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Analysis of Economic efficiency of coffee production technologies in the case of smallholder farmers in the selected districts of Hadiya Zone, Southern Ethiopia

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Abstract

Coffee is the primary source of income for more than 10 million households in coffee-growing African countries. Coffee also serves as an important source of export revenues and some of these countries rural population depend on this kind income. So, this study was carried to estimate and analyse factors affecting the level of economic efficiency of coffee production and its implication for increased productivity of coffee producers in the selected districts of Hadiya Zone. To achieve the objective, the target sample households were selected in multi-stage sampling techniques. Then, the primary data collected randomly from a sample of 200 households during 2013/14 production season. Cobb-Douglas production function was fitted using stochastic production frontier approach to estimate the efficiencies levels, whereas Tobit model is used to identify determinants that affect efficiency levels of the sample smallholder farmers. The estimated results showed that the mean technical, allocative and economic efficiencies were 81.78%, 37.45% and 30.62% respectively. It indicated that there was significant inefficiency in coffee production in the study areas. Among 14 explanatory variables hypothesised to affect the level of efficiencies, education level and extension contact of the sample household was the most important factor that found to be statistically significant to affect the level of technical, allocative and economic efficiency all together. In addition, farm size determined farmers' technical, allocative and economic efficiencies negatively and significantly. Hence, in order to increase the economic efficiency level in coffee production, all concerned bodies and stakeholders should give due attention in determining coping up mechanism to significant determinants.

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Introduction

Coffee is the primary source of income for more than 10 million households in coffee-growing African countries. Coffee also serves as an important source of export revenues and some of these countries rural population depend on this kind income (ICC, 2015). Ethiopia's production trend is generally upward despite some downward interruptions, reaching 6.6 million bags in 2021/22. It is the world's fifth largest coffee producer next to Brazil, Vietnam, Indonesia, and Colombia and Africa's top producer, with estimated 500,000 metric tons during the coffee or marketing season for (ICC, 2014). Moreover, the coffee subsector of Ethiopia has been and continues to be the base for the country's agricultural and economic development. Similarly, coffee in Ethiopia accounts for more than 25% of GNP, 40% of the total export earning, 60% of agricultural export, 10% of the total government revenue and about 25% of the total population of the country are dependent on production, processing, distribution, and export of coffee (MOARD, 2012). About 25% (15 million) of the Ethiopian population depend, directly or indirectly, on coffee production, processing and marketing (Mekuria, *et al*., 2004).

According to Woods (2003), Coffee is the major agricultural export crop, providing currently 35% of Ethiopia's foreign exchange earnings, down from 65% a decade ago because of the slump in coffee prices since the mid-1990's in a country where about 44% of the population is under poverty. Ethiopia's most important export crop contributing 60% of the country's foreign currency income was coffee. Coffee cultivation plays a vital role both in the cultural and socio-economic life of the nation. It is the most important export commodity for Ethiopia agriculture and plays an important role in the country's economy. This is especially true for the Oromia, South Nations and Nationalities of people (SNNP) and Gambella Regional States.

The decline in market share and price has significant impacts on productivity since the high price motivates farmers to produce more and more production efficiently and vice versa. Efficiency is an important factor to increase productivity farmers in coffee production. Post-harvest problems from the farm to the retail level results in high losses, high costs of foodstuffs and disincentive and discouragement to producers, marketers and consumers. While it is obvious that the coffee production technologies in Gombora and Gibe are not efficient and knowledge about the exact level of inefficiency, land, labour productivity is quite blurred. In order to adopt measures in solving the problem of inefficiency in the coffee production technologies, there is the need to obtain more specific evidence as to the magnitude of inefficiency. So, this study will contribute to fill this gap through measure the level of technical efficiency and identify the main determinants which lead technical efficiency difference between small holder farmers in coffee production.

Our study seeks to add to the existing knowledge on the economic efficiency of coffee farmers' technologies in Hadiya Zone with particular emphasis on Gombora and Gibe district. To do so, we use a combination of stochastic production functions and field surveys to measure the relationship between economic efficiency and coffee production technologies. These will create the possibility of building a broad knowledge on the technical and allocative efficiency of the smallholder coffee farmers and socioeconomic aspects of the study area. In general, the study focus in estimating and analysing factors affecting the level of economic efficiency of coffee production and its implication for increased productivity of coffee producers in the selected districts of Hadiya Zone and specifically to estimate the farm level economic efficiency and inefficiency of the coffee producers technologies at farm household level in the study site; to measure the level of technical, allocative and economic efficiencies in coffee production technologies in some selected districts of Hadiya Zone, and to analyse factors affecting economic efficiencies of smallholder farmers in coffee production technologies in the study areas. It can further provide a basis for the sustainable production of coffee elsewhere in Hadiya Zone.

Research methodology

Description of the study area

The study was conducted both in Gombora and Gibe districts. Gombora district (GD), which is one of the districts in Hadiya zone, Southern Nations, Nationalities and peoples' Regional State (SNNPRs). Gombora woreda is located about 259 km south of Addis Ababa and about 28 km from Hosanna, the capital town of Hadiya zone. It is geographically located between 7°33′ and 7° 37′ northern latitude and 37° 35′ and 37° 40′ eastern longitudes. The total land area coverage of the Woreda is 52,325 ha which comprises a total of 24 *Kebeles*. It is bounded by four different Woredas such as Lemo in the east, Yem Special Woreda in the west; Misha and Gibe in the North, and Soro in the south as indicated in the figure below (GWFEDO, 2012). The demographic characteristics of the study area can be described as follows: Gombora district has 24 Kebeles (KAs) with a total population of 102,332; with 50,225 males and 52,107 females. The population density of Gombora district is about 270 persons per square kilometer. The economic activity of the people in the district depends mainly on mixed agriculture (crop-livestock production). The major kebeles known by coffee production are Wondo, Shodira, Setere and Wogeno.

The Gibe district is located at Hadiya zone of Southern Nation Nationalities and regional state /SNNRS/, southern part of the country. It situated at 260 Km south of Addis Ababa and 30 Km South West Hossana town. Geographically it lies at 70 37'53" -70 42'43"N Latitude and 37037'07"-37044'25" E Longitudes. Average rain fall from 600 to 1200 mm. The total area of Gibe woreda is 44783 ha. Gibe woreda has a Kola, Woynedega and Dega climatic characteristics with the mean annual rainfall range from 600 to 1200mm. The rainfall in the woreda is bimodal, which is locally called belg and meher. The mean annual temperature ranges from 17.6°C to 25°C. The area coverage of the land use system indicates that 69.8% is cultivated lands, 14.5% is forest lands, 8.4% is grazing lands and 7.3% is others. The main annual crops grown in the area under the rain fed system are wheat (Triticum aestivum), barley, maze (Zea mays L.), Teff (Eragrostis teff) and sorghum. The major kebeles known by coffee production are Awwosa, Worcho, Megacho, Danga, Halelicho, Omochora, Tatama, Muma, etc.

The Hadiya zone have highly conducive agro-ecology and potential land to produce coffee, for local's people coffee is not only income source crop but also "consumption crop", the Zone include five districts out of this two districts became specializing coffee. The coffee productivity potential of the Zone covers around 37,164 ha of land out of which 21698.35ha land became productive annually. The Zone was endowed with enormous genetic diversity and different coffee types with unique taste and flavor. Nowadays average productivity of coffee in the area was 4.73Qu/ha which is below the national average, but the productivity was vary from field to field some farmers obtain around 16Qu/ha on the basis of full coffee productivity package they use, while the other getting below 5Qu/ha. Therefore, reviewing Coffee production potential and constraints were used to develop appropriate technology for productivity improvement and inform policy makers to identify gap. Hence, this studies being intended to review Coffee farming, Production potential and constraints in Hadiya Zone, Southern Ethiopia.

Coffee production is the major income generating cash crop to feed households in both the study area. Wet and dry Coffee processing industry planted became source of income, entrepreneur, rural road access, availability of network in rural area, etc. Good indigenous knowledge of coffee production, introduction of improved variety of coffee by some households, hopeful practices of coffee productivity technologies recently in the study area were an opportunity for coffee production. Farmers in the area were interested in using improved coffee production technologies and incorporating their indigenous knowledge of coffee tree interaction with improved practice because they were supposed that with existed potential indigenous knowledge on coffee production, it would improve their production and productivity.

Data collection methods

Sampling strategy and sample size determination

In this study, both primary and secondary data were collected from various sources. Primary data were collected from sampled households based on 2021/22 coffee production season. Primary data were collected through personal interviews by using data collection instruments or questionnaires with structured interviews, schedules and key informant discussion. The questionnaire were include issues on the demographic and institutional factors, input types, resources endowment and input amount used and output obtained by sample households during coffee production season. The researcher tries to collect information based on recording of the day to day activities, information exchange, sales, prices, assets, liabilities, credits taken, repayments and profits or losses would be collected from coffee producer farmers and relevant offices, marketing issues ,acquisition of inputs, income derived from the irrigation scheme, financial and economic analysis, employment, labour and wealth creation of both Gombora and Gibe Districts.

A multi-stage sampling technique was used to select sample producers. In the first stage, two main coffee producer districts namely, Gombora and Gibe, were selected using purposive sampling technique due to its high potential coffee production technologies. In the second stage, 10 main coffee producer kebeles were also selected using purposive sampling technique due to the best producers' experience in production and marketing of coffee production output. In the third stage, 200 sampled coffee producers were selected using a systematic simple random sampling technique proportionate to size sampling methodology.

A total of 200 farmer households (Gibe-120 and Gombora-80) were randomly selected for 2013/14 producing season based on proportion of number of target population of each kebeles. According to Yamane, T. (1967) sample size determination formula cited in Kothari (2004), the following sample size calculation formula is given by following calculation as follows.

$$n = \frac{N}{1+N(e)2} = \frac{6900}{1+6900\,(0.07)2} = 200 \text{ (sample size)} \ldots\ldots\ldots (1)$$

Where n= estimated sample size, e = the level of precision= 7%; N= number of population in the study area. Using the formula and the information from Gombora and Gibe District, the sample size for this study is calculated as follows. N=6900 Number of farm households of selected kebeles (Table-1).

Methods of data analysis and model specification

Various data analysis methods such as descriptive statistics and econometric model would be used to analyse the data. Descriptive statistics such as means, frequencies, and percentages were used to examine the socio-economic, institutional and demographic characteristics of sampled producers. STATA 16 software and Microsoft excel 2016 was used to analyze both inferential and descriptive statistical data. T-test were also used in the analysis of economic efficiency. Technical, allocative and economic efficiency estimates derived from Stochastic Production Frontier (SPF) were regressed using a censored Tobit model on the following farm-specific explanatory variables that might explain variations in coffee production efficiencies across farms. The technical, allocative and economic efficiency measures derived from the model were regressed on socio-economic and institutional variables that explain the variations in efficiency across farm households using Tobit regression model.

Empirical model specification

In coffee production technologies, multiple outputs and inputs were common features and for the purpose of efficiency analysis output were aggregated into one category and inputs were aggregated into seven categories namely: farm size, compost, labour, capital, land, rental value of land, and other variable inputs. An approach to the measurement of efficiency employed in this study was the stochastic frontier approach that combines the concept of technical and allocative efficiency in the quantity relationship (Parikh, A., *et al.* 1995). The derived measure of inefficiency is then related to socio-economic, asymptotically efficient, consistent and asymptotically demographic and farms size variable. Farrell (1957) illustrated the idea of input oriented efficiency using a simple example of a given firm that uses two factors of production, capital (K) and labour (L), to produce a single output (Y). And face a production function, y = F (K, L), under the assumption of constant returns to scale, where the assumption of constant return to scale would help us to present all necessary information on a simple isoquant. The input approach addresses the question "by how much a production unit can proportionally reduce the quantities of input used to produce a given amount of output?" (Coelli *et al*, 1998).

Since measurement of production efficiencies relies on the estimation of production frontiers, as derived from a given production function, there is a need to first specify the proposed functional form of the coffee production function to be estimated. The most commonly used production function in econometric estimations (due to its simplicity) is the Cobb-Douglas function. In addition, the stochastic production function was used to evaluate the level of farmer technical efficiency. Here, we assume the production technology of the coffee farmers to be specified by the Cobb-Douglas frontier production function according to (Amos, T. (2007).

The common stochastic frontier function was used by the studies given as:

$$Y = f(Xa, \beta) + Vi - Ui \quad \text{...} (2)$$

Where Y is output, Xa is input vector and β the vector of production function parameters. The specified coffee production function is written in the form;

$$lnY = \beta 0 + \beta 1 lnX1ij + \beta 2 lnX2ij + \beta 3 lnX3ij + \beta 4 lnX4ij + \beta 5 lnX5ij + \varepsilon \ldots\ldots\ldots\ldots\ldots (3)$$

Where; subscripts ij refers to the i^{th} observation on the j^{th} farmer.

ln=logarithm to base e; Y= the farm output; X1=total farm size; X2=household size; X3=hired labour used in production; X4=coffee production in per hectare; X5=quantity of fertilizer; εi =composite error terms In technical analysis, influence of some socioeconomic factors on technical efficiency was obtained by introducing socioeconomic variables into the frontier model according to (Kalirajan, K. (1999).

The technical efficiency model is written as:

$$Ui = \alpha 0 + \alpha 1 lnZ1i + \alpha 2 lnZ2i + \alpha 3 lnZ3i + \alpha 4 lnZ4i + \alpha 5 lnZ5i + \alpha 6 lnZ6i + \alpha 7 lnZ7i + \alpha 8 lnZ8i + \alpha 9 lnZ9i + \alpha 10 lnZ10i + \alpha 11 lnZ11i + \alpha 12 lnZ12i + \alpha 13 lnZ13i + \alpha 14 lnZ14i + \varepsilon i. \quad (4)$$

Where, Ui = Technical efficiency; Z1 = Gender; Z2 = Family size (numbers), Z3 = Age of farmer (in years); Z4 = Education (years of schooling); Z5=Farm size, Z6 = Access to credit; Z7 =Off-farm income; Z8 = Technology adoption; Z9=Market distance (in km); Z10 = Extension services, Z11 = Livestock ownership (TLU in number); Z12 = Compost application (in kg); Z13= Age of coffee tree; Z14= On-farm income and $\alpha 0$ = y – intercept and $\alpha 1$ to $\alpha 12$ are coefficients that were estimated.

It is assumed that the economic efficiency effects were independently distributed and varies and uij arises by truncation (at zero) of the normal distribution with mean μ and variance σ^2; where uij is defined by equation.

$$\text{Inefficiency Model: } Uij = \alpha o + \alpha 1 lnZ\ ij + \alpha 2 lnZ\ ij + \alpha 3 lnZ\ ij \quad \text{...} (5)$$

Where: uij = represents the economic inefficiency of the i^{th} farmer; Z1 = age of the household head; Z2 = year of schooling or education; Z3 = represents years of farming or experience.

The α and β coefficient are unknown parameters to be estimated together with the variance parameters. The parameters of the stochastic production function are estimated by the method of maximum likelihood.

Description of variables for efficiency measurement

Production function variables

The variables that were used in the stochastic frontier model are defined as follows.

i. Outputs: physical yield of coffee are used to compute the output of the farm.
ii. Inputs: these are defined as the major inputs used in the production of coffee. They are: Land: This represents the physical unit of cultivated land in hectares;
Human labour: This is man days worked by family, exchange and hired labour for land preparation, planting, weeding, or cultivation, irrigation, harvesting of coffee
Oxen: This is oxen days worked by the household using oxen labour for land preparation, planting and threshing;
Nursery: This includes the amount of improved and local seed used in production of a farm household
Compost: This includes the amount of chemical/organic fertilizers, improved and local seeds used by the farm household.

Variables included in the determinants of production efficiency model
The dependent variable is the technical efficiency scores, which are computed from parametric methods of efficiency measurement (Table 2).

iii. Efficiency factors
Dependent variable: Inefficiency of coffee farmers
Independent variables: This denotes various factors hypothesized to explain differences in technical efficiency among farmers. These are:
Agehh: the age of the household head in years.
AgeCt: the age of coffee trees in years.
Gender: the sex of the household head whether a household is male = 1 or female = 0
Farm size: the total area of cultivated and grazing land in hectare.
Education level: a continuous variable defined as years of formal schooling;
Labour available: the total active labour available in the family in man days.
Livestock ownership: the total livestock available in TLU.
Off-farm income: includes income from off-farm and non-farm activities. It is a dummy variable that the variable is 1 if the household earned off-farm income and 0 otherwise.

Credit service: includes access to credits for the farm inputs and other farm production activities from formal and semi-formal sources. It is a dummy variable defined as 1 if the farmers have received credit and 0 otherwise.

Extension service: it is defined as whether the farmer had access to the extension service during the survey year or not. It is a dummy variable defined as 1 if the household had access to extension service and 0 otherwise.

Technology acceptance: this is whether or not the household adopted at least one improved soil and water technology. It is a dummy variable defined as 1 if the farmer had adopted at least one improved technology and 0 otherwise.

Distance to markets: the distance of the household head to market in minutes (Table 2).

Results and discussion

Socio economic characteristics of sampled households
This section discusses the socio-economic characteristics of farmers which are known to influence resource productivity and returns on the farms. The demographic and socio economic variables considered include age, gender of farmers, household size, farm size, years of farming, level of education and marital status. The summary of the demographic and socio-economic characteristics of farmers is presented in Table 3. About 82% of the farmers are married while 84% are male. About 68% of the sampled farmers were between the age groups 20-50 years. This suggests that majority of the farmers were middle aged and this implies that the farmers were still in their economic active age which could result in a positive effect on production (Anyaegbunam, H.M., 2013).

This result inlines with the findings of (Idumah, F.O., P.T Owombo and U.B. Ighodaro, 2014). Alabi *et al.*,

(2005) who observed that farmer's age has great influence on maize production in Kaduna state with younger farmers producing more than the older ones possibly because of their flexibility to new ideas and risk. Furthermore 78.5% of the sampled respondents had one form of formal education. (Onyeaweaku, C.E, B.C. Okoye and K.C. Okorie, 2010) observed that formal education has positive influence on the acquisition and utilization of information on improved technology by the farmers as well as their adoption of innovations. Some of the farmers (80.5%) have been farming for over 5 years. This means that they must have acquired good experience in coffee farming. (Rahman, S.A, A.O. Ogungbile and R. Tabo, 2002) Indicated that the length of time in farming activity can be linked to age. Age, access to capital and experiences in farming may explain the tendency to adopt innovation and new technology.

Table 1. Total number of sample household heads of the selected districts of Kebeles.

Kebeles	Total household heads	Sample
Wondo	560	22
Shodira	450	20
Setere	380	20
Wogeno	340	18
Awwose	670	22
Worcho	620	21
Megacho	580	20
Danga	585	18
Halelicho	545	18
Omochora	640	21
Total	6,900	200

Source: Authors own computation, 2022.

Table 3 shows the summary statistics of some of the socioeconomic variables and farm outputs. It reveals that the average age of the farmers was 49 years. An average farmer has a fairly large household of 6, cultivating about 1.92 hectares of land typifying a small scale holding with no one having more than one field thus suggesting that land fragmentation is not common in the forest reserve because farm lands are allocated to them by the government on year to year basis.

Table 2. Description of the hypothesized variables.

Variables Name	Description	Type	Expected effect
Gender	Gender of the household head 1 if female and 0 otherwise	Dummy	+
Agehh	Age of Household head	Continues	+/-
AgeCt	Age of Coffee tree	Continues	+/-
Education level	Years of formal education of the household head	Continues	+
Family size	Amount of household in adult equivalence	Continues	+
Livestock ownership	The amount in TLU of livestock owned by the household	Continues	+
Farm size	Amount of hectare of land available	Continues	+
On-farm Income	1 if the household earned on-farm income and 0 otherwise	Dummy	-
Off-farm income	1 if the household earned off-farm income and 0 otherwise	Dummy	-
Credit access	1 if a household has accessed credit service and 0 otherwise	Dummy	+
Distance to markets	1 if a household head has distance to markets and 0 otherwise	Dummy	-
Compost application	1 if a household used fertilizer in coffee production and 0 otherwise	Dummy	+
Extension service	1 if the household had access to extension service and 0 otherwise	Dummy	+
Technology acceptance	1 if the farmer had adopted at least one improved technology and 0 otherwise	Dummy	-

Source: Description of expected effect of the variables.

Estimating Maximum Likelihood Using Stochastic Production Frontier Function

Table 4 depicts the Maximum Likelihood values as obtained from stochastic frontier production functions. Our results show coffee production to be determined by agro-chemical quantities and labour and which are both is statistically significant at the level of significance of 10%. Additional analysis showed that though fertilizer use is statistically significant, it had a positive influence on coffee output. This study also found a negative relationship between the level of output and the seeds (number of coffee trees per hectare).

Table 3. Socio economic characteristics of sampled farmers (N=200).

Variables	Respondents	Percentage	Cumulative Percentage
Age in years			
21-30	21	10.5	10.5
31-40	32	16	26.5
41-50	47	23.5	50
51-60	36	18	68
61-70	27	13.5	81.5
71-80	24	12	93.5
Above 81	13	6.5	100
Total	200	100	
Educational qualification			
Informal	42	21	21
Primary	63	31.5	52.5
Secondary	52	26	78.5
Vocational	23	11.5	90
Tertiary	20	10	100
Total	200	100	
Marital status			
Single	43	21.5	21.5
Married	121	60.5	82
Divorced	27	13.5	95.5
Widow/widower	9	4.5	100
Total	200	100	
Farming experience			
5-9 years	26	13	13
10-14 years	78	39	52
15-19 years	57	28.5	80.5
20 and above	39	19.5	100
Total	200	100	
Household size			
1-5	81	51.6	51.6
6-10	65	41.4	93
11 and above	11	7	100
Total	157	100	
Gender			
Male	168	84	84
Female	32	16	100
Total	200	100	
Farm size(Ha)			
0.5-1.4	16	8	8
1.5-2.4	39	19.5	27.5
2.5-3.4	61	30.5	58
3.5-4.0	52	26	84
Above 4.0	32	16	100
Total	200	100	

Source: Calculated from Field Survey 2022.

This study observed a positive relationship between the level of coffee output, quantities of agro-chemical and labour used. This may be related to the fact that production levels largely depend on the quantities of these various farm inputs. However, this can only be up to a level that is considered optimal after which farmers will be operating at sub optimal levels. Additionally, there was a positive relationship between output and compost application because increase in compost application, is known to increase coffee output. Relatedly, the negative relationship between the level of output and nurseries of coffee trees may be as a result of delays in weeding, pruning and lack of adequate shade control. It is also often likened to poor coffee breeds as well as lack of regular and systematic suppression of side shoots.

Table 4. Descriptive statistics of socioeconomic and efficiency variables.

Variables	Mean	Standard deviation	Minimum	Maximum
Output (kg)	1689.21	1854.37	48	12000
Compost (kg)	4.38	18.57	0.25	200
Agro-chemicals (litres)	3.85	3.77	0.76	43.26
Labour (man days)	4.96	4.57	0.22	37
Coffee trees (number of trees)	1065.98	38.16	958	1119
Farm size (hectares)	3.64	2.52	1	17
Gender (dummy)	0.91	0.32	0	1
Household size (dummy)	6.45	3.78	2	20
Age of farmer (years)	40.28	11.90	20	69
Education (dummy)	7.59	3.96	0	16
Credit (dummy)	0.37	0.49	0	1
Years of farming (units)	13.49	9.68	1	48
Age of coffee trees (years)	22.97	10.96	7	57
Farmer's association (dummy)	0.06	0.26	0	1
Access to extension services (dummy)	0.14	0.36	0	1
Number of extension visits (units)	0.28	0.85	0	7
Production contracts (dummy)	0.68	0.70	0	1

Source: Calculated from field data 2022.

Gender had a positive coefficient indicating that male farmers obtained higher levels of technical efficiency than their female counterparts in the area. Similar results were obtained by (Agom, D., Susan, O., Itam, K and Inyang, N. (2012) showed that coffee farming is quite dominated by males in the study area. This is due to coffee farming being a tedious job that requires more physical strength which females are often not able to provide. The positive coefficient of age of farmers proved that old farmers are technically more inefficient than younger ones. According to (Amos, T., 2007 and Cobbina, J. 2014). older farmers are less likely to have contact with extension workers and are equally less inclined to adopt new techniques and modern inputs. Here, younger farmers have greater opportunities for formal education and may be more skilful in the search for information and the application of new techniques.

Table 5. Maximum likelihood estimates of the stochastic production function for the coffee production.

Variable	Parameters	Coefficients	t-value
Constant	β0	12.580*	1.970
Ln (Compost)	β1	0.009	0.273
Ln (Agro-chemical)	β2	0.371***	12.786
Ln (Labour)	β3	0.170***	3.289
Ln (Nursery)	β4	-0.917	0.898
Variance parameters			
Sigma U	-2.376***	-5.769	
Sigma V	-1.604***	-22.131	
Log likelihood function	-407.92		

Note *** significant at 1%, ** significant at 5% and * significant at 10% respectively
Source: Output of Frontier 4.1 by Coelli (1994).

Farm size was negative but significant illustrating those farmers with larger farms was more technically efficient than farmers with smaller farms (Nchare, A. 2007) and Onumah, J., Ramatu, M and Onumah, E., 2013). In addition, credit value was positive and significant which means that credit accessibility is vital in improving the performance of coffee producers. This is because credit is thought to assist farmers in enhancing efficiency by overcoming financial constraints. These constraints often influence farmer ability to purchase and apply inputs as well as timely implement farm management decisions thus increasing efficiency. Therefore, farmers who have access to credit are technically more efficient than those with little or no access to credit (Binam, N., Gockowski, J and Nkamleu, G. 2008). Still from a financial perspective, farmers belonging to farmer associations were more technically efficient than farmers who were not. This can be attributed to the fact that farmers who were members of an association had access to relevant information on farm management and introduction of new technologies which could boost productivity (Cobbina, J. (2014).

Table 6. Values of technical efficiency as derived from the inefficiency model.

Variable	Coefficient	t-values
Gender	0.178	0.393
Household size	-0.000	-0.011
Age of farmer	0.017	1.274
Education level	-0.004	-0.189
Farm size	0.768***	-3.937
Access to credit	0.652***	2.905
Years of farming	0.045	-1.249
Age of coffee farms	0.019	-0.997
Farmer's supportive society	-0.879	-1.578
Access to extension services	3.987***	8.720
Number of extension service visits	-3.784	0.000
Production agreements	-0.699**	-2.870
Constant	-21.879	-0.897

Source: own survey result (2022). Note:

***significant at 1%, **significant at 5% and *significant at 10% respectively.

Access to information as a factor which increases technical efficiency is portrayed in extension service visits or contacts. Here increasing number of contacts with extension officer's increases technical efficiency due to availability of market, technical and farm management information (Cobbina, J. 2014)., Binam, N., Gockowski, J and Nkamleu, G. (2008). Similarly, coffee farmers who sign production contracts are more technically inefficient than those without contracts. In the study area, coffee farmers often sign input (provisions), (output) produce, supply and credit contracts with individual output buyers. The contract terms are always not mutually beneficial, and where agrochemicals are supplied to the coffee farmer at higher prices which often doubles local market prices. These farmer also bound by these contracts to sell their output only to these individual buyers, thus affecting the farmers' credit availability. This credit provisions contracts between the farmers and the individual output buyers always have high interest rates. Most often, the farmers receive these inputs and credit too late which affects their farming calendar and hence productivity and efficiency (Table 5).

The above table 6 illustrates values of technical efficiency as derived from the inefficiency model. Our results show the coefficient of gender to have a positive sign. Meanwhile, household size coefficient is negative and not significant whereas the age of farmer coefficient is positive. Our results also show the education coefficient (years of school) to be negative whereas access to credit coefficient is positive and 10% significant. Similarly, years of farming (farmer's experience) and age of coffee trees have negative coefficients. Studying smallholder farmers in the slash and burn agriculture zone of Cameroon Binam, N., Tonyè, J., Wandji, N., Nyambi G and Akoa, M. (2004) obtained similar results. Farmer's supportive society (association, groups) and extension service visits (contacts) have negative influences on technical inefficiency. The estimated coefficients of the inefficiency function explain the technical inefficiency levels among individual coffee farmers. None of the estimated variables was significant and all showed negative sign implying that all the factors (age, years of schooling and years of farming) are not strong enough to reduce inefficiency of the farmers.

Table 7. Distribution of technical efficiency of coffee farmers across the study area.

Efficiency class	No. of farmers	Percentage
≤0.50	6	3
0.51-0.65	11	5.5
0.66-0.75	32	16
0.76-0.85	46	23
0.86-1.00	105	52.5
Total	200	100.00
Mean	91.2	
Standard deviation	31.4	
Minimum	83.4	
Maximum	99	

Source: own survey result (2022).

The following table 5 shows the efficiency levels of the sampled farmers and which indicates a technical efficiency range from 0.13 to 0.98. Additional analysis illustrates that the mean technical efficiency of the coffee farmers in the study area is 79%. Therefore, on the average, coffee farmers in the study area are 21% below the best practice frontier output given the existing technology and available input in the locality. The efficiency distribution also shows 93.4% of farmers to have efficiency scores between 0.61 and 1.00 while 6.6%, were less than 60% efficient in their production process (Table 7). Distribution of Economic Efficiency: The results presented in Table 5 below indicate an economic efficiency range from 83.4 to 99. The mean estimate is 91.2. The efficiency distribution shows that 52.5 attained between 0.86 and 1.00 efficiency levels while none had below 50 percent level of efficiency. The high level of efficiency is an indication that only a small fraction of the output can be attributed to wastage (Udoh, E.J and J.O. Akintola, 2001). The fact that all the sampled agroforestry farmers are below one implies that none of the farmers reached the frontier of production. With a mean efficiency index of 91.2, there is scope for increasing output and efficiency. The results further showed that there are allowances for farmers to improve their economic efficiency by 7.4 percent in the area.

Efficiency scores: The mean TE was found to be 82.42%. It indicated that in the short run farmers on average could decrease inputs (land, seed, labour and inorganic fertilizers) by 17.58% if they were technically efficient. In other words, it indicated that if resources were efficiently utilized, the average farmer could increase current output by 17.58% using existing resources and level of technology. Similarly, the mean allocative efficiency of farmers in the study area was 37.24%. It indicated that coffee producing farmers could save 62.76% of their current cost of inputs by behaving in a cost minimizing way. Conversely, the mean economic efficiency of 32.64% prevails that an economically efficient farmer can produce 67.36% additional coffee (Table 8).

Table 8. Summary of descriptive statistics of efficiency measures.

Types of efficiency	Minimum	Maximum	Mean	Std. Deviation
TE	0.52	0.93	0.8242	0.0928
AE	0.31	0.71	0.3724	0.0726
EE	0.32	0.68	0.3264	0.0627

Source: own survey result (2022).

Table 9 showed that the TE, AE and EE level of sample households. Majority of the sample households had a higher technical efficiency levels. Among the total sample households, 26% of them were operating above 90% of and 35% of them were operating in the range of 80-89% of technical efficiency levels. The result indicated that potential of improving coffee productivity for individual farmers through improvement in the level of TE is the smallest as compared to that of the AE and EE.

Determinants of efficiency in coffee production: The result of the model showed that among 14 variables used in the analysis, determinants hypothesized to affect efficiencies of coffee production; educational level of household head, land size, livestock unit, frequency of extension visit and soil fertility were significant factors influencing efficiencies of farmers (Table 10).

Education level was positive and had a significant effect on all types of efficiencies. Positive and significant impact of education on all types of efficiencies verifies the importance of education in increasing the economic efficiency of coffee production. Because of their better skills, access to information and good farm planning, educated farmers are better to manage their farm resources and agricultural activities than uneducated one. The result was matched with the finding made by Abdul W. (2003), Ayodele A. and Owombo P. (2012) and Himayatullah K. and Imranullah S. (2011).

Table 9. Frequency distribution of coffee production.

Efficiency level	TE		AE		EE	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
0-9	0	0.00	0	0.00	0	0.00
10-19	0	0.00	4	2	22	11
20-29	0	0.00	30	15	32	16
30-39	0	0.00	80	40	74	37
40-49	0	0.00	69	34.5	72	36
50-59	4	2	17	8.5	0	0.00
60-69	30	15	0	0.00	0	0.00
70-79	44	22	0	0.00	0	0.00
80-89	70	35	0	0.00	0	0.00
90-100	52	26	0	0.00	0	0.00

Source: own computation (2022).

Farm size had negative and statistically significant impact on TE and AE. The result was in line with expectation made. Fragmented land leads to inefficiency by creating shortage of family labour, wastage of time and other resources that should have been available at the same time. Moreover, as the number of plots operated by the farmer increases, it may be difficult to manage these plots. In the study area, land is fragmented and scattered over different places.

Thus, farmers that have large number of plots may waste time in moving between plots. The result was in line with the finding made by Fikadu Gelaw (2004).

Frequency of extension visit had statistically significant impact on allocative and economic efficiency. It shows that the efficiencies in resource allocation are declining as the frequency of extension of the contact raises. Besides, during the survey, most farmers explained that they do not have new skills and information they learn from development agents. There are development agents who agree with the farmers concern. If this is the case, the contact with extension agent will only result in under-utilization of resources, giving a negative relationship with allocative efficiency. The result is also revealed to those obtained by Mbanasor J. and Kalu K.C. (2008).

The coefficient for soil fertility was positive and had a significant effect on technical efficiency. The farmers who allocate fertile land were having good economic efficiency. Therefore, decline in soil fertility could be taken as impact for significant coffee output loss. The result is harmonized with the opinions of Fikadu Gelaw (2004) and Alemayehu Ethiopia (2010).

Table 10. Determinants of efficiency in coffee production among sample households.

Variables	TE		AE		EE	
	Marginal Effect	Stad.Err.	Marginal Effect	Stad.Err.	Marginal Effect	Stad.Err.
Education level	0.00321*	0.00324	0.0051**	0.01631	0.00521*	0.00152
Family size	-0.0026	0.0023	0.0010	0.0000	0.0010	0.0030
Agehh	0.000012	0.00040	0.00232	0.00152	0.00031	0.0000
AgeCt	0.000011	0.00030	0.00121	0.00141	0.00021	0.0000
Cultivated land	0.0130	0.0040	0.1320	0.0060	0.0020	0.0010
Crop rotation	0.0221	0.02103	0.051	0.023	0.0640	0.0012
Land size	-0.0310*	0.006	-0.003 *	0.002	-0.001	0.0000
Livestock unit (TLU)	0.0020	0.0020	0.0010**	0.002	0.006	0.0008
Extension visit	0.0073	0.0410	-0.030*	0.0160	-0.0021*	0.0430
Farmer’s training	0.0112	0.0226	0.053	0.032	0.0131	0.0050
Credit Service	0.0262	0.0043	0.0210	0.013	0.003	0.006
Market distance	0.0011	0.0021	0.0043	0.00131	0.001	0.0032
Off-farm activity	0.073	0.0121	0.003	0.023	0.053	0.000
Soil fertility	0.033***	0.0146	0.011	0.000	0.005	0.0032
Constant	0.6210**	0.076	0.423***	0.052	0.236***	0.047

Source: own survey result (2022). Note: *, ** and *** show significance at 1%, 5% and 10% respectively.

The coefficient for total livestock holding (TLU) was positive and had a significant impact on AE, which confirms the considerable contribution of livestock in coffee production. The result is consistent with Solomon B. (2012).

Conclusions

This study analyses the economic efficiency of coffee producers in Gombora and Gibe Districts of Southern Regional state of Ethiopia. The study employed the stochastic frontier approach and both primary and secondary data were used. Primary data were collected through household survey from a sample of 200 households using structured questionnaire. Secondary data were collected from relevant sources to support the primary data. Data analysis was carried out using descriptive statistics and econometric techniques**.** The Cobb-Douglas stochastic frontier production and its marginal production functions were estimated from which TE, AE and EE were extracted. The results from the production function showed that land, compost and nursery were positively and statistically significant. The study also indicated that 79%, 12% and 8% were the mean levels of TE, AE and EE, respectively indicating that there was 21%, 88%, and 92% allowance for improving TE, AE, and EE, respectively. The relationships between TE, AE and EE, and various variables that expected to affect farm efficiency were examined. Among 14 explanatory variables hypothesised to affect efficiencies; education level, land size and soil fertility were found to be statistically significant to affect the level of technical efficiency. The model also showed that education level, land size, livestock ownership and frequency of extension visit were important factors that affect allocative efficiency of farmers in the study area. However, the sign of the coefficients for extension contact in allocative and economic efficiencies was not as expected. The results also further revealed that educational level of the household head and extension contact were important determinants in determining economic efficiency in coffee production.

Policy implications

The study reveals that coffee producers in the study area are not operating at full technical, allocative and economic efficiency levels and the result indicated that there is ample opportunity for coffee producers to increase output at existing levels of inputs and minimize cost without compromising yield with present technologies available at the hands of producers. The study found that different types of efficiencies and their determinants were found to be different and allocatiive and economic efficiency were found to be low. Therefore, intervention aiming to improve efficiency of farmers in the study area has to be given due attention for resource allocation in line with output maximization as there is big opportunities to increase output without additional investment. Education was very important determining factor that has positive and significant impact to technical practices, agricultural information and institutional accessibilities which improve farm households' economic efficiencies. Thus government has to give due attention for training farmers through strengthening and establishing both formal and informal type of framers' education, farmers' training centers, technical and vocational schools as farmer education would reduce both technical and economic inefficiencies. Access to credit has a positive influence on both technical and economic efficiencies. Therefore, better credit facilities have to be produced via the establishment of adequate rural finance institutions and strengthening of the available micro-finance institutions and agricultural cooperatives to assist farmers in terms of financial support through credit so as to improve coffee productivity. Distance to market has a significant influence on the technical and economic efficiency of smallholders. Therefore, farmers have to get inputs easily and communication channels have to be improved to get better level of efficiency. Extension contact has positive and significant contribution to technical efficiency. Since extension services are the main instrument used in the promotion of demand for modern technologies, appropriate and adequate extension services should be provided and strengthened. Moreover, improvements in the coffee productivity in the use of modern technologies are expensive, require relatively longer time to achieve and farmers have serious financial problems to afford them. In addition to this, the result of increment of productivity and production of coffee sector by using improved technologies will be high if it is coupled with the improvement of the existing level of inefficiency of farmers.

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