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Technical Efficiency Across Agro-Ecological Zones in Ethiopia: The Impact of Poverty and Asset Endowments

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Abstract: Currently, Ethiopia focuses on agriculture so that it can spur growth in other sectors of the economy. In order to help policy makers understand factors affecting agriculture, studies on efficiency are important. Especially, the impact of poverty and asset endowments could be highly pronounced in an agrarian country such as Ethiopia. In this regard, the objectives of this study are two fold: to investigate efficiency variations across agro-ecological zones and to examine the impacts of poverty and asset endowments on inefficiency in the study area. Data were collected from 254 randomly selected households. Stochastic frontier production function was estimated and the results of the analysis revealed a mean technical efficiency of 75.68%. F-test also showed a statistically significant difference in technical efficiency among agro-ecological zones. On the other hand, maximum likelihood estimates indicated positive and significant elasticities for asset endowments including physical (land and draft power), financial (credit access and market) and human (labor and education). However, poverty was found to reduce efficiency levels significantly. Thus, future endeavoers should envisage better market and education access and reduced liquidity constraints.

Key words: Technical efficiency, agro-ecological zone, poverty, asset endowments, stochastic, Ethiopia

INTRODUCTION

Agriculture dominates the Ethiopian economy in terms of its contribution to GDP, employment opportunities, foreign exchange earnings, income and food. However, the sector has several problems, which are manifested in the form of low input use, land degradation and low productivity. As indicated by various studies in the area (Croppenstedt and Demeke, 1997) the most important factors responsible for these problems are lack of dynamism to follow sustainable intensification, ill-conceived policies, poverty and lack of assets.

Most Ethiopians reside in rural areas, where agriculture is the mainstay of their income source and land is a means of their survival, object of utilization and source of income (Demeke *et al*., 1997). Currently, Ethiopia is following an Agricultural Development-Led Industrialization (ADLI) strategy with the major goal of bringing about transformation of the country's economy. The assumption is that growth in agriculture spurs a series of interlinks in other sectors of the economy, as it has backward and forward linkages (MoFED, 2002). Other supportive strategies have also been formulated. Nevertheless, these strategies, which target at intervening in the agricultural sector need to have pertinent information as to how farmers are operating and what factors are really impeding them from producing at efficient levels.

Since, Ethiopia is endowed with a variety of agro-ecological zones, which differ in terms of rainfall patterns, temperature conditions, soil types, altitude and other physical landscapes, a one-fits-all approach does not help much. The reason is that there is tremendous variation in farming systems, population density and socio-economic conditions in the different agro-ecological zones. For instance, in the highlands, there is limited farmland, but population pressure mounts. On the other hand, in kola areas (lowlands) there is very erratic rainfall, high poverty and severe resource degradation.

Therefore, accelerated and sustainable agricultural development can be brought about only if we take into account these variations, identify appropriate development strategies which will take advantage of the development opportunities in each agro-ecological zone and implement them accordingly. There is therefore, a need to articulate a detailed development plan for each agro-ecological zone to exploit the growth opportunities in those areas (MoFED, 2002).

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Studies that systematically analyze technical efficiency and its determinants across different agro-ecological zones in Ethiopia are lacking. Most focus on a particular agro-ecology, where there results may not allow inter and intra-regional comparison. On the other hand, others estimated efficiency levels with no regard to the analysis of factors causing in/efficiency (Admassie and Heidhues, 1996; Seyoum *et al.*, 1998). Still other studies focused on land renting, leasing and sharecropping issues (Gavian and Ehui, 1999; Kassie and Holden, 2007; Pender and Fafchamps, 2002).

Therefore, this study intends to fill the existing gap with the major objectives of gauging technical efficiency of farming systems across three agro-ecological zones in East Gojjam, Northern part of Ethiopia using stochastic frontier production function and investigating the impact of poverty and asset endowments on in/efficiency.

MATERIALS AND METHODS

Study area and sampling: This study was conducted in East Gojjam zone of the Amhara Regional State, which is located in the North-western part of Ethiopia. The Amhara region enjoys diverse agro-ecological zones with altitudes ranging from 500-4620 m above sea level. The study area is generally a traditional cereal producing area. Like other areas of the rural economy in Ethiopia, lack of technology, poverty and little asset endowments are major factors why farming remains to be traditional. In Ethiopia, in general and the study area in particular, application of modern inputs is very low, which definitely indicates that the country has not yet benefited from the green revolution.

As regards data collection, multistage sampling techniques were used to collect data. First, three districts were purposively selected from East Gojjam zone namely, Debay Tilatgin, Enemay and Shebel Berenta. Once, the selection of the districts was done, peasant associations in the three districts were grouped into three such as dega (2300-3200 m a.s.l), woina dega (1500-2300 m a.s.l) and kola (500-1500 m a.s.l). In the second stage, a total of ten peasant associations/kebeles were randomly selected from all the districts (3 from dega, 4 from woina dega and 3 from kola). In the third stage, 285 households were randomly selected from the chosen peasant associations.

A detailed questionnaire was administered to household heads during the cropping season of 2007. A total of 10 enumerators were assigned to administer the questionnaires to the farmers. It was a face to face interview. A follow-up was done to make sure the interview worked out well. Eventually, 254 questionnaires were used for the final analysis; others were simply refuted because either they were not returned or not properly filled out. In addition, observations and key informant interviews were held to gather primary data. Data pertaining to general issues in the study area also stem from secondary sources, i.e., from different government offices.

Analytical approaches: Assume that there are j observation of farmers indexed as j = 1 who use a vector of X>0 inputs, which are indexed as $X = 1....X_n$ to produce y>1 outputs. Following Kumbhakar and Lovell (2000), the stochastic frontier production function can be specified as:

$$y_i = f\left(X_j, \beta\right).e^{\phi} \tag{1}$$

where, $f(X_j; \beta)$ and e^{Φ} represent the deterministic and stochastic part of the production frontier, respectively. β is a vector of parameters to be estimated, where as, Φ is the random error term, which can be decomposed as follows:

$$\phi = v_j + u_j \tag{2}$$

where, v is the symmetric error component, which is assumed to be independently and identically distributed as N (0, σ^2). It accounts for the random variations in output due to factors outside the control of the farmer such as weather, disease, measurement error etc. On the other hand, u represents the technical inefficiency relative to the stochastic frontier and assumes only positive values (Neff *et al.*, 1993). Its distribution is assumed to be half normal being identically and independently distributed as N (0, σ^2).

Let σ_v^2 and σ_u^2 be the variances of the parameters symmetric (v) and one-sided (u) error terms. It then follows that

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \tag{3}$$

and the ratio of the two standard errors as used by Jondrow *et al.* (1982):

$$\lambda = \sigma_v + \sigma_u \tag{4}$$

According to Jondrow *et al.* (1982), the variance ratio parameter γ, which relates the variability of u_i to total variability (σ^2) can be calculated in the following manner:

$$\gamma = \lambda^2 / \left(1+\lambda^2\right) \text{ or } \gamma = \sigma_u^2 / \left(\sigma_u^2 + \sigma_v^2\right) \tag{5}$$

So that $0 \le \gamma \le 1$.

This means that if the value of γ equals zero, the difference between yields (outputs) of farms is entirely due to statistical noise. On the other hand, a value of one would indicate that the difference is attributed to technical inefficiency (Coelli, 1995).

Following Kumbhakar and Lovell (2000), the stochastic frontier production function in Eq. 1 can be specified as:

$$y_i = f\left(X_j, \beta\right) \times \exp\{v_j\}.TE \tag{6}$$

After dividing both sides by $f(X_j; \beta) \times \text{Exp}\ \{v_j\}$, we can rewrite Eq. 6 as follows:

$$TE_j = \frac{y_j}{f(X_j, \beta) \times \exp\left\{v_j\right\}} \tag{7}$$

where, TE refers to the technical efficiency of the jth farm, y_j is the observed output, $f(X_j;\ \beta)$ indicates the deterministic part that is common to all producers, $\exp\{v_j\}$ is a producer specific part, which captures the effect of random noise on each producer.

From Eq. 7, we can observe that technical efficiency is the ratio of observed output to maximum feasible output in an environment characterized by $\exp\ \{v_j\}$.

Following a one-step approach of Battese and Coelli (1995), stochastic frontier production function was estimated using a Cobb-Douglas formulation where, the natural logarithm of gross volume of output per hectare (expressed in Ethiopian Birr) is considered as a dependent variable. Since, farmers are producing quite a mix of crops (sometimes even from the same plot or even if they grow one crop in one plot, they pile it together with another crop of the same type from another plot after it comes to a threshing point), it is practically difficult to express output in quantity terms such as kg ha^{-1}. Therefore, all crop outputs were converted into monetary values using the price information collected during the survey and developing a conversion index. The analysis was conducted at household level. The model specified at household level looks like the one indicated here under:

$$\begin{aligned} LnY = {} & \beta_0 + \beta_1 \ln L + \beta_2 \ln O + \beta_3 \ln A + \beta_4 \ln I + \\ & \beta_5 \ln F + \delta_1 Age + \delta_2 Sex + \delta_3 Memborg + \\ & \delta_4 Credit + \delta_5 Extension/training\ on\ farm \\ & land\ management + \delta_6\ Liter + \delta_7\ non\text{-}farm \\ & + \delta_8\ Pop\ Pres + \delta_9\ livestock\ (TLU) + \\ & \delta_{10} Male\ labor + \delta_{11} Woina\ Dega + \delta_{12} \\ & Kola + \delta_{13}\ proximity\ to\ markets + \delta_{14} \\ & poverty\ status + \varepsilon \end{aligned} \tag{8}$$

RESULTS AND DISCUSSION

Before proceeding to the analyses of technical efficiency and its determinants, it was necessary to detect the presence of inefficiency in the production input-output data for the sample households. The test was carried out by estimating stochastic frontier production function and conducting a likelihood-ratio test assuming the null hypothesis of no technical inefficiency. The test statistics were computed automatically when the frontier model was estimated using STATA version 9 (Table 1).

Table 1: Detecting the presence of inefficiency

Explanatory variables	Coeff.
Ln labor input (in man days)	0.229* (0.068)
Ln draft power (in ox-days)	0.154** (0.075)
Ln fertilizer use (kg)	0.237*** (0.012)
Ln area planted (ha)	0.175** (0.087)
Ln farm implements	0.167 (0.142)
Constant	5.078*** (0.541)
Lambda	1.349*** (0.171)
Gamma ($\gamma = \lambda^2/(1+\lambda^2)$)	0.64
Number of observations	254
Wald chi-square (χ^2) (5)	117.69
Prob >chi-square (χ^2)	0.0000
Log likelihood	-165.985
Likelihood-ratio test of sigma_u	-
Chibar 2 (01)	5.75

Results indicate that the inefficiency component of the disturbance term (u) is significantly different from zero suggesting that the null hypothesis of technical inefficiency (H_0: Sigma u = 0) is rejected. This indicates that there is statistically significant inefficiency in the data. The lambda (λ) value is also greater than one in all the cases, which is a further indicator of the significance of inefficiency. On top of that, the value of gamma (γ) indicates that there is 64% variation in output due to technical inefficiency. This means that technical inefficiency is likely to have an important effect in explaining output among farmers in the sample. Therefore, Maximum Likelihood Estimates (MLE) give appropriate results, but OLS estimates fail to do this.

In crop production, technical efficiency is likely to be affected by a wide range of household, farm and village-specific factors. Forsund *et al.* (1980) argue that inefficiency is typically related to factors that are associated with farm management practices of the farmers themselves. Such factors include education, family size and composition, experience, extension visits and training on farmland management, proximity to markets and access to credit. In this study, as indicated in Table 2, factors that affect the technical inefficiency of peasant farmers are considered in the MLE estimates.

Table 2 shows that the output elasticities for major inputs used significantly enhance efficiency levels. The result is similar with what others have found in Tigray (Tesfay, 2006).

Crop production is labor-intensive activity in Ethiopia. In this regard, the effect of household size on technical efficiency cannot be overemphasized. In fact,

Table 2: Maximum Likelihood (ML) estimates of the parameters for stochastic frontier production function and inefficiency determinants (dependent variable is aggregate crop output in Ethiopian currency, Birr)

Production function part	Coeff.
Ln labor (in May-days)	0.107* (0.059)
Ln area planted (ha)	0.293* (0.075)
Ln draft power (in ox-days)	0.198*** (0.063)
Ln fertilizer use (kg)	0.052*** (0.011)
Ln Farm implements (Birr)	0.051 (0.043)
Constant	7.189*** (0.164)
Technical inefficiency part	
Age of household head (years)	0.146 (0.098)
Sex of the household head (1 if male)	-0.296 (0.180)
Membership in organizations (1 if yes)	-0.361 (0.589)
Access to credit (1 if yes)	-0.855* (0.515)
Extension visits/training on farmland management (1 if yes)	-0.343 (0.210)
Literacy status of the household head (1 if L)	-0.781** (0.449)
Involvement in non-farm activity (1 if yes)	0.568 (0.512)
Male labor endowment	-0.173** (0.079)
Proximity to markets	-0.742*** (0.217)
Ratio of family size-farm size (population pressure)	-0.116 (0.232)
Livestock ownership (TLU)	-0.608** (0.273)
Dummy for woina dega (1 if yes)	0.248 (0.413)
Dummy for kola (1 if yes)	0.144* (0.063)
Poverty status (predicted value)	0.203* (0.110)
Constant	-6.707* (0.973)
Sigma v	0.380*** (0.033)
Number of observations	254
Wald chi-square (χ^2) (5)	105.61
Prob>chi-squase	0.0000
Loglikelihood	-172.23

SE in parentheses; *, ** and ***: Indicate significance at 10, 5 and 1%, respectively

the study offers mixed results. On the one hand, people argue that an increase in the number of adults in the family could increase technical efficiency if it results in increased labor devoted to crop production. On the other hand, the effect of household size could be negative if adults have higher chances of obtaining off-farm and non-farm employment, ultimately, reducing the effect on technical efficiency.

A part from the impact of family size as a whole, the role of male labor can be singled out, as farming is highly labor-intensive and cumbersome. In this regard, it is hypothesized that households with higher male labor are found to be more efficient than labor-constrained households. This is because the availability of male labor is associated with timeliness of farming operations especially during peak periods. As expected, the sign for this variable in the present study is negative and significant indicating that the more the number of male labor in family the less the inefficiency level. The result is in line with the findings of Abdulai and Eberlin (2001) and Ahmed *et al.* (2002). As regards livestock ownership, the results in this study are in line with the findings of several other empirical researchs (Abdulai and Eberlin, 2001; Ahmed *et al.*, 2002). The sign for livestock ownership is positive and significant indicating that the availability of these assets is essential in several respects. For instance, farmers who have livestock can sale and buy fertilizers, apart from smoothing their incomes and better nourish their families with animal products such as milk and meat. They also, use dung cakes to fertilize homesteads. Besides, pack animals are used for timely transportation of the crops to a threshing point. Since, threshing is conducted using animal power, the availability of livestock especially during peak periods is vital. It helps reduce post harvest loses. Several empirical researchs have proved the impact of livestock ownership on efficiency to be positive and significant (Abdulai and Eberlin, 2001; Ahmed *et al.*, 2002).

The results of this analysis show that education level negatively and significantly affects inefficiency. The positive sign for education indicates that increase in human capital enhances the productivity of farmers since, they will be better able to allocate family-supplied and purchased inputs, select the appropriate quantities of purchased inputs and choose among available techniques (Pender and Fafchamps, 2002; Abdulai and Eberlin, 2001; Ahmed *et al.*, 2002).

Another factor worth considering, as a variable affecting technical efficiency, is proximity to factor markets. The hypothesis in this study is that households located near markets are expected to have higher technical efficiency than those located in remote areas. The assumption is that proximity to markets increases farmers' access to credit facilities and income-generating activities. By contrast, other people argue that access to markets may increase the non-farm employment opportunities with higher returns than from farming, leading them to reallocate labor from farm to non-farm activities. In the analysis, we observe that proximity to markets reduces technical inefficiency levels significantly.

Access to credit improves problem of liquidity and enhances use of agricultural inputs in production, as it is often claimed in development theory. In the study area, credit is used for purchase of oxen and inputs. In fact, there is quite a great deal of fungibility in the sense that most people use the loan for unintended purposes such as consumption smoothing. Better-fed families can be more productive in their fields. The result of the maximum likelihood estimates show that access to credit reduces inefficiency levels.

When, we look at the situation across agro-ecological zones, which is the major contribution, we found that as one moves from dega areas (highland zones) to that of kola (lowland zones), technical efficiency is found to decrease. Kola areas are poverty stricken areas. The reasons for the inefficiency of these areas are that the poor lack resources to timely prepare their fields, apply

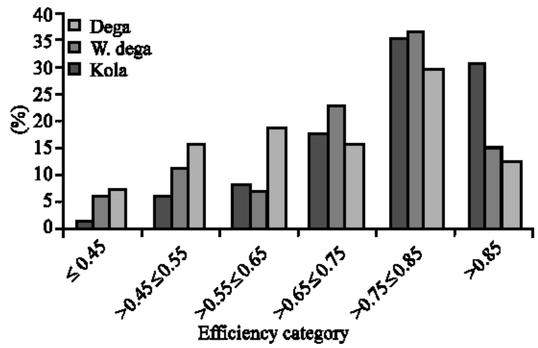

Fig. 1: Efficiency distribution across agro-ecological zones

inputs in time (as they are far from markets and institutions) and manage their land intensively. Besides, farmers in these areas allocate their human capital among diverse portfolio of activities to avert risk, which distributes their meager resources that would have been invested in their farms. Although, the neoclassical theory assumes that the poor use all their available inputs under their control in a manner that is technically efficient, this is not the case in the study area. Using ANOVA, it is found that mean efficiency is higher in degaareas (77.90) followed by woina dega agro-ecology (76.70). The least is observed in kola areas (71.67). For the whole study area, ranging from 32.15-92.66%, the mean technical efficiency is found to be 75.68%. The analysis further indicates that the mean differences in technical efficiency scores among farmers of the three agro-ecologies are statistically different from zero. The null hypothesis that there is no efficiency difference across agro-ecological zones is rejected at 1% significant level. A more disaggregated Fig. 1 would show us that most of the respondents in all the three agro-ecologies have shown efficiency scores well above 65%. In fact, this Fig. 1 shows that there is still a significant room for improving the productivity levels given the current technology.

CONCLUSION

Despite the wider attention it has received from several researchers, technical efficiency has not been studied much in Ethiopia. Particularly, the variations of farmers´ performances across agro-ecological zones have been neglected. It should be noted that studies considering agro-ecological zones will have important policy implications to identify appropriate development strategies in order to enhance the current performance of the agricultural sector. The present study is, therefore, an attempt to fill the existing gap by examining the level of technical efficiency and its determinants across agro-ecological zones in Eastern Gojjam, Ethiopia.

From the stochastic frontier analysis, the mean technical efficiency (ranging from 32.15-92.66%) was found to be 75.68%. F-test result shows that there exists a statistically significant difference in technical efficiency between agro-ecologies with dega areas scoring the highest. Interesting results emerge out from this study. As indicated in maximum likelihood estimates, poverty and asset endowments play essential role in influencing technical efficiency levels of farm households in the study area. However, extension services did not help much. Thus, future endeavors may need to look into mechanisms by which farmers can get access to better ways of farming through extension services (that are tailored to the peculiarities of the farming systems), improved market outlets and reduced liquidity constraints. Besides, investment in education should be considered as a central ingredient in the development strategy if improvement in agricultural productivity is to be achieved.

In a nutshell, this study indicates that improving farm household production efficiency brings substantial productivity gains under the current technology. Hence, it is important for the agricultural development strategy of the study areas to have an institutional environment that facilitates farmers' accessibility and entitlement to critical assets such as land, education, better extension provisions as per the peculiarities of the agro-ecological zones and improved access to formal credit and market.

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