Technical Efficiency of Maize Production in Southwestern Ethiopia: a case of Jimma zone

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Abstract
Ethiopia's agriculture is one of the most ancient in the world characterized by very traditional production technologies and is dominated by smallholders. The agricultural sector although employs around 85 percent of the labour force contributes only 50 percent of the GDP. Its productivity is one of the lowest and even showing a decreasing trend bringing a decline in per capita cereal consumption. In this paper an attempt is made to investigate if there are potentials of maize productivity gains in Jimma zone, Ethiopia by improving the technical efficiency of the farm households. To this end, a Cobb-Douglas type stochastic frontier production function was specified. It was found out that the technical inefficiency is a significant component of the composed error term of the stochastic specification, at a significance level of 2.5 percent. And about 50 percent of the variation in maize production in Jimma zone is explained by the difference in technical efficiency among maize producing farmers. Ownership of livestock, participation in extension program and access to infrastructure were found to differentiate farmers in attaining different levels of technical efficiency in maize production. Therefore, improving the extension and infrastructure access of farmers in Jimma zone can help in increasing the technical efficiency of maize production.

1. **Introduction**

Ethiopia is one of the poorest countries in the world unable to meet its domestic food demand. During the Second World War, its agriculture has been sustaining the population and was producing excess for export. By that time Ethiopia was reported to be potentially the ‘ bread basket of the Middle East’ (Singh, 1987).

However, within the last five decades changes in economic policy accompanied by changes in political leadership, drought and continuous war and other factors put the country on the list of food aid dependent countries. The agricultural sector, which is the major supplier of food to the domestic consumption is dominated by smallholders, who cultivate 95 percent of the total area under crop and for more than 90 percent of the total agricultural output (MEDaC, 1999).

These smallholders cultivate their land with very traditional methods, the use of modern inputs being minimum, for instance Ethiopia’s fertilizer utilization in terms of nutrient content averaged 7 kg, which is below the sub-Saharan average of 9 kg. Per hectare of arable land (MEDaC, 1999). As a result, cereal yields are one of the lowest in the world, the average yield of tef, barley, wheat, maize and sorghum being 0.8, 1.1, 1.2, 1.6, and 1.2 t/ha, respectively(Mulat, 1996). The performance of the sector is not only low, but also declining for instance per capita cereal production declined by an average of 4 kilograms per year between the early 1960s and the late 1980s and cereal consumption per capita has also been declining at an average of 3.3 kilogram per year (Braun, et. al. 1999).

In addition, the very fact that 85 % of the employed labour force in the country produces only 50 % of the GDP shows the poor performance of the Ethiopia agricultural sector. Or, as (Griffin, 1987) put it, agriculture is by far the weakest sector of the economy requiring reversal of its decline.

However, in spite of its poor performance the Ethiopian agriculture shoulders the major responsibility in the supply of cereals (Braun, et. al, 1999), which makes analysing cereal production systems in Ethiopia of paramount importance. In addition, in Ethiopian context, where agriculture derives the highest share of gross domestic product any concern for poverty alleviation would place substantial weight on the generation of rural income, which is mainly generated from its agricultural operations. A strategy emphasizing growth in Ethiopia's rural economy would not only alleviate poverty in the rural sector but also contribute substantially to income in non-agriculture, as well as make the greatest progress towards overall poverty alleviation in the country (Block, 1999).

Therefore, the answer to poverty alleviation in the rural part of Ethiopia rests on improving the performance of the agricultural sector, or in short, on increasing the productivity of the agricultural sector. This productivity increase can be attained through one or all of its determinants, which are the state of technology, the quantities and types of resources used as inputs into the production process, and the efficiency with which those resources are used (Antle, et. al, 1993). Therefore, any attempt to increase the productivity of the agricultural sector will follow one or all of these routes of increasing productivity.

2. Statement of the Problem

The decline in productivity of the agricultural sector in developing countries is found to be widespread contrary to agricultural productivity the developed world, where there is productivity progress. Some cross country studies showed decline in agricultural productivity, even in those countries, where green revolution varieties of wheat and rice have been widely adopted (Fulginiti, et. al, 1998).

This decline in productivity has been given due attention in the international development efforts. However, especially because of the influential " poor but efficient" hypothesis of Schultz (1964) resources have been concerned mainly with increasing the productivity of agriculture by the introduction of new technologies (Heady, et. al. 1987).

From the technological status of the Ethiopian agriculture, where agricultural production techniques for the vast majority of peasant farmers have changed little since pre modern times, the introduction of modern farming techniques appears to be a priority. However, the adoption of modern inputs is found to be very slow, for example the adoption rates of fertilizer, an input which is relatively adopted than other external inputs, are estimated to be 20 percent (Block, 1999). Different socio-economic factors lie behind the low rate of technology adoption, including price and marketing of inputs. For example, the price of fertilizer has increased from 38 Birr per quintal of DAP and 30 Birr per quintal of Urea in 1971 to 262 Birr per quintal of DAP and 237 Birr per quintal of Urea in 1997(MEDaC, 1999). This will for sure make fertilizer expensive and less adoptable.

Therefore, investigating the potential of increasing agricultural production through improvement in the level of technical efficiency appears to be another alternative demanding due attention. Cross country studies (Heady, et. al, 1987) and location specific studies like Audibert (1997) in Mali, Tian, et. al (2000) in China and others show that there are rooms for increasing agricultural productivity in developing countries by improving technical efficiency of agricultural production.

Studies from some parts of Ethiopia have also confirmed that, in the short run, there are significant gains to be made by increasing the efficiency of resource use within given technology environment (Seyoum, et. al, 1998; Getu et. al, 1998; Assefa, 1995).

Though, these studies are already done on Ethiopian context, they were localized and there is no guarantee of generalization for the nation as a whole. In addition, there is no direct correlation in the production condition across regions in Ethiopia (Braun, et. al., 1999), which implies that specific production information need to be generated at specific locations. Therefore, in this study an attempt was made to see if maize production in the Southwestern part of Ethiopia, Jimma zone, can be increased through improvement in the technical efficiency of maize production.

Maize is one of the staple foods in Ethiopia, whose importance in consumption as well as production has significantly increased. At national level, maize output increased by nearly 2 % per annum during 1980/81- 1996/97 for the 1995/96 and 1996/97 crop seasons output has reached a record level of 2.5 million tons (Befekadu et. al., 1999). But this growth rate was mainly explained by expansion of area which increased by 1.4 % per annum (Befekadu et. al., 1999).

In the study area too maize is the leading cereal in area cultivation and output. As the population size increases the option of expanding agricultural production in general and maize production in particular through expansion in cultivated land will not be possible. Therefore, this study attempts to the following two objectives, to see if there is a room to increase maize production by improving the technical efficiency of small farmers in Jimma zone and to identify and quantify factors, which explain the difference in technical efficiency among maize producing farmers.

3. The Study Area and Data

The Southwestern part of Ethiopia represents the former Keffa, Illubabor and Wellega administrative zones. This area is known for accommodating the country's remaining forest resource and 52 percent of the total coffee area of the country, which is estimated to be about 290,000 ha to 321000 ha (MCTD, 1985; Admassu, 1989 as quoted by Tafesse, 1996). The total area cover is approximately 40415 km^2 , comprising different micro climates suitable for specific crops, namely, barley at high elevation, coffee in the more humid areas, and Maize and Sorghum in low lying areas. Coffee and forest cover accounts for about 10% of the total area, while cultivated and grazing land constitutes 70% of the area(Tafesse, 1996).

Seka Chekorsa wereda is one of the 13 weredas found in Jimma zone of the Oromia region in the Southwestern Ethiopia. The capita of the wereda, seka is found 351 km west of the capital, Addis Ababa. Geographically It extends from $7^0 20'$ to $7^0 45'$ N latitude and $36^0 16'$ to $36^0 53'$ E longitude (OBAD, 1997).

This wereda has been selected for the study because of its significant contribution in maize production and accessibility. It has a surface area of 1607.66 km^2. Out of the total area 30063 ha (19%) falls in altitude above 2400 masl, which is locally known as '' Dega'', 103237 ha (64%) in 1500 - 2400 masl, which is also known as '' Weyna-Dega'' and 28086 ha (17%) below 1500 masl.

The sample households for the study were selected form three Peasant Associations (PA), *Shane Koche, Gibe Boso and Bore* from the Weyna-Dega agro-ecology, where maize is a predominant crop. A total of 53 maize producing farm households were randomly selected and input- output data on maize and other socio-economic data has been collected.

4. The Econometric Model

Following the Aigner et al. (1977) and Meeusen and Van den Broeck (1977) method of estimating a stochastic frontier production function, With a Cobb-Douglas type production function specification can be represented as:

$\text{Ln } Y_i = \ln\beta_o + \sum \beta_j X_{ij} + \varepsilon_i$ ---(1)

Where Y_i = maize output in qt; X_{1i} = land input in hectare; X_{2i}= labor input in man-days; X_{3i}= Oxen input in oxen-days; X_{4i}= fertilizer input in Kg; and X_{5i}= seed input in Kg; ln is natural logarithm; β_j's are parameters to be estimated (they are elasticity coefficients in the case of a Cobb- Douglas specification of the production function); and the disturbance term $\varepsilon_i = V_i - U_i$ is composed of two components, a symmetric error term accounting for deviation because of factors which are out of the farm (v_i) and error term accounting for the deviation because of inefficiency effects (u_i), and i= 1,2,…n farms.

V_i - is *independently and identically distributed(i.i.d)* $N(0, \sigma^2_v)$;

U_i - is a non-negative and is assumed to be i.i.d. $N(0, \sigma^2)$ truncated at zero or exponential distribution independent of V_i ;

For this study the parameters of equation (1) were estimated using the Maximum – Likelihood (ML) method, following the likelihood function estimation by Battese and Corra (1977).

Where: $\boldsymbol{\sigma^2_s = \sigma^2 + \sigma^2_v}$ **and** $\boldsymbol{\gamma = \sigma^2 / \sigma^2_s}$**,**

And σ^2 is the variance of U_i and σ^2_v is variance of V_i

And γ is defined as the total variation of output from frontier which can be attributed to technical (in)efficiency. And it is the γ, that is used in the estimation of the technical efficiency level and the frontier function by the FRONTIER 4.1 (Coelli, 1996) soft ware, which is used in this study.

The technical efficiency level, which is the main focus of this study is estimated as:

$$TE_i = \frac{Y_i}{f(x_i, \beta)exp\,(V_i)}$$

$$TE_i = \frac{f(x_i, \beta)exp\,(\varepsilon_i)}{f(x_i, \beta)exp\,(V_i)}$$

$$TE_i = exp\,(-U_i) \text{-------------------------------------} (\,)$$

However, it is the ε_i which is observed not its components. But following Jondrow et. al (1982), the farm-specific technical efficiency (TE) of the i^{th} farm was estimated by using the expectation of U_i conditional on the random variable ε_i.

After the technical efficiency level at which maize is produced was calculated, the TE level is explained based on some farm level factors following the model Battese and Coelli (1995). This model specifies technical inefficiency effects in the stochastic frontier model that are assumed to be independently (but not identically) distributed non-negative random variables (Coelli, et al., 1998).

$U_i = Z_i \delta + W_i$

Where Z_i is a (1x M) vector of explanatory variables, in this study: number of livestock owned, number of years in the extension program in the last five years, the status of visit by a development agent (DA) in the 1999/ 2000 crop season, which is a dummy 1 if the DA has visited the household and 0 otherwise, access to infrastructure, age of the head of the household and educational status of the head of the household;

δ is an (M x 1) vector of unknown parameters to be estimated; and

W_{it} are unobservable random variables, which are assumed to be independently distributed, obtained by truncation of the normal distribution with mean zero and unknown variance, σ^2, such that U_{it} is non-negative (i.e., $W_{it} \geq U_{it}$).

5. Results

Both the OLS and ML estimates of a Cobb-Douglass production function for maize in Jimma zone are presented in Appendix 1. Though the estimates of the production function are of minor interest to this paper, they are worth looking. In terms of sign, all of the parameters but land in the case of ML estimation have shown the expected positive sign, implying that maize production is positively influenced by the incorporated variables.

However, except for seed and fertilizer use, which are significant at 5 percent, the remaining variables were found to be statistically insignificant. This could be because land and labor are use relatively more than the other accompanying inputs, like fertilizer and seed. In addition, land quality in the area was found to be ranging between average and poor quality, therefore any additional use of land unless accompanied by fertility improvement mechanisms will decrease maize production.

The other reason for the insignificance of these inputs could be effect of aggregations in the inputs. That is, no account is made to the quality difference in land, which is different from plot to plot. This is not done, because if the analysis is done plot wise, it would have been impossible to incorporate the other socio-economic variables, which were collected at household level not at plot level. The possible aggregation of family and hired labor, could also contribute to the insignificance of the parameter responsible for labor. In addition, the problem of multicollinearity, which is a common feature of production functions, might have also contributed to the insignificance of the individual parameter estimates.

Fertilizer and seed use were not only significantly different from zero, but also had the largest elasticity values. That is, for a one percent increase in fertilizer use, other factors kept constant, maize output will increase by 0.32 percent. Likewise, for a one percent increase in seed use, other factors kept constant, maize output will increase by 0.33 percent. This implies that, extension activities focusing on the introduction and supply of fertilizer and seed need to be encouraged. Especially, supply of high yielding maize varieties, will have significant effect on maize production in the study area.

With respect to level of technical efficiency, it was found out that γ, which is the variation in maize production attributed to variation in technical efficiency, was a significant component of the composed error term. The likelihood ratio value of 18.69 was significant at 2.5 percent significance level. About 50 percent of the variation in maize production in Jimma zone is explained by the difference in technical efficiency among maize producing farmers. Thus, the production function can best be estimated by a frontier function than an average function. The intercept value of the ML estimate, which is greater than the OLS estimate shows that, the estimated frontier function lies above the average function.

The level of technical efficiency at which farm households operate is presented in Table 2. Most of the farms had a higher technical efficiency levels. Around 60 percent of maize producing farmers were operating at a TE level of more than 80 percent.

Table 2. Frequency distribution of technical efficiency of individual farms

Range of TE (%)		Frequency	Percent	Cumulative percent
20 – 30		1	1.9	1.9
31 – 40		4	7.6	9.5
41 – 50		0	0	9.5
51 – 60		6	11.3	20.8
61 – 70		5	9.4	30.2
71 – 80		6	11.3	41.5
81 – 90		21	39.6	81.1
91 – 100		10	18.9	100
Mean	76			
Maximum	94			
Minimum	23			
Median	83			
Total		53	100	

The mean TE was found out to be 76 percent. This implies that, at the mean level there is a potential of increasing maize production by 25 percent, with the given resource level, by improvement in the TE level of the farm households. For some 10 percent of the farm households maize production can be increased by up to 60 percent through improvement in TE, while for some 40 percent of the farm households between 10 to 20 percent. Though the inefficiency of the last group is small the large number of farm households in this group makes the impact of improvement in the TE level significant for the overall maize production in the region.

Generally speaking, the potential of improving maize productivity for individual farmers through improvement in the level of TE is small, however, at regional level there is an overall potential of increasing it. This is because, for some households it is possible to increase the present level of production up to 70 and 80 percent (fig. 1). As can be seen in the figure below, the difference in the level of technical efficiency among farm households is not significant, by large, that is most of the farmers lie in the same range. However, there are some 20 percent of farmers, who lie out of the range, where the majority of the farmers belong.

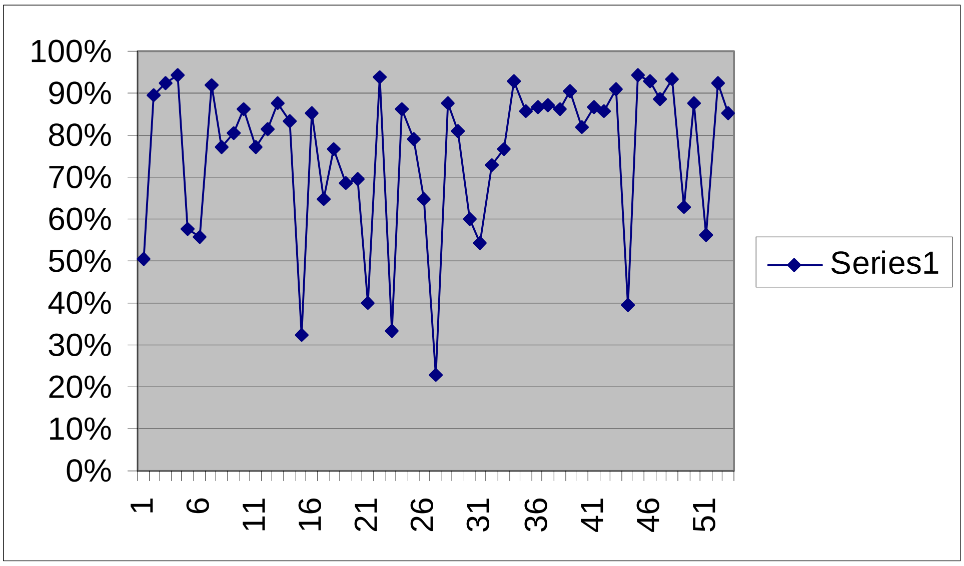

Fig 1. Frequency distribution of technical efficiency of individual maize producers

Therefore, the existing variation in the level of TE, demands analyzing, what factors differentiate the farmers in attaining different levels of TE. As is seen in Appendix 1, some socio-economic factors were included in the model and the likelihood ratio test, for the overall significance of these variables, showed that the LR value of 16 is significant at 2.5 percent significance level. This implies, that the difference in the level of technical efficiency among the farm households can be expressed in terms of the variables included in the model.

Livestock ownership, the number of years farmers participated in the agricultural extension program and access to infrastructures had positive effect on the level of TE. That means, other factors kept constant increase in the number of livestock owned or increase in the number of years farmers attended extension program will increase the technical efficiency of farmers. The number of years in the agricultural extension might have affected the level of TE through the information and knowledge they get through working in close contact with agricultural experts. In addition, the nearer a farm household is to road or other infrastructures will make it attractive for agricultural experts, who visit villages. As a result farmers who live in the near by are found to be technically efficient.

However, education had unexpected sign. This might be, because the knowledge required by farmers for agricultural operation may not be properly measured by the number of years in school or the reading and writing ability. The fact that the number of years in the extension program improves the TE level could support this idea, because the new information and knowledge, which farmers have used for improving their TE level, might not be accounted by the variable education in this study.

Though, the variables in the model were in overall significant, the individual parameters were not significantly different from zero. This might be because, most of the variables are related in one way or another like the nearer a farmer lives the more likely that he participates in the extension program. Therefore, this bring the problem of multicollinearity, where even in the presence of less than perfect multicollinearity, the regression coefficients, although determinate, possess large standard errors (in relation to the coefficients themselves), which decrease the precision at which the coefficients are estimated (Gujarati, 1995).

6. Conclusion

The increase in the gap between population size and agricultural production requires due attention in addressing rural poverty in Ethiopia. Low use of improved inputs coupled with loss of soil fertility are leading to decrease in agricultural production. From this study, it was concluded that boosting maize production in the Jimma zone rests mainly on the introduction of improved technologies, there is a need for technological change.

However, still in the short run there is a potential of productivity gain through increasing the technical efficiency level of maize production in Jimma zone.

Therefore, improving the managerial skill of the farm households can lead to increase in maize production at household and regional level.

To this end, agricultural extension programs aimed at improving resource allocation in maize production methods need to be expanded. The presence of households in the study area, which are attaining higher levels of TE, should be utilized as a source of knowledge that could be transferred more easily to the less efficient ones.

In addition expanding rural infrastructure need to be given due attention in order to increase the technical efficiency of farmers in Jimma zone. Rural credit efforts, which give oxen credit will also have a positive effect in the improvement of the technical efficiency of maize production.

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8. Appendix

Appendix 1. A Cobb-Douglas production function estimation of maize production in Jimma Zone, Ethiopia

Variable	Parameters	OLS Estimation	ML Estimation
Stochastic Frontier			
Constant	β_o	0.19 (0.15)	0.26 (0.23)
Land	β_1	0.10 (0.3)	- 0.003 (-0.009)
Labor	β_2	0.06 (0.24)	0.05 (0.22)
Oxen	β_3	0.1 (0.4)	0.09 (0.40)
Fertilizer	β_4	0.23 (1.45)*	0.32 (2.24)**
Seed	$\beta 5$	0.35 (2.05)**	0.33 (2.18)**
Constant	δ_0		-2.12 (-0.93)
Livestock	δ_1		-0.14 (-1.20)*
Extension	δ_2		-0.13 (-0.91)
DA visit	δ_3		1.34 (1.11)
Infrastructure	δ_4		-0.02 (-0.54)
Age	δ_5		0.04 (1.41)*
Education	δ_6		0.05 (0.10)
Variance Parameters			
	σ_s^2	0.31	
	R^2	0.75	
	γ		0.52
Logliklihood function		-41.5	-32.2
Likelihood-Ratio	LR = 18.69***		

Values in parenthesis are t-ratios; * 10 %, ** 5 % and *** 2.5 %
The LR is tested using the corrected χ^2 table (Kodde, et. al, 1986)