# Production Efficiency and Agricultural Technologies in the Ethiopian Agriculture

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**Abstract**

Stochastic frontier production function analysis was performed to examine relative crop and milk production efficiency among peasants in Ada and Selale districts of the Central highlands of Ethiopia. The results indicate that Ada farmers exhibit relatively higher efficiency scores in cereal production compared to Selale producers. Farmers who adopted cross-bred cows attained higher efficiency scores than farmers who did not adopted. Production efficiency scores are higher in enterprises that enjoys experience and location specific comparative advantages.

The magnitude of the impacts of knowledge-related variables (i.e., production knowledge and schooling) on production efficiency are higher relative to other variables. Adoption of one or two innovations show a consistently large, positive and significant effect on all measures of production efficiency in the Selale region. Higher production efficiency is attained in Ada region if producers adopt two or more technologies. Development strategies should examine the mixes of production technologies that may contribute to increases in agricultural production compared to the conventional package approach.

## Production Efficiency and Agricultural Technologies in the Ethiopian Agriculture

### Introduction

Inability to produce adequate food is the major problem of most less developed countries (LDCS). In order to reduce the severity of this problem, several agricultural development strategies have been implemented since the 1960's. These strategies include new agricultural technologies as their major component. However, adoption of new agricultural technologies were met with failure. Those which were adopted did not ensure sustainable increases in food production. There were several problems with technological intervention strategies that were aimed at increasing food production.

Between 1950's and 1970's, the emphasis was on technology transfer without eliminating the structural obstacles (e.g., land tenure) facing peasants. Furthermore, the skills needed to manage the technologies were tied to the suppliers rather than to the beneficiaries (peasants). Thus, not only the increases in food production short-lived, but also resulted in dependence of peasants in LDCs on developed nations for technologies (i.e., materials and associated skills). In some LDCs, introduction of technologies created environmental degradation, in others income disparity and social restructuring (Hayami and Ruttan, 1985; Stevens, 1988; Belay; 1977; Molnar et al. 1983; Ortiz, 1980).

For decades economists have advocated the existence of vast unutilized resources in developing countries. With rapid increases in population, however, policy makers and planners realized that resources are scarce. And, development strategies should focus on strategies that are intended to increase the productivity of scarce resources. One such alternative is the introduction of "appropriate" agricultural technology (ies). Introduction of appropriate technologies is, however, by no means the only solution to sustainable agricultural development but a strategy towards attainment the over all objective of food self-sufficiency.

The social, cultural, technical and economic feasibility of new technologies should be examined before introduction. The extent to which technologies are suited to the socio-economic structures of peasants and their ability to effectively compete with traditional production techniques determines their successful adoption. One method of evaluating the feasibility of new agricultural technologies involve examining the efficiency of production attributed to new technologies.

Several researchers have studied production efficiency of peasants in LDCs. Most of these studies can be seen as attempts to characterize the behaviour of peasants (e.g., Ellis, 1988). These studies assume ideal socio-economic environment such as appropriate marketing policies, access to technologies and other inputs, and adequate infrastructure. The results of these studies portray peasants' behaviour in several ways. For some the behaviour of peasants is static, largely because they are not innovative or efficient. For others, they are efficient because the environment in which they are operating is static (Wharton et al. 1969; Mellor, 1969). Yet, there are a number of studies which convincingly argue that peasants are efficient, that their goals, strategies and decisions are logical and rational given the constraints and choices they face.[1]

Peasants employ several inputs in the production of crop and livestock outputs. Farm inputs include traditional (e.g. land and labour) or new technologies. Research in the peasant

[1] For details on the efficiency of peasants refer to Ellis (1988), Schultz (1964, 1978), Stevens, et al. (1988) and Barlett (1980).

agriculture has focused on the impact of a technology on production rather than selective combination of technologies. Adoption of a single or mixes of production technologies are anticipated to have a differential impact on the production structure (crops grown, inputs used and milk produced) of smallholders (Eisemon and Nyamete, 1988). Of particular interest is whether or not selective mixes of production technologies produce different results in farm efficiency compared to a single technology or traditional inputs. The present study investigates the distribution of relative production efficiency and socioeconomic factors that influence this distribution within and across regions, and the impact of selective mixes of agricultural technologies on the measures of production efficiency among peasants of the Central highlands of Ethiopia. The study is also expected to provide information on the feasibility of cross-bred cows husbandry.

Selale farmers were instructed that inputs necessary for the management of cross-bred cows were available in their locality, and that they should take full responsibility for the management of such cows. Farmers in the Ada area, however, joined the International Livestock Research Center (ILCA) technology diffusion program voluntarily because it provided a relatively risk-free environment (e.g., subsidized cost of feed). The approach to diffusion of technologies in the Selale region, therefore, is different from that implemented in Ada area. Comparative analysis of the two sites is hypothesized to reveal significant differences in the choice of inputs or technologies and the resulting efficiency of production. The findings of this study would provide valuable evidence on strategies of technological intervention to planners and policy makers of agricultural development in LDCs.

**The Study Sites and Research Design**

The research was carried out over a period of 17 months in 1990-1991. The research sites are Selale and Ada districts of the central Ethiopian highlands. These two sites have similar farming systems and belong to the high potential cereal-livestock zone ( Kebede, 1993; FINNIDA, 1989).

Selale is representative of the high altitude zone (more than 2000 meters above sea level) of the country. The major crops grown in Selale include oats, teff, barley, wheat, horse beans and field peas. The average farm size is 3.1 hectares, 30% of which is used as permanent pasture or grazing land with the rest cultivated. The average livestock holding is 3.5 cows, 1.8 oxen, 0.55 bulls, 1.8 young animals and 2.96 calves (FINNIDA, 1989). Farmers in this region have extensive experience in livestock production than those in the Ada region.

Ada is characterized by mild weather and represents the country's large middle-altitude cropping zone (1500 to 2000 meters above sea level). The major crops grown include teff, wheat, barley, horse beans, chickpeas and field peas. The average farm size is 2.6 hectares. There is virtually no fallow land. The average livestock holding is 1.28 cows, 1.98 oxen, 0.50 bulls, 0.53 young animals and 0.84 calves (Gryseels et al. 1983). Compared with the Selale region, Ada farmers specialize more in crop than in livestock production. That is, Ada farmers have extensive experience in crop production. A summary of selected socio-economic characteristics of farmers in both study sites (analysis of variance) is presented in Table 1.

Table 1: Selected Characteristics of Selale and Ada Farmers

| | | **Selale** | | **Ada** | | | |
|---|---|---|---|---|---|---|---|
| | | **N** | Average | N | Average | F-Value | Prob>F[1/] |
| No. of Household Members who are: | Dependent | 173 | 4.47 | 41 | 4.29 | 0.412 | 0.469 |
| | Independent | 207 | 1.75 | 48 | 1.5 | 4.52 | 0.03* |
| Education of Household Head (yrs) | | 55 | 2.5 | 23 | 3.6 | 5.671 | 0.001* |
| Experience (years): | Dependent | 176 | 11.24 | 50 | 13.44 | 0.044 | 0.83 |
| | Independent | 176 | 24.58 | 50 | 27.88 | 4.173 | 0.04** |
| Income (Ethiopian birr) from Sale of: | Grain | 203 | 230.27 | 49 | 828.6 | 65.46 | 0.006* |
| | Livestock & Livestock Products | 194 | 451.4 | 22 | 203.11 | 1.09 | 0.058** |
| | Fuel wood | 169 | 343.58 | 31 | 63.97 | 13.84 | 0.004* |
| Expenses (Ethiopian birr) for | Purchase of food | 214 | 268.2 | 50 | 228.14 | 2.366 | 0.125 |
| | Clothing | 205 | 114.49 | 39 | 106.09 | 0.309 | 0.579 |
| Milk production (in liters) per Month: | Local cows | 193 | 56.9 | 35 | 42.6 | 6.79 | 0.05** |
| | Cross-bred cows | 66 | 320.35 | 14 | 186.29 | 5.76 | 0.011* |
| Area under (hectares) | Crop | 217 | 2.5 | 52 | 2.3 | 19.56 | 0.001* |
| | Grazing | 208 | 0.8 | 37 | 0.2 | 26.29 | 0.006* |
| Livestock Number | | 165 | 10.89 | 16 | 5.18 | 0.69 | 0.016* |
| Crop Production ('00kg) | | 217 | 14.88 | 52 | 21.41 | 2.98 | 0.05** |

1/ * and ** refer significance at 1 and 5 percent respectively; the F-values test differences in the average values of socioeconomic characteristics between Selale and Ada farmers.
2/ Household members who are capable of working without supervision are categorized as independent or "workers" (age 15-60) and those who have to be supervised are considered dependent or "consumers" (age <15 and >60).

Statistical analysis of the socioeconomic profile of the two study sites suggest that the two regions exhibit statistically significant differences with respect to the: i) number of household members who are independent ii) number of years of education, iii) number of years of farming experience as an independent farmer, iv) number of livestock owned, vi) average income earned from the sale of grain, livestock and fuel wood, vii) crop and grazing area, viii) amount of milk produced per household, and ix) amount of grain produced (Table 1).

Ada farmers had more years of schooling and more years of farming experience. They gain most of their income from the sale of grain while that of Selale farmers from livestock and livestock products. The productivity of dairy cows (litres/month) is higher among Selale farmers while Ada farmers produce greater crop yields per hectare.

**Determination of Sample Size**

Several crop production technologies have been introduced in the study sites since the 1960's. However, introduction of cross-bred cows took place not only recently but was also implemented by different agencies with relatively different approaches to technological intervention strategies. Furthermore, the present research is conducted to provide information on the feasibility of cross-bred cows husbandry. Therefore, it was felt appropriate to compare farmers who have adopted cross-bred cows (test) with those who did not (Control). These farmers may have adopted any combination of crop-production augmenting technologies.

Households which received cross-bred cows and were selected for this study in the Ada and Selale areas numbered 26 and 89 respectively.[2] A confidence level of 95%, coefficient of variation of crop and milk yields of 96 percent and precision level of ± 20% resulted in a sample size of 89 farmers for the Selale region. For the Ada region, however, time and financial resources limited the number of test farmers to only 26. Comparison of average values of the socioeconomic variables derived from a district-wide survey by the Ministry of Agriculture and average values of similar socioeconomic characteristics calculated from the present study showed that the two data set are approximately the same ( see MOA, 1988). Therefore, the small sample size for the Ada region will not bias the foregoing analysis.

After determining the sample size, the need to use farmers who joined the International Livestock Center for Africa (ILCA) and FINNIDA (Finnish International Development Agency)/ MOA (Ministry of Agriculture, Ethiopia) programs as test groups necessitated the use of a systematic selection of the control group. A method was designed such that all test farmers were compared with farmers who exhibit similar socioeconomic characteristics (control farmers) but were different in ownership of cows (see Kebede, 1993).

The control farmers were to have a comparable number of oxen, cows, sheep/goat, family size, age (farming experience), education, annual farm income and farm size (crop and grazing) with the test farmers. Moreover, the two groups had to exhibit similar ethnic, climatic and

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[2] Prior to selection of the control group, the sample size was determined according to the following procedure. The sample size (N) is given as: $N= (KV)^2/D^2$ , where D is the largest acceptable difference (in percent) between the estimated sample and the true population parameters. K is a measure of confidence ( in terms of the number of deviations from mean) with which it can be stated that the result lies within the range represented by plus or minus D and V is the coefficient of variation of crop and/or milk yields (Casely et al. 1982).

geographical characteristics. To accomplish this task, a three-step procedure was followed. Firstly, a group of farmers involving political leaders and elders in each peasant association were asked questions such as, "With whom do you think farmer "A" compares with respect to income, livestock holdings, living standard, etc., except that he does not own cross-bred cows?". [3]

Secondly, each test farmer was asked questions such as, "To whom do you think you are comparable with respect to income, livestock holding, family size, etc., except that you own cross-bred cows and the other farmer does not?". This method of identify a control farmer is difficult and socially controversial.[4] Nevertheless, it would provide a clue to identifying control farmers. 116 and 26 control farmers were selected from Selale and Ada regions respectively.

Thirdly, 150 farmers who did not receive cross bred cows were interviewed with respect to the above socioeconomic characteristics. The results were compared with background socioeconomic data obtained from test farmers. Combination of the above three steps enabled identification of control farmers that were used in the present study.

**The Empirical Model**

Most empirical studies efficiency analysis used parametric production function ( see Koopmans, 1951, 1957; Debreu, 1951; Fare, Grosskopf and Lovel, 1985; Farrel, 1957; Fare et al.

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3 A peasant association is a geopolitically delimited association of peasants covering an area of about 400 hectares. Political leaders are farmers who, through democratic election processes, were elected to take administrative positions within a peasant association.

4 Evaluating the economic well-being of other farmers would force farmers to think as if they were intruding into private life of others. This is not a socially acceptable norm. However, options were explored with groups of farmers and they suggested that this method could be feasible if used in conjunction with step one.

1983; Greene, 1980a,b, 1982; Schmidt et al. 1985; Lee, 1983; Waldman, 1984; Kumbhakar, 1987). Among the broad spectrum of parametric production functions, full and stochastic frontier models have been widely used to examine production efficiency ( see Fare et al. 1983). To study relative farmer-specific production efficiency among peasants in the Ethiopian highlands, stochastic frontier production function is selected ( see Greene, 1980; Aigner et al. 1977; Meeusen et al. 1977).

Statistically efficient technique would be to estimate stochastic production function with conditioning variables. This procedure may contribute to methodological development. However, the present study adopted a two-stage estimation procedure. Parameters of the production function will be estimated from stochastic frontier production function. Then, tobit model will be employed to examine relationships between measures of relative production efficiency and socioeconomic factors that were not included in the production function but hypothesized to influence the production structure of peasants (see below). There are two reasons for adopting this procedure. Firstly, the objective of this study is to examine the impact of selected socioeconomic variables on measure of production efficiency so that realistic recommendation could be drawn to benefit agricultural policy making. Secondly, traditionally non-physical resources such as those related to "skill" are assumed to be reflected by an aggregate measure referred as "management" (see Mundlak, 1961). However, several factors contribute to the skill with which decisions are made. Aggregating all factors that are hypothesized to independently or jointly influence decision-making under the management variable could create problems of colinearity and lack of convergence in estimation. Therefore, the present study argues that two stage estimation procedure may reveal the strength of impacts of selected socioeconomic variables on measures of relative production efficiency.

The stochastic frontier production function for the $i^{th}$ farm can be specified as:

$$Y_i = f(X_k,\beta)e^{\varepsilon} \qquad i=1...n,\ k=1..m \qquad \text{.................... ............. (1)}$$

where $Y_i$ is output of the $i^{th}$ farm, $X_k$ is a vector of k inputs of the $i^{th}$ farm, $\beta$ is a vector of parameters and $\varepsilon$ is farm-specific error term ( see Dawson and Lingard, 1989; Bravo-ureta, 1990).

The stochastic frontier production function ( equa. #1), assuming the logarithmic Cobb-Douglas form, can be written as:[5]

$$\ln Y_i = \ln\alpha_0 + \Sigma\, \beta_i \ln X_{ik} + \varepsilon_i \qquad \text{........................................................ (2)}$$

The error term in equations (1) and (2) is called composed because it has two components. That is,

$$\varepsilon_i = V_i - U_i$$

$V_j$ is the two sided random error that permits variations in output due to factors outside the control of the farm and distributed as $V_j \sim$ iid $N(0,\sigma v^2)$, $U_j$ is the one-sided measure of technical in(efficiency) relative to the stochastic frontier and distributed as $U_j \sim$ iid$|N(0,\sigma u^2)|$ ) ( see Aigner et al. 1977; Meeusen et al. 1977). V and U are assumed to be uncorrelated and $\varepsilon$ is assumed to be independent of X.[6]

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5 Kopp and Smith (1980) argued that the choice of functional specification has a very small impact on measured efficiency. The Cobb-Douglas production function is a compromise between a complex production process and a complex estimation technique.

6 Estimation of the parameters of the stochastic frontier production function was accomplished by the maximum likelihood technique using the LIMDEP software (Greene, 1990). The algorithm is based on an iterative solution to the likelihood equation and yields the appropriate maximum likelihood estimates.

The measures of efficiency are residual values after accounting for production inputs included in the production function. In leu of parsimony and to facilitate convergence, selected farm- and region-specific variables were excluded from estimation of stochastic production function.

Measures of (in)efficiency obtained from stochastic frontier production function do not explain the contribution of socioeconomic factors to differences in relative efficiency between farmers or regions. To explain differences in production efficiency, therefore, it was found necessary to examine relationships between selected socioeconomic factors and scores of production efficiency.

Production efficiency scores lie within the range of 0 and 1. Formulation of a regression equation that include truncated continuous dependent variable (efficiency score) will result in a predicted output that may lie outside the 0-1 interval (Maddala, 1983). Therefore, tobit model is selected to examine factors that may explain differences in efficiency scores between farmers and regions ( see Upadhyaya et al. 1993; Amemiya, 1981).

The tobit model can be written as:

$$Y_j = \beta' X_j + Uj \quad \text{if } \beta' X_j \geq 0 \qquad \text{.....................................} \ (3)$$

$$Y_j = 0 \quad \text{otherwise}$$

Where $\beta$ is a vector of unknown parameters, $X_j$ is a vector of known constants and $U_j$'s are residual that are independently and normally distributed, with zero mean and a common variance of $\sigma^2$ ( for details see Tobin, 1958; Goldberger,1964; and Madalla, 1983).

**Description of Variables**

The research involved interview, observation and participatory methods. Traditional inputs that are anticipated to influence the crop production structure of peasants include plot size (hectares), oxen (oxen-days), seed rate (kg), labour (man-days), pesticides (kg), plot characteristics (0-1 variable), and milk production is hypothesized to be influenced by grazing area (hectares), stubble feed (hectares), labour (man-days), number of cows (head), concentrates (kg), and roughage (kg) (see Kebede, 1993). A summary of selected technical, social and economic variables that directly or indirectly influence production is presented in Table 2. Only physical inputs are included in the estimation of stochastic frontier production function.

Variables that are anticipated to cause variation in production efficiency include years of farming experience under parents control or as a dependent farmer (in years), farming experience after marriage or as an independent farmer, number of years of schooling, number of visits by extension agents, worker:consumer ratio ( the ratio of independent to the number of dependent members of the family), region (0-1 variable), production knowledge(score within a range of 0-10) and number of technologies adopted.

**Table 2:** Selected Socioeconomic Characteristics of Test and Control Farmers in Selale and Ada Regions, Ethiopia

| | Selale | | Ada | |
|---|---|---|---|---|
| | Control | Test | Control | Test |
| Education (years) | 2.23 | 2.4 | 3.37 | 3.75 |
| Experience (yrs):Dependent | 14 | 11 | 15 | 12 |
| Independent | 22 | 23 | 26 | 23 |
| Crop Production knowledge | 7.02 | 7.32 | 7.52 | 8.7 |
| Livestock Production Know. | 7.4 | 8.5 | 6.18 | 7 |
| Market knowledge | 5.85 | 5.01 | 7.98 | 8.1 |
| No. of extension Visits/yr | 8 | 17 | 10 | 19 |
| Crop Area (ha) | 2.6 | 2.5 | 2 | 2.1 |
| Livestock numbers (head) | 13.89 | 15.1 | 6.75 | 6.5 |
| Grazing area (hectares) | 1.1 | 1.3 | 0.4 | 0.5 |
| Oxen (oxen-days) | 1.9 | 1.89 | 2 | 1.93 |
| Seed rate (kg) | 1.45 | 1.55 | 1.4 | 1.87 |
| Labour (man-days) | 1.44 | 1.56 | 1.15 | 1.46 |
| Pesticides (kg) | 1.94 | 1.71 | 1.49 | 2.2 |
| Plot characteristics(score) | 1.55 | 2.01 | 1.48 | 1.83 |
| Milk production (litres/mont) | 65 | 380 | 50 | 190 |
| Grain Produced ('00kg) | 14.01 | 15.1 | 21.41 | 23.1 |

Source: Computed from field survey, 1990/91.

Most of the variables used in the study are obtained from interviews. The only exception is with respect to the measurement of production knowledge. There is no hard and fast rule to measure or quantify production knowledge. Studies in cognitive psychology have demonstrated the usefulness of measuring knowledge using problem solving tests or comprehension ability (see Eisemon, 1988; Bransford et al. 1983).

In the present study, problem solving tests are constructed to measure agricultural knowledge and skills related to current production technologies and practices. The tests are intended to examine the kinds of solutions households provide to crop and livestock production problems. For instance, farmers who plant barley are presented with the following problem solving task:

> *Your barley plants are stunted exhibiting yellowish colour and do not grow tall enough to produce good seed. What are the possible causes of this problem? How may it be prevented?*

Answers obtained from problem solving tests are scored to compare variations in production knowledge of farmers within and between regions. The basis for scoring are answers obtained from group discussions with farmers of different age-groups. The premise behind this basis for scoring is that experience and indigenous knowledge vary by age. Answers from a consensus by group of farmers with different age groups are expected to reflect actual problems and solutions of the farming system in the study sites. A score of 1 to 10 is prepared and individual farmers response is ranked relative to the answers given by the group consensus.

**Empirical Results of Frontier Production Function Analysis**

Statistical analysis using stochastic frontier production function is performed for cereal, milk and the major crops grown in the study sites (Kebede, 1993; Appendix 1 and 2). The results for individual crops is very similar to that of cereals. Thus, only results from cereal and milk production efficiencies are presented (Table 3).

Efficiency scores for Ada and Selale regions indicate that Ada farmers exhibit relatively higher cereal production efficiency compared to Selale producers. It has been indicated in previous section that income from the sale of crop production is higher in Ada region. Farmers in Ada region have greater years of farming experience compared to Selale farmers. Furthermore, Ada farmers have access to more infrastructural facilities than Selale farmers. Consequently, they may be able to produce greater output with minimal outlay of inputs.

Test farmers of both study sites show higher efficiency scores than control farmers. The findings also indicate that most Selale farmers are efficient in milk production relative to Ada producers. Selale farmers own large grazing area, access to other feed sources and more years of experience in livestock husbandry compared to farmers in Ada region. Selale farmers consider livestock husbandry part of their culture. These and related factors may have contributed to greater milk production efficiency than Ada farmers. The empirical findings regarding the distribution of production efficiency imply that best results of intervention strategies are obtained not only from the recognition of appropriate combination of technological package, but also comparative advantages of regions with respect to production of specific crops or classes of livestock.

**Table 3. Percentage of Producers Grouped by Efficiency Scores Obtained from Stochastic Frontier Production Function Analysis**

| Ranges | Efficiency Mid-point | Selale Test Farmers | Ada Test Farmers | Selale Control Farmers | Ada Control Farmers | All Selale Farmers | All Ada Farmers |
|---|---|---|---|---|---|---|---|
| 0.00-0.5 | 0.255 | 2.2 | 0 | 6.1 | 0.4 | 7.6 | 1.8 |
| 0.51-0.6 | 0.555 | 2.3 | 5.5 | 6.3 | 4.4 | 4.6 | 9.4 |
| 0.61-0.7 | 0.655 | 10.5 | 6 | 11.2 | 3.7 | 9.2 | 1.9 |
| 0.71-0.8 | 0.755 | 17 | 15.3 | 12.5 | 11.1 | 11.2 | 10.1 |
| 0.81-0.9 | 0.855 | 13.4 | 13.7 | 18.8 | 18.5 | 16.6 | 11.3 |
| 0.91-1.00 | 0.955 | 55.6 | 69.5 | 45.1 | 61.9 | 50.8 | 65.5 |
| **MILK Production Efficiency** | | | | | | | |
| 0.00-0.5 | 0.255 | 2.4 | 4 | 16.5 | 20 | 4.8 | 9 |
| 0.51-0.6 | 0.555 | 3.4 | 5.8 | 10.6 | 19.1 | 14.1 | 7.5 |
| 0.61-0.7 | 0.655 | 10 | 23.9 | 14.9 | 7.4 | 12.9 | 12.7 |
| 0.71-0.8 | 0.755 | 20.5 | 25.4 | 21.1 | 28.2 | 28 | 30.1 |
| 0.81-0.9 | 0.855 | 30.1 | 20.6 | 20.5 | 14.8 | 30.8 | 20.5 |
| 0.91-1.00 | 0.955 | 38.3 | 20.3 | 14.1 | 10.5 | 37.1 | 20.2 |

**Explaining Variability in Production Efficiency**

Variations in production efficiency arise from various factors. Statistical analysis is performed to identify those factors that may contribute to variations in efficiency scores. Several variables are considered for inclusion in the tobit regression. Preliminary analysis indicate that some of the variables are significantly collinear.[7] Of 15 regressors, nine variables are selected for detailed analysis. The results suggest that most of the variables significantly influence production efficiency (Table 4). Furthermore, one of the objectives of the study is to identify factors that may contribute the most to variations in production efficiency of test farmers. Thus, tobit analysis is performed only for this group of farmers. The magnitude of the impacts from production knowledge and education are very high relative to other variables. The average years of schooling among Ada farmers is double that of Selale farmers. The results from Table 4 indicate that the impact of this variable on relative efficiency of Ada farmers is higher than that of Selale farmers.

Region is included as dummy (0-1) variable to capture differences (including modernizing conditions) between Ada and Selale. Region contributes negatively to cereal production efficiency in the Selale and to milk production efficiency in the Ada region. It reflects location, experience and enterprise- specific advantages. In other words, it favors livestock and crop production in the Selale and Ada regions respectively.

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[7] For instance, because of high degree of collinearity between the number of technologies adopted and number of visits by extension agents, the later was excluded from the tobit model.

**Table 4. Efficiency (Tobit Regressions) 1/**

| | Selale region | | Ada region | |
|---|---|---|---|---|
| **Variables** | Cereal | Milk | Cereal | Milk |
| Intercept | 1.37 | 2.2 | 3.11 | 1.79 |
| | (2.95)* | (2.08)** | (1.98)** | (2.01)** |
| Depenexp | 0.26 | 0.46 | 0.52 | 0.178 |
| | (3.18)* | (4.97)* | (3.95)* | -1.77 |
| Indepexp | 0.35 | 0.94 | 0.76 | 0.45 |
| | (3.31)* | (2.98)* | (3.08)* | (3.01)* |
| Scholling (yrs) | 0.39 | 0.32 | 0.63 | 0.57 |
| | (2.04)** | (2.09)** | (2.89)* | (3.71)* |
| Worker:consumer ratio | 0.29 | 0.25 | 0.5 | 0.31 |
| | (2.10)** | -1.95 | (5.56)* | (2.88)* |
| Region | -0.32 | 0.45 | 0.33 | -0.4 |
| | (1.97)** | (2.09)* | (4.52)* | (2.94)* |
| Production know. | 0.59 | 0.78 | 0.79 | 0.46 |
| | (2.99)** | (3.69)* | (3.87)* | (3.08)* |
| One Technology | 0.73 | 0.86 | 0.45 | 0.41 |
| | (4.55)* | (3.72)* | (1.97)** | -1.55 |
| Two Technologies | 0.55 | 0.65 | 0.7 | 0.83 |
| | (1.99)** | (2.04)** | (6.03)* | (5.17)* |
| Three technologies | 0.54 | 0.61 | 0.75 | 0.7 |
| | (2.01)** | (1.96)** | (3.67)* | (3.01)* |
| F-Value (Chi-Square) | 67.3* | 61.1* | 59.2* | 53.8* |
| Log likelihood | 250.55* | 198.1* | 278.5* | 181.2* |
| N | 89 | 89 | 26 | 26 |

1/ Values in parenthesis are asymptotic t-values.
* and ** indicate statistical significance at 1 and 5 percent respectively.

In peasant economies, children are brought up learning methods of raising livestock and growing crops from childhood (Sperling, 1987). They are taught the practices of production and management of enterprises which parents believe profitable. Thus, the number of years that children spend under the control of their parents (depenexp) exerts a relatively greater impact on milk efficiency scores in the Selale region, and on crop efficiency scores in the Ada region. This impact is strengthened by the number of years of farming experience after marriage or becoming an independent farmer (indepexp).

The empirical results indicate that different combinations of innovations affect production efficiency of households differently. Despite the combination of innovations, most of them affect efficiency scores positively and significantly. A combination of two or more innovations show a consistently large and significant effect on relative measures of production efficiency in Ada region. However, Selale farmers would attain greater efficiency if they adopt one or two technologies. In general, the model performed well and most variables significantly influence variations in production efficiency.

**Summary**

The results of frontier production function analysis indicate that Ada farmers exhibit relatively higher efficiency scores in cereal production compared to Selale producers. Test farmers of both study sites show higher efficiency scores than control farmers. Most Selale farmers are efficient in milk production compared to Ada producers.

The results of tobit regressions indicate that magnitude of the impacts of knowledge- related variables (i.e., production knowledge and schooling) on production efficiency are relatively higher than other variables. The region variable contributes negatively to cereal production efficiency in the Selale and to milk production efficiency in the Ada region. The implications of these findings is that the hypothesis that the success of intervention strategies is determined by appropriate selection of technological packages, that recognize the skills and the comparative advantages of regions in the production of specific crops or livestock. That is, for technological intervention strategies to succeed, policy makers should identify what kind of crop and/or livestock production technologies contribute the most to production efficiency and whether or not those technologies make use of physical (e.g., land) and non-physical (skill) resource endowment of producers and regions. It is only when strategies are designed on such kind of substantive evidence coupled with social and cultural acceptability, and environmental and/or technological feasibility studies that sustainable increases in food production attained.

Considering the impact of years of education and production knowledge on differences in relative production efficiency, policy makers should examine ways of integrating indigenous agricultural knowledge and knowledge gained from secular education so that the skill with which peasants make decisions would contribute to greater increases in crop and livestock production.

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**Appendix 1. Maximum Likelihood Estimates of Stochastic Frontier Production Function for Milk**

| | Selale region | | Ada region | |
|---|---|---|---|---|
| Variables | Test Farmers | Control Farmers | Test Farmers | Control Farmers |
| Intercept | 5.8 | 5.31 | 3.71 | 4.96 |
| | (3.36)** | (3.86)** | (1.97)* | (4.64)** |
| Grazing | 0.71 | 0.62 | 0.32 | 0.29 |
| | (2.75)** | (2.15)* | -1.91 | -1.22 |
| Stubble | 0.31 | 0.48 | 0.32 | 0.44 |
| | (2.09)* | (1.99)* | (2.53)** | (2.21)** |
| No. of cows | 0.75 | 0.65 | 0.49 | 0.44 |
| | (3.87)** | (3.09)** | (2.36)** | -1.81 |
| Labour | 0.66 | 0.53 | 0.35 | 0.29 |
| | (2.36)** | (2.49)** | -1.73 | -0.59 |
| Roughages | 0.46 | 0.49 | 0.34 | 0.36 |
| | (2.58)** | (2.96)** | (2.59)** | (2.04)* |
| Concentrates | 0.49 | 0.38 | 0.58 | 0.41 |
| | (2.29)** | (2.07)* | (2.96)** | (2.01)* |
| Lamda | 11.29 | 4.33 | 3.25 | 3 |
| | (4.12)** | (3.12)** | (2.98)** | (2.01)* |
| Likelihood ratio | 150.55 | 168.11 | 128.5 | 158.2 |
| N | 88 | 127 | 25 | 26 |

1/ Values in parenthesis are t-statistics.
* and # indicate statistical significance at 1 and 5 percent respectively.

**Appendix 2. Maxi**
**mum Likelihood Estimates of Stochastic Frontier Production Function**
**for Cereals**

| | Selale region | | Ada region | |
|---|---|---|---|---|
| Variables | Test Farmers | Control Farners | Test Farmers | Control Farners |
| Intercept | 1.61 | 1.56 | 1.99 | 1.78 |
| | (2.28)** | (2.79)** | -1.29 | -1.36 |
| Plot size | 0.66 | 0.55 | 0.76 | 0.79 |
| | (3.18)** | (3.01)** | (2.41)** | (2.95)** |
| Oxen | 0.59 | 0.55 | 0.51 | 0.67 |
| | (2.42)** | (1.96)* | (1.98)* | (2.38)** |
| Seed rate | 0.49 | 0.45 | 0.54 | 0.26 |
| | (2.01)* | -1.66 | (1.98)* | -1.38 |
| Labour | 0.59 | 0.73 | 0.52 | 0.88 |
| | (2.42)** | (1.88)* | (1.97)* | (2.01)* |
| Fertilizer | 0.78 | 0.54 | 0.76 | 0.72 |
| | (1.97)* | -1.66 | (2.84)** | (2.09)* |
| Pesticide | 0.34 | 0.35 | 0.39 | 0.33 |
| | -1.47 | (1.13)* | -1.81 | -1.46 |
| Plot characteristics | -0.28 | -0.39 | 0.58 | 0.51 |
| | (-0.65) | (-1.98)* | (1.85)* | (2.01)* |
| Lamda | 5 | 3.33 | 10.75 | 6 |
| | (2.91)** | (2.0)* | (3.01)** | (1.99)* |
| Likelihood ratio | 143.15 | 208.2 | 128.05 | 183.5 |
| N | 88 | 127 | 25 | 26 |

* and ** indicate statistical significance at 1 and 5 percent respectively.