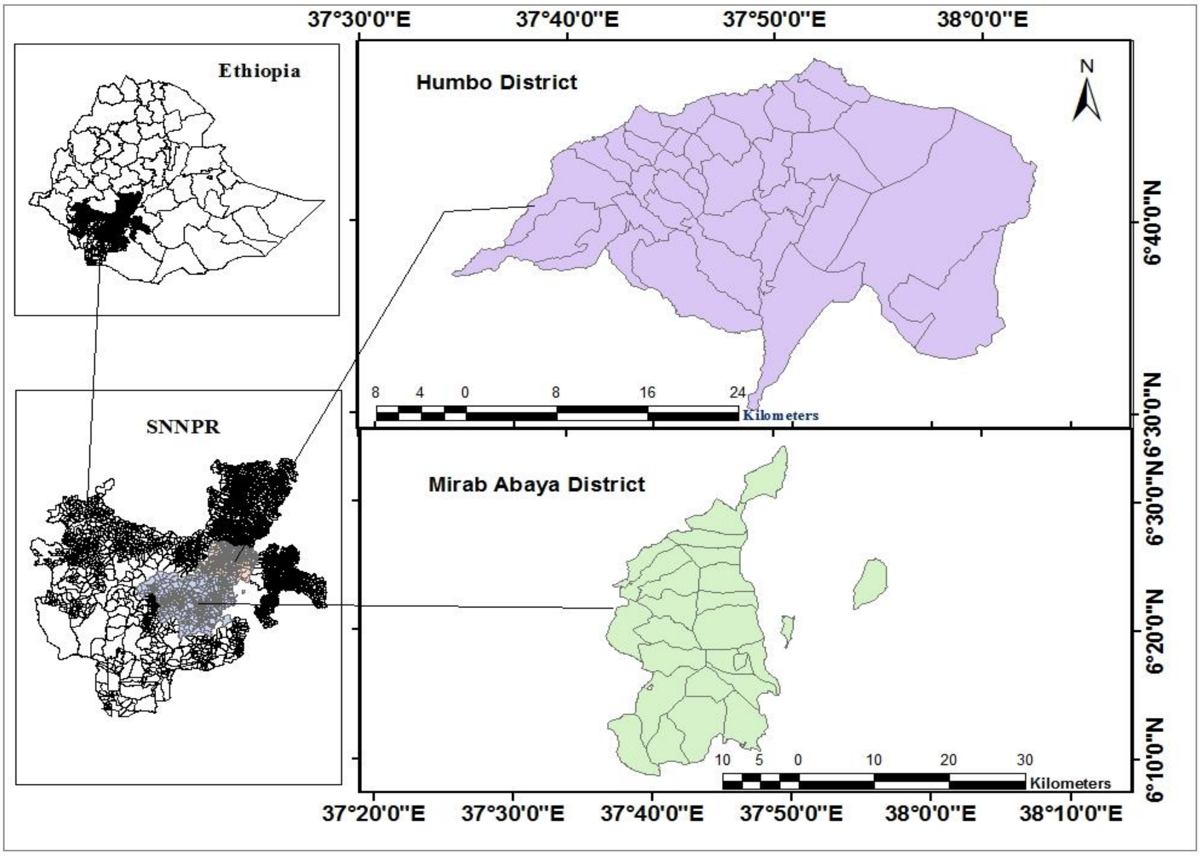

Figure 1. The study area setting

2.2 Data

Primary data were collected through a household questionnaire. In doing so, all the respondents were asked a basic set of questions that can help to get the right response to achieve the objective of the study. Secondary data was collected from different institutions, organizations, and offices through direct contact as well as through reviewing documents and publications. Before the data collection task, the data collectors were trained on how to collect the necessary data and a pre-testing survey was carried out. Furthermore, the researchers have also supervised the data collectors.

2.3 Sampling Design

The study has used a multistage sampling technique. That is first, two Moringa growing districts from two zones were identified based on their potential to grow Moringa, one from each zone. Then based on actual production potential, four Moringa growing kebeles (Note 1) from each district were selected randomly among other Moringa growing kebeles. In the third stage, based on proportional to the total sizes of households in each kebele, respondents were selected from respective kebeles. Finally, simple random sampling was used to select respondents in the sampled kebeles. Hence, the selected households for current studies were 232 Moringa producing households in Abala Faracho, Abala Kolshobo, Buke Dongola, Abala Longena, Wanke Wajifo, Kola Barana, Yayike and Delbo kebeles of Woliata and Gamo zones. However, for the purpose of research reliability from these numbers of selected Moringa producing households only 117 homogeneous respondents with having 5 years of Moringa production period were used for the current analysis of technical efficiency of Moringa production.

2.4 Methods of Data Analysis

The descriptive statistics and econometric methods of data analysis were used. The econometric model was used to analyze the efficiency of Moringa producers. The quantitative data collected on producers' socio-economic, demographic and spatial settings; the quantity of Moringa produced; and others were analyzed using descriptive statistics like means, frequencies, ranges, and percentages. The Stochastic Production Frontier Model (SPF) was used for this study to analyze the efficiency of Moringa production. The stochastic frontier production function was first proposed by Aigner, Lovell, and Schmidt (1977) and then Meeusen and van Den Broeck (1977) and Kumbhakar, Ghosh, and McGuckin (1991) extended the model by openly introducing the determinants of technical efficiency. Its applications in research works were well developed in recent times (Kumbhakar and Lovell, 2003). The model has gained popularity as opposed to the Data Envelopment Analysis (DEA). The assumption that all deviations from the frontier arising from inefficiency as assumed in the data envelopment analysis approach is considered difficult to accept, given the natural variability of agricultural production; and the rareness of farm record data availability, even the data is available on production it is likely to contain measurement errors (Coelli, Rao and Battese, 1998).

Most commonly the Cobb–Douglas form of the stochastic frontier production model is used with a log-log or log-linear or other functional form depending on the nature of data which are collected by following merits in the application in smallholder farming. According to Kopp and Smith (1980), functional forms have minimum effect on efficiency measurement, even if it requires specification of the model first. However, the study tested the two functional forms in Table 3 and observed that the data fitted Cobb-Douglas form. The study has used production data of Moringa production in the 2018/19 season by each selected farmers. As indicated above the general model first developed by Aigner *et al.* (1977) and Meeusen and van Den Broeck (1977) and later developed by Battese and Coelli (1995) and Meeusen and van Den Broeck (1977). It is specified as:

$$Y = f(X; \beta) + \varepsilon i(Vi - Ui) \tag{1}$$

Where: in current study case Y is amount of yield of the Moringa output produced per year (Kg); f(X; β) is a production function; β are the parameters estimated; X's are exogenous factors affecting the amount of Moringa yield; εi is the error term, equal to ($Vi - Ui$); Vi is a two-sided random error component beyond the control of the farmer; Ui is one-sided inefficiency component.

The dependent and independent production function variables are:

Amount of Moringa Produced: is the dependent variable, which measured the natural logarithm of the total quantity of Moringa, produced by households in the 2018/19 production year that expressed in kg.

Labor: is a continuous input variable that measured the natural logarithm of the amount of pre-harvest, harvest and post-harvest labor used by Moringa producing households in 2018/19 and measured in adult-equivalent.

Extension contact: is a continuous variable measured in the natural logarithm of a number of days that development agent (DA), agricultural experts and researchers gave households technical advice on agricultural activities including Moringa production in the 2018/19 production year.

Moringa Tree: a continuous variable that measured in the natural logarithm of the number of Moringa trees in the plots of Moringa producing households in 2018/19.

The above equation 1 was estimated using maximum likelihood estimation where yield estimators for β and γ;

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad and \quad \gamma = \sigma_u^2 / \sigma^2 = \sigma^2 / \left(\sigma_u^2 + \sigma_v^2\right) \qquad (2)$$

Where: γ parameter has a value between 0 and 1. A value of γ of zero indicates that the deviations from the frontier are due entirely to noise, while a value of one would indicate that all deviations are due to technical inefficiency.

According to Battese and Coelli (1995) σ_u^2 is the variance parameter that denotes deviation from the frontier due to inefficiency; σ_v^2 is the variance parameter that denotes deviation from the frontier due to noise, and σ^2 is the variance parameter that denotes the total deviation from the frontier.

Technical inefficiency determinants are explained as:

$$\begin{aligned} TE &= Exp\left(-Ui\right), \text{ so that } 0 < TEi < 1 \\ \left(Ui\right) &= \delta_0 + \delta_1 Ci + Zi \end{aligned} \qquad (3)$$

Where: U_i is technical inefficiency; δ_0 ….δ_1 are the parameters estimated; C_i is a vector of a farmer and household socio-economic characteristics described in Table 1 below; Z_i *is* a random error.

The stochastic production frontier function, defined by equation 1 and the technical inefficiency model, defined by equation 3, were jointly estimated by the maximum likelihood method by using sfcross command in STATA 14. The table below shows the variables used in the current study that are hypothesized to affect the technical efficiency of Moringa production.

Table 1. Description of the hypothesized variables

Variables Name	**Description**	**Type**	**Expected effect**
Gender	Gender of the household head 1 if female and 0 otherwise	Dummy	+
Age	Age of Household head	Continues	+/-
Education	Years of formal education of the household head	Continues	+
Family size	Amount of household in adult equivalence	Continues	+
Livestock	The amount in TLU (Note 2) of livestock owned by the household	Continues	+
Land size	Amount of hectare of land available	Continues	+
Distance to the nearest market	km to travel to sale *Moringa* to market	Continues	-
Distance to the main road	km to reach the nearest all-weather road	Continues	-
Credit access	1 if a household has accessed credit service and 0 otherwise	Dummy	+
Irrigation access	1 if a household head has access to Irrigation and 0 otherwise	Dummy	+
Fertilizer application	1 if a household used fertilizer in Moringa production and 0 otherwise	Dummy	+
Cooperative membership	1 if a household is a member of cooperatives and 0 otherwise	Dummy	+
Participation in off-farm	1 if household participated in off-farm activities and 0 otherwise	Dummy	+

3. Results and Discussions

3.1 Household and Demographic Characteristics

The summary Table 2 provided below shows the statistical report of household and demographic characteristics. It has indicated that the proportion of female-headed households was only 4% that is they are quite fewer than male-headed households. On the other hand, the mean average age of sample households was 43 years with the youngest being 25 and the oldest is 90 years old. On average, a typical household attended 4 years and 7 months of informal education with a minimum of zero years and a maximum of 13 years of schooling. Additionally, selected households owned 2 livestock in TLU with a minimum of 0 and a maximum of 6. The mean land holding of sampled households was about 1.15ha with a minimum of 0.1 and a maximum of 5.5. When institutional access of selected households observed 68% participated in various cooperative organizations and 47% accessed credit from different credit institutions in the area. This shows credit facility in the area is less sufficient. On another hand, 43% of households have access to irrigation in the area. The mean distance of households from the main road was 0.06km with a minimum of 0.01 and a maximum of 0.4 km. This indicates that road infrastructure access in the research area is not bad. In addition to this, the distance of households from the market was 0.42km with a minimum of 0.01 and a maximum of 2km. Finally, the descriptive statistics result revealed that the proportion of households using inorganic fertilizer on their Moringa account for about 50% on average.

Table 2. Statistical summary of household and demographic characteristics

Variables	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Age	117	43.47	11.40	25	90
Gender	117	0.04	0.20	0	1
Family size	117	3.79	1.46	2	8.6
Education	117	4.70	4.03	0	13
Livestock (TLU)	117	2.26	1.60	0	6.1
Land size	117	1.15	0.83	0.1	5.5
Cooperative membership	117	0.68	0.46	0	1
Distance to the main road	117	0.06	0.05	0.01	0.4
Distance to nearest market	117	0.42	0.36	0	2
Irrigation access	117	0.44	0.49	0	1
Participation in off-farm	117	0.62	0.48	0	1
Credit access	117	0.47	0.50	0	1
Fertilizer application	117	0.52	0.50	0	1

Source: Survey result, 2018/19.

3.2 Parameter Estimates of the SFP Model

In this part input variables used in the production of Moringa and their estimation using the SFP model were discussed. The study used 3 inputs mainly labor, number of Moringa tree and frequency of extension contracts for the production of Moringa. As displayed in Table 3 below in the SPF model only labor and number of Moringa trees were found positively and significantly determining the maximum possible level of Moringa output. However, the frequency of extensions of contact found insignificant.

Table 3. Parameter estimates of the OLS and SPF model

Variables	**OLS (Ordinary least square) estimates**		**Maximum likelihood SFP estimates**	
	Coef.	**Std. Err.**	**Coef.**	**Std. Err.**
Lnlabor	0.94***	0.16	0.92***	0.13
Lnsizemorgtree	0.19	0.14	0.36***	0.12
Lncontactfrequency	0.19	0.13	0.03	0.11
Constant	-0.64	0.44	0.16	0.43
Logliklihood	-107.04		-88.36	

Note: *** represent statistical significance at 1%.

Source: Survey result, 2018/19.

The level of labor and number of Moringa tree coefficient in the above SPF model implies that a percent increase in labor and number of Moringa tree increased the amount Moringa production by 92% and 36%, respectively. This result is similar to Sekhar *et al.* (2018) of whom indicated the number of human labor used (man-days) per ha per annum was found to influence the yield of Moringa in India. The estimated value of gamma is 0.74 which implies that 74% of the total variation in Moringa production farm output is accounted for by technical inefficiency. The return to scale of 1.26 indicates increasing returns to scale observed in the current research. This meaning a percent increase in all inputs proportionally would bring the total production by more than a percent increase. This finding is similar to a result by Sekhar *et al.* (2018) that indicated the increasing return to scale with 1.48 value in their study of the economic efficiency of Moringa in India.

3.3 Tests of Hypotheses

This study used the LR test which is among the most important test methods that users check the fitness of parametric models. This part, thus discuss the different tests used in this study using LR as it is specified by Equation (4) provided as follows;

$$\begin{aligned} LR &= \lambda = -2\left[L(H_o)/L(H_1)\right] \\ \lambda &= -2\left[L(H_o) - L(H_1)\right] \end{aligned} \tag{4}$$

Before taking tests for the SPF model, the test for multicollinearity and heteroscedasticity was made. The VIF test for the continuous and contingency coefficient (CC) test for categorical explanatory variables was conducted. The values 1.36 and 0.31, respectively indicate the existence of no sever problem of multicollinearity among the independent demographic and household characteristics variables. Moreover, the heteroscedasticity test was made among each explanatory variable by including these variables into usigma and vsigma in the model to check their significant relation (Guermat and Hadri, 1999). It is indicated that none of the variables have a significant relation with residuals (vsigma) and inefficiency (usigma) terms.

The other important test is checking the presence of inefficiency in the respondent's production function. The test was made by comparing the OLS and SPF to fit the data. This was conducted using the likelihood ratio formula displayed in equation 4 above. As it is indicated in Table 3 the critical value of 3.84 at χ^2 (x^2) at 1 degree of freedom at a 5% significance level is less than 37.36, which leads to rejecting the $H_{o,}$ no technical inefficiency. Hence, there is a statistically significant inefficiency in the observed data. This implies that the stochastic frontier production function is an appropriate functional form for the current data.

It is also required to test the relevant functional form best fit the data. The most common functional forms are Cobb-Douglas production and Translog production functions. The log-likelihood ratio (LR) test was made for these two functional forms. As indicated in the table below, the LR value of 27.54 is greater than the critical value of χ^2 (x^2) at 9 degrees of freedom at a 5% significance of 16.92 as it is suggested by Coelli *et al.* (1998). Hence, this implies that the null hypothesis that dictates all coefficients of the Cobb-Douglas functional form is equal to zero is rejected and the alternative hypothesis of coefficients of Cobb-Douglas functional form not different from zero is accepted. That is coefficients of Translog functional form different from zero are rejected. Thus, Cobb-Douglas's production functional form best fits the current data.

Moreover, the null hypothesis stating the independent variables related to the technical inefficiency effect are zero, tested against the alternative hypothesis of these variables related to the technical inefficiency effects are different from zero. The computed LR value of 37.36 is greater than that of the critical value of χ^2 (x^2) at 13 degrees of freedom at a 5% significance level of 28.87. Thus, this implies that the variables included are simultaneously affecting the efficiency disparity observed between the selected respondents.

Lastly, as it is indicated in Table 6 the value of sigma-squared which is statistically significant at a 1% significance level is estimated at 0.38. The gamma was estimated at 0.74 that implies 74% of the total variation in Moringa output is coming from technical inefficiency. The return to scale value 1.26 in Table 6 showed the production structure, with given inputs that are characterized by increasing returns to scale form.

Table 4. Tests of hypotheses

Hypothesis	Degree of freedom	LR	Critical value	Decision
H_O:γ=0	1	37.36	3.84	Reject H_O
H_O:= β_1= β_2= β_3=0	3	27.54	16.92	Reject H_O
H_O: δ_1= δ_2= δ_3 = δ_4… α_{13}=0	13	37.36	28.87	Reject H_O

Source: Survey result, 2018/19.

3.4 Technical Efficiency Scores and Moringa Yield gap due to Inefficiency

The estimation of output obtained from the SPF model displayed in Table 5 shows the average level of Technical Efficiency (TE) of 52.19%. TE is obtained by dividing actual output by potential output as described by Coelli *et al.* (1998). This implies the possibility that with existing levels of inputs and technology, in the short run the Moringa output level could be increased by 47.81% or to obtain a given level of output it is possible to decrease the level of inputs by 47.81%. However, this could be possible only if the existing level of inefficiency removed or if Moringa producing farmers operate at a fully efficient level. It should be also remarked that this analysis is made in the relative sense meaning Moringa producer farmers fall at the inefficient level relative to those efficient farmers in the area who set the frontier.

Furthermore, the frequency distribution of TE displayed in Figure 2 below shows that more than 89% of Moringa producing farmers fall below 80% level efficiency. It also shows a big disparity between the efficiency level of farmers with a minimum level of 14% and a maximum of 92%.

Table 5. Efficiency scores and Moringa yield gaps

Variable	Mean	Std.Dev.	Min	Max
Actual Production	103.11	41.30	20	196
Potential production	249.97	199.96	28.21	1068.20
Output Difference	146.85	178.20	6.65	918.20
Technical Efficiency	52.19%	0.20	0.14	0.92

Source: Survey result, 2018/19.

The table above also shows the output difference due to the presence of inefficiency. The mean actual, potential and output different levels of Moringa producing sampled households were 103.11, 249.97 and 146.85kg, respectively. The potential output is obtained by dividing the actual output by individual farmers' technical efficiency (Coelli *et al.*, 1998). This implies that if the farmers eliminate inefficiency or operate at full efficiency level through experiencing good internal management practice and learning from Moringa producing farmers from their locality they have a possibility to increase their current production by 146.85 kg with the existing level of input and technology. Even if the commodity is different this study is in line with Ateka, Onono, and Etyang (2018) on the technical efficiency study of tea production in Kenya.

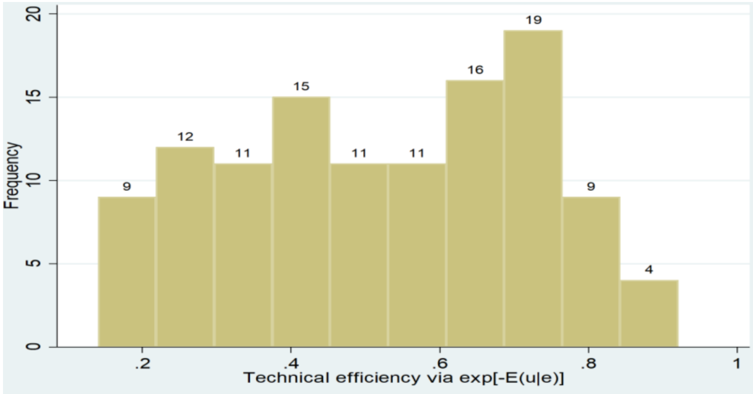

Figure 2. Technical efficiency distribution of Moringa

Source: Survey result, 2018/19.

3.5 Determinants of Technical Inefficiency

The results mentioned above showed the level of efficiency, the presence of the inefficiency and distribution of efficiency levels among Moring producing farmers. The estimations outputs were made using a stochastic frontier model considering the Cobb-Douglas production function. This part thus discussed the estimated results of the SFP model to find the determinants of the technical inefficiency of Moringa producers. As it is displayed in Table 6 below, the maximum likelihood estimates of stochastic frontier model, indicated that from among 13 demographic and socio-economic explanatory variables used in the analysis to find factors affecting inefficiency of Moringa production, land size, off-farm participation, distance to main road, access to credit service and access to irrigation were found to be statistically and significantly determine the level of technical inefficiency of Moringa producing smallholder farmers.

Table 6. Determinants of technical inefficiency

Variables	**Coefficients**	**Std. Dev.**
Age	-0.001	0.088
Gender	-0.991	0.687
Family size	0.068	0.060
Education	0.021	0.023
Livestock (TLU)	-0.033	0.062
Land size	0.196	0.118**
Cooperative membership	-0.160	0.183
Distance to the main road	2.703	1.617*
Distance to market	0.095	0.294
Irrigation access	0.721	0.288**
Participation in off-farm	1.058	0.356***
Credit access	-0.347	0.200*
Fertilizer application	-0.079	0.169
Constant	-0.767	0.856
Sigma-squared (δ^2)	0. 38***	
Gama (γ)	0.74	
Return to scale	1.26	
Mean Technical efficiency	52.19	
Logliklihood function	-88.368	

Note: *, ** and *** represent statistical significance at 10%, 5% and 1%, respectively.

Source: Survey result, 2018/19.

The land size of households had a statistically significant and positive relationship with the technical inefficiency of Moringa production at a 5% level of significance. The finding indicates that households with larger land sizes are less efficient than households with smaller land size in Moringa production. This might be due to farmers with larger land sizes are more concerned with the production of other mainly grown crops in the area such as maize, pigeon pea, banana and other productions than Moringa. This result is in line with Ateka *et al.* (2018).

The distance of households from the main road had a statistically significant and positive relationship with the technical inefficiency of Moringa production at a 10% level of significance. The finding indicates that households living far away from the main road are less efficient than their counterparts in Moringa production. This might be due to farmers' proximity to all-weather roads encourage market participation due to their effect of reducing transaction costs, thus improving productivity.

Household participation in off-farm activities had a statistically significant and positive effect on the technical inefficiency of Moringa production at a 1% level of significance. The finding indicates that households who participate in off-farm activities are less efficient than households not participated in off-farm activities in relation to the production of Moringa. This might be due to the farmer's provision of attention to off-farm activities than the production of Moringa.

Household access to credit had a statistically significant and negative relationship with the technical inefficiency of Moringa production at a 5% level of significance. The finding indicates that households received credits from financial institutions are more efficient than household households not received credit in Moringa production. Boucher and Guirkinger (2007) indicated that credit constraints have lowered the value of agricultural output in

Peru by 26%. In the current case, it might not be due to the farmer’s cash requirement from credit institutions to cover inputs costs for Moringa production that lead to an increase in the productivity of Moringa. However, the positive relation of credit with technical efficiency of Moring might be due to farmers' capability to meet the liquidity need to discharge their formal credit responsibility through Moringa selling. This finding is similar to the TE study of Coffee by Ngango and Kim (2019) in Rwanda.

The household's access to irrigation is statistically significant and positively related to the technical inefficiency of Moringa production at a 5% level of significance. This finding indicates that households who have access to irrigation are less efficient than a household without access to irrigation in the production of Moringa. It is known that irrigation is most commonly used for the production of cash crops. Thus, an implication of this result is households with better irrigation access might be less concerned with the production of Moringa rather they might prefer to produce other annual or biannual crops.

4. Conclusions and Policy Implications

The study used the SFP function model to estimate the level of efficiency and factors affecting Moringa production inefficiency in the area where there was no other study prior to the knowledge of the authors. The results of the model indicated that the positive relation between inputs and Moringa output implying an increase in input leads to more increase in the level of output. The required tests to check model fitting for data, the presence of inefficiency and others were made.

The estimated Cobb-Douglas functional form indicated in mean 52% level of technical efficiency among Moringa producing smallholder farmers. The estimated gamma value indicated that 74% of the total variation in Moringa output is resulting from technical inefficiency. It is also considered that if the farmers operate through minimizing inefficiency problems of Moringa production they have a possibility to increase their current production with the existing level of input and technology.

The results of maximum likelihood estimation of SPF indicated that land size, off-farm participation, distance to the main road, access to credit service and access to irrigation were found to be statistically and significantly determine the level of technical efficiency of Moringa production. Access to credit service is the only variable that has a positive and significant effect on the efficiency of Moringa production. Hence, in sum, the following three recommendations were set from the research. First, any direction to increase Moringa production should consider the land size and access to irrigation of the households in the area. Second, road infrastructure development in the area should be considered to increase agricultural productivity. Thirdly, alternative sources of modern credit institutions, as well as facilities, are required to improve the livelihood of Moringa producers in Wolaita and Gamo zones, southern Ethiopia.

Lastly, for more reliability of research results, future research works on Moringa production efficiency in the area should effectively consider the average Moringa production output of at least 10-year data through capturing the variables such as access to credit, off-farm participation and cooperative membership as level of access to credit facilities, off-farm income, and co-operative society credit support, respectively.

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Notes

Note 1. The smallest administrative unit in Ethiopia.

Note 2. Tropical Livestock Unit.

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