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Full Length Research Paper

Technical efficiency of smallholder coffee farmers in Gedeo Zone, Southern Ethiopia: A Stochastic Frontier Approach

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Abstract

Coffee is the major source of income for smallholder farmers and is a leading export crop for Ethiopia. Even though the great proportion of coffee production comes from smallholder farmers with farm size below two hectares, its productivity in these farms remained very low. With the aim of identifying the causes of low productivity this study identified technical efficiency level of smallholder coffee farmers and the factors that influence technical efficiency in coffee production. With the aim of identifying the causes of low productivity, this study involved the use of a stochastic frontier analysis to predict the farm level technical efficiency in coffee production in Gedeo zone, Southern Ethiopia, using 120 smallholder farmers. Moreover, the socio-economic factors which affect the technical efficiency level of smallholder coffee farmers were identified using Tobit regression model. The result of the study revealed that the average level of technical efficiency was 62.01%, which indicates that an average farmer was producing about 38% below a frontier production level. Factors such as credit access, extension visit, farmer's education level and soil fertility affected technical inefficiency significantly and negatively. Therefore, the study suggests that availing credit access to purchase farm inputs, and provision of technical support that would improve the production efficiency of smallholder farmers.

Keywords: coffee farms, stochastic frontier analysis, technical efficiency

Introduction

Ethiopia is the birthplace of Arabica coffee. More genetically diverse strains of Arabica coffee exist in Ethiopia than anywhere else in the world, which has led botanists to agree that Ethiopia is the center of origin, diversification, and dissemination of the coffee plant (Taye, 2013). Coffee plays a pivotal role in the socio-economy of the country. Itemploys more than 20% of the economically active population and contributes more than 25% of the country's foreign exchange earnings.

Ethiopia is the leading Arabica coffee producer in Africa, the fifth largest worldwide and the tenth in coffee exports worldwide. The average annual production amounts to about 229,351.3 tons. The average yield is about 0.71ton/ha. Ethiopian coffee is intrinsically organic and renowned for its superior quality. Smallholder farmer's account for more than 95% of the total coffee produced in Ethiopia, but still traditional farming systems. In Ethiopia, Coffee is produced under four broad production systems, i.e forest coffee (8-10%), semi forest coffee (30-35), cottage or garden coffee (50-57%) and modern coffee plantation (5%). Ethiopia has a huge potential to increase coffee production as it is endowed with suitable elevation, temperature, soil fertility, indigenous quality planting materials, and sufficient rainfall in coffee growing belts of the country (Taye, 2013)

Despite Ethiopia's immense potential for increasing coffee production, average per hectare yield remains very low at 0.71 tons per hectare. Many factors are responsible for less yield of coffee production among many high expansions of Khat (Catapults) at the expense of coffee farm, next to this, the Ethiopian coffee farm management system and the agronomic practices are traditional.

Moreover, extension services provided to smallholder farmers are inadequate. The government of Ethiopia doesn't have a specialized institution that provides extension support for coffee production (Abu, 2013).

Increasing productivity and efficiency in coffee production depends on several factors like farm characteristics, socioeconomic characteristics of the farmer, types of farming system and government policies. However, for one to design better measures aimed at increasing productivity, it is important to understand the magnitude of inefficiencies and the factors that influence them. In the past, most of the efficiency studies on crop production worldwide have concluded that lack of technical knowledge, poor accesses to credit and low levels of education are the primary sources of technical inefficiencies. This implies that increasing the efficiency of input use by improving farmer knowledge and skills allows for the exploitation of the potential productivity growth in the medium and long term.

Moreover, there is currently no empirical evidence on the level of efficiency of smallholder coffee farmers. Accordingly, policy formulations have been hampered by a lack of empirical studies at the farm level. It is important to establish whether the causes of low productivity are due to smallholder farmer inefficiency and if so, what extent. Providing an indication of the current farm-level efficiency and factors that hold back smallholder farmers from increasing their production is crucial. This means an understanding on the relationship between efficiency and farm specific factors should be acquired. This information can ultimately be used to guide policymakers to make sound policy decisions towards the empowerment of smallholder farmers. In short, this study aimed to bridge the gap between efficiency and the practical aspects of smallholder coffee production in Gedeo Zone, Southern Ethiopia with the following specific objectives:

- To determine the technical efficiency level of smallholder coffee farmers;
- To identify factors that influence technical inefficiency in coffee production.

Materials and Methods

The study area

The Gedeo lives between 5 and 7 degrees North latitude and 38 and 40 degrees East longitude in the escarpments of the Southeastern Ethiopian highlands overlooking the Rift Valley, in the narrow strip of land running from North (Sidama zone) to South (Oromiya region). In altitude, the area ranges from 1200 m.a..sl in the vicinity of Lake Abaya to 2993 m.a...sl at Haro Wolabu Pond, Bule woreda (Ethiopian mapping authority,1988) .

Geographically, the Gedeo Zone lies in the inter-tropical convergence zone (Lundgren, 1971). As a result, the Gedeo highlands benefit from both equatorial and the monsoons, the two most important trade winds in the region. Thus, the climate of Gedeo Zone is characterized as warm humid temperate(Lundgren, 1971) .Mean annual temperature ranges between 17 º C and 22.4º C and means annual rainfall between 1200 and 1800 mm. Gedeo Zone is thus endowed with two rainy seasons, which mainly known for the production of perennial crops like coffee, inset (false banana) and different fruits. , The people are predominantly peasant farmers.

Sampling technique and data collection

The total population of rural household of Yirga chefe woreda is 237,431 and 148,927 rural household in Kochore wored. The total population from two woredas was 386,358 rural households according to office of finance and economic development (OoFED) of Gedeo zone 2015/16. The sample size was specified based on Simplified Yamane (1967) formula. The data used for this study were collected from 120 smallholder coffee farmers. A three-stage random sampling method was used in the selection of the sample respondents. At the first stage of sampling, two woredas namely Kochere and Yirgachefe were selected purposively depending on area coverage by a coffee plantation. In the second stage, out of chosen woredas, three kebeles were selected randomly after listing all available kebeles and 20 households from each chosen kebeles were arbitrarily selected, after a simple household listing. Thus, a total of 120 sample smallholder coffee farmers were included in the sample. From selected household's information on input utilization and production levels of coffee were collected.

Theoretical framework of measuring efficiency

Efficiency is a very important factor of productivity growth, especially in developing agricultural economies where resources are meager and opportunities for developing and adopting better technologies are dwindling (Ali and Chaudhry, 1990). Such economies can benefit greatly by determining the extent to which it is possible to raise productivity or increase efficiency, at the existing resource base or technology. For efficient production, non-physical inputs, such as experience, information, and supervision, might influence the ability of a producer to use the available technology efficiently. Each type of inefficiency is costly for a firm or production unit (e.g., a farm household) in the sense that any inefficiency causes a reduction in profit below the maximum value attainable under full efficiency.

The two most popular methods of measuring efficiency, assuming the presence of inefficiency on the production system, are data envelopment analysis (DEA) and the stochastic frontier method DEA is a non-parametric method, while the stochastic frontier method is parametric. (Coelli et al., 1998) compared the two methods and concluded that the main strengths of the stochastic frontier approach are its ability to deal with stochastic noise and the incorporation of statistical hypothesis tests pertaining to production structure and the degree of inefficiency.

Most studies that have measured technical efficiency in agriculture were used the stochastic frontier method because of the above-stated advantages. They study by (Betty, 2005); (Samuel et al., 2014); (Thong et al., 2014); (Fadil and Mitsuyasu, 2012); (Elias and Zubaidur, 2012); (Audu et al., 2013) and (Ajibefun et al., 2002) have used the stochastic parametric model to measure the technical efficiencies in recent agricultural production efficiency studies. (Elias and Zubaidur, 2012) in their study of the technical efficiency of rice farmers in Bangladesh, Naogaon District, and the result indicated that technical inefficiency is influenced negatively by the age, education, experience, agriculture policy, rice monoculture and use of high yielding variety variety of seeds whereas the same were influenced positively by the farm size.

Thong *et al.,* (2014) investigated the factors affecting technical efficiency of smallholder coffee farming in the Krong Ana Watershed, Vietnam, and concluded that formal education of the household head, the amount of financial credit obtained, ethnicity, coffee farming experience of the household head, and agricultural extension service used were key factors that can increase technical efficiency in coffee production.

Samuel *et al.,* (2014) in their study on analysis of economic efficiency and farm size: a case study of wheat farmers in Nakuru District, Kenya, and their finding indicates that the number of years of school a farmer has had informal education, distance to extension advice, and the size of the farm have strong influence on the efficiency levels.

The stochastic frontier method was used for this study. In addition to this, to identify the sources of inefficiency the relationship between the farm/farmers characteristics and the computed technical efficiency indices Tobit model were used.

The basis of a frontier function can be illustrated with a farm using n inputs (*X1, X2,…..,Xn*) to produce output *Y*. Efficient transformation of inputs into output is characterized by the production function f(*Xi*), which shows the maximum output obtainable through various input vectors used. The stochastic frontier production function assumes the presence of technical inefficiency of production. Hence, the function is defined us:

$$Y = f\left(x_{i;}a_i\right) exp\ (v_i - u_i)\ where\ i = 1,2 \ldots \ldots . . N \qquad (1)$$

whereby $Y_i$is the output of farmer *i*, *Xi* are the input variables, *a*i are production coefficients and *vi* is a symmetric error term associated with random factors, not under the control of the farmers and assumed to be independently and identically distributed (i.i.d.) with a random error that is independent of *ui*. On its part, *ui* is the non-negative efficiency measured relative to the stochastic frontier, which is also assumed to be i.i.d. as half normal (at zero mean) or truncated half-normal (at mean μ), or according to (Greene, 1990) with two parameter gamma distributions.

Technical efficiency (TE) of an individual farm is defined as the ratio of the observed output to the corresponding frontier output, given the available technology:

$$TE = \frac{Y}{Y^*} = \frac{f\,(X_i,a)\,\exp\,(v_i - u_i)}{f\,(x_i,a)\,\exp\,(v_i)} = \exp\,(-u_i) \qquad (2)$$

Whereby $Y_i^*$the maximum possible output and Y is the actual observed output

Technical efficiency takes values within the interval (0, 1), where 1 indicates a fully efficient farm.

Model specification

According to (Kopp and Smith, 1980), functional forms have a limited effect on empirical efficiency measurement. Cobb-Douglas forms have been used in many empirical studies, particularly in those relating to developing agriculture (Battese and Coelli, 1992).

The Cobb-Douglas functional form also meets the requirement of being self-dual, allowing an examination of economic efficiency. In this study, the following Cobb-Douglas functional form was used for smallholder coffee producing farmers:

$$Y = \beta_0 . X_1^{\beta_1} . X_2^{\beta_2} . X_3^{\beta_3} . X_4^{\beta_4} . X_5^{\beta_5} . X_6^{\beta_6} e^{v_i - u_i} \qquad (3)$$

Which when linearized becomes:

$$lnY_i = \beta_o + \beta_1 lnx_1 + \beta_2 lnx_2 + \beta_3 lnx_3 + \beta_4 lnx_4 + \beta_5 lnx_5 + \beta_6 lnx_6 + (v_i - u_i) \qquad (4)$$

Y_i = Coffee output (Kg)

β_o=intercept

x_1=organic fertilizer used (Kg)

x_2=Farm size (ha)

x_3=Family labor (man days)

x_4= Hired labor (man days)

x_5=Capital (birr)

u_i = farm specific technical efficiency related factor which is assumed to be independently and identically distributed as truncations (at zero) of the normal distribution with mean, μ, and variance, $\delta_u^2(N(u, \delta_u^2)$

The technical inefficiency estimates obtained are regressed on some socioeconomic factors using the Tobit model. This use of a second stage regression model of determining the socioeconomic attributes in explaining inefficiency has been suggested in a number of studies like (Sharma et al., 1999) and (Dhungana et al., 2004).

The tobitmodel consider the theoretical tobit model, which takes the following form:

$\varphi_k^* = X_k\beta + \text{U}_k$---(5)

Where φ_k^* is represents the inefficiency effect of kth farm obtained (1-TE); X_k is the vector of independent variables which have been postulated to affect efficiency. The vector β comprises the unknown parameters associated with the independent variables for the k^{th} farm and Uk is an independently distributed error term assumed to be normally distributed with zero mean and constant. The variables with a negative (positive) coefficient will have a positive (negative) effect on efficiency levels.

Results and Discussion

This section highlights a key result of the study and gives some evidence through discussion of the results. The results on factors influencing technical efficiency of coffee production also presented.

Description of Production function variables

The summary statistic of the variables used for the stochastic production function analyses is presented in Table 1. The mean coffee output per farmer per annum was 1386 kg while the analysis of the inputs revealed a mean land size of 1.89 ha per farmer an indication that the study covered small-scale, which is mostly managed by family members. The average hired labor and family labor used of were 69.35 and 225.52 man days per annum, which indicated that farmer manages most of the coffee farming activities by human labor.

Table 1: Summary Statistics of Variables for Stochastic Production

Variables	Mean	Minimum	Maximum
Coffee output (Kg)	1386 (12.77)	1	94
Land size (ha)	1.89(1.70)	0.1	9.5
Hired labor (man days)	69.35(70.421)	61	91
Family labor (man days)	225.52(0.55)	223	231
Organic fertilizer (Kg)	3290(7.55)	1	811
Capital(Birr)	657.70(508.49)	50	3425

Value in parenthesis indicates the standard deviation, Source: own survey

Estimation of production function

The ordinary least square and maximum likelihood estimates of the parameters of the stochastic production frontier were obtained by using the program frontier 4.1 and presented in Table 2. The result from both models has presented for comparison. Estimated MLE results obtained from the study revealed that out of five variables included into the model and three variables, coefficients were statistically significant at either 1% or 5% level of significance. The signs of the coefficient in both estimate cases are the same and positive. The variance parameter gamma (γ) it is significantly different from zero and its value is 0.7619 indicating that about 76.19% of the variation in coffee output is attributable to technical efficiency differences among production units.

Table 2: The ordinary least square (OLS) and maximum likelihood (ML) estimates of the stochastic frontier production function (SFPF)

Variable	OLS estimates		ML estimates	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-60.00(45.61)	-1.32	-70.10 (41.03)	-1.70
Ln (Land size)	0.590(0.075)	7.82	0.600 (0.070)	8.46***
Ln (Organic fertilizer)	0.078(0.038)	2.03	0.033(0.040)	0.81
Ln (Family labor)	0.001(8.37)	1.30	0.130(7.555)	1.72
Ln (hired labor)	0.543(0.669)	0.81	0.143(0.666)	2.16**
Ln (capital)	0.194(0.083)	2.33	0.261(0.077)	3.36**
Sigma-squared	0.3670		0.6676(0.142)	4.67***
Gamma			0.762(0.109)	6.98***
Log likelihood			-104.42	

*** and ** means significant at 1% and 5% respectively, Value in parenthesis indicates the standard error Source: own survey.

Frequency distribution of technical efficiency estimates

In Table 3, the distribution of technical efficiency indicates the existence of a difference in the efficiency level of smallholder coffee farmers in Gedeo Zone. Here the variations in technical efficiency of producers were probably due to differences in managerial decisions and farm characteristics that may affect the ability of the producer to adequately use the existing technology.

Table 3: Frequency distribution of coffee technical efficiency estimates

Technical efficiency (%)	Frequency	Percent	Cumulative percent
<30	6	5.0	5.0
31-40	4	3.3	8.3
41-50	14	11.7	20.0
51-60	22	18.3	38.3
61-70	39	32.5	70.8
71-80	27	22.5	93.3
81-90	8	6.7	100.0
91-100	0	0	100.0
Total	120	100.0	
Mean	62.01 (15.33)		
Minimum	16.69		
Maximum	89.04		

The value in parenthesis indicates the standard deviation, Source: own survey.

A study revealed that technical efficiency ranges between 16.01% - 89.04%. The lowest level of efficiency is 16.69%, which is far below the efficient frontier by 84.31%. Such production units are technically inefficient. The majority around (32.5%) of smallholder coffee producer were achieved technical efficiency in between 61-70%. The mean technical efficiency score (62.01%) of the sample production units implies that on the average, 37.99% more coffee output would have been produced with the same level of inputs if the producer would have been in their most efficient frontier following best practices. From this, it can be concluded that on an average farmer in the sample could save an average of 30.35 percent [i.e. 1-(62.01/89.04) x100] of cost saving if a farmer was to achieve the technical efficiency level of his most efficient counterparts. A similar calculation for the most technical inefficient farmer reveals cost saving of 81.25 percent [i.e. 1-(16.69/89.04) x100]

Factors determining technical efficiency of coffee production

The determinants of efficiency were modeled using socio-economic factors that affect farm operations and also have policy implications. For this purpose, the parameter's technical inefficiency (1-TE) indices were estimated by using censored Tobit procedure, and the results are presented in Table 4.

Education level of the farmers had a negative coefficient for technical inefficiency. The negative coefficients obtained for the level of education implied that education contributes to a decrease in inefficiency of coffee production. Educated farmers were more sensitive to technical change, and they have higher adoption rate than those educated less. From this, it can be concluded that more educated farmers were achieved a higher level of technical efficiency than farmers with less education. The result from this study is consistency with evidence from (Battesse and Coelli, 1992) indicated that education enhances the ability to utilize available technology and increase's efficiency of farmers thereby.

Access to credit was represented as dummy variable in the model; i.e., 1 having had access to credit and 0 otherwise. Its coefficient was negative and it affected efficiency significantly. The negative coefficient of access to credit means that the use of credit tends to result in decreases of technical inefficiency. If the credit obtained by farmers were invested in the farm, it is expected that it would lead to higher levels of technical efficiency since the farmers would be able to purchase high-yielding production inputs. Similar studies that focused on technical efficiency and access to credit reported the similar result (Himayatullah and Imranullah, 2011).

The coefficient of a number of times of coffee extension visit per week during active production season had negative for technical inefficiency and significant at 5% level. This implies that, as the coffee farmers visited per week more frequently the technical efficiency of the farmer’s increases by decreasing inefficiency. This is because coffee extension workers help the farmers to adopt some scientific techniques and practices without any mistake in a continuous manner. Similar findings were also reported by (Kaliranjan and Shand, 1985) and (Bravo-Ureta et al., 1997) which found a positive relationship between farm level efficiency and availability of extension services.

Table 4: Impact of farm/farmer characteristics on technical efficiency of coffee production in Gedeo zone, Ethiopia

Variable	B	t-ratio	Sig.
Constant	0.562(.0688)	8.20	0.000***
Age of farmers	0.002(.0018)	1.32	0.188
Education level	-0.006(.0038)	-1.66	0.099*
Experience in coffee farming	-0.002(.0018)	-1.19	0.238
Livestock holding	-0.0002(.0040)	-0.06	0.952
Coffee variety planted	0.0229(.0280)	0.18	0.422
Coffee extension visit	-.0212(.00920	-2.29	0.024**
Access to credit	-0.067(.0268)	-2.52	0.013**
Distance from plot to household residence	-0.0001(0.000)	-1.22	0.224
Fertility of soil			
Medium	-0.1072(0.0339)	-3.18	0.002***
Good	-0.14654(0.03401)	-4.31	0.000***
Slope of coffee plot			
Medium	-0.04847(0.0382)	-1.27	0.207
Flat	-0.04335(0.0384)	-1.13	0.262

***, **,* means significant at 1%, 5%, and 10% respectively, Value in the parenthesis indicate the standard error of the coefficient, Source: own survey.

The other important variable affecting technical inefficiency of coffee producers was soil fertility. The measures of soil fertility were constructed by forming indices based on farmer's perception on the productivity of soil (the qualities of soil were organized into three groups as good fertility soil (2), medium-fertility soil (1) and poor fertility soil (0). Accordingly, the fertility of soil significantly and negatively influences technical inefficiency of farmers. Farmers' producing on good and medium fertile soil was more efficient than Farmers' operating on poor soil fertility.

Conclusion and Recommendations

This study used a stochastic frontier analysis to estimate and analyze the technical efficiencies of smallholder coffee farmers in Gedeo Zone, Southern Ethiopia. The result of the study indicated that an average level of technical efficiency equal to 62.01 percent. From this, it can be concluded that depending on the relative size of the technical efficiency of the farm obtained from analysis, smallholder coffee farmers in Gedeo zone operating below a production frontier level. The mean technical efficiency of the pooled sample was 62.01% confirm the 'poor but efficient hypothesis' propounded by (Schultz, 1964).

The main socio-economic factors which were assumed to have an influence on the technical efficiency of farmers and hence the variables included within the model were the age of the farmer, access to credit, extension visit, educational level of a farmer, soil fertility, the slope of coffee plot and years of experience on the coffee production. Among the variables included in the model access to credit, coffee extension visit, education level of farmers and fertility of soil having a negative impact on technical inefficiency, and it contributes to increase in technical efficiency. Therefore, effort needs to be made by the government by increasing and improving access to credit and coffee extension visit to smallholder coffee farmers. A high level of financial support will help to acquire necessary input for coffee production and expanding extension services for easy adoption of technology and implementation. This kind of policy may be vital in achieving increased efficiency and productivity of farmers.

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