TECHNICAL EFFICIENCY OF PEASANT FARMERS IN NORTHERN ETHIOPIA: A STOCHASTIC FRONTIER APPROACH

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Abstract

Schultz's popular *'poor-but-efficient hypothesis':* the idea that peasant farmers in traditional agricultural settings are reasonably efficient in allocating their resources and they respond positively to price incentives; triggered a number of empirical work on efficiency of small farmers. If farmers are reasonably efficient, then increases in productivity require new inputs and technology to shift the production frontier upward. If, on the other hand, there are significant opportunities to increase productivity through more efficient use of farmers' resources and inputs with current technology, then a better allocation might be essential.

Several different approaches could be applied to measure and compare the efficiency. We have chosen for the output-oriented or primal approach, where the central issue is by how much output could be expanded from a given level of inputs. For empirical analysis we used a farm dataset referring to the 1996 and 1997 production years from stratified sample of peasant farmers in Tigrai, northern Ethiopia. We analyzed both technical efficiency and factors of inefficiency simultaneously. Our findings showed productivity differences among farmers are dominated by the symmetric error term rather than the one-sided error term, suggesting the discrepancy between the observed level of output and the maximum attainable level of output is dominated by random factors outside the control of the farmer rather than technical inefficiency.

Key words: technical efficiency, stochastic production frontier, peasant farmers, northern Ethiopia.

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1. INTRODUCTION

The concept of efficiency has its origin with Farrel (1957). Most of the research on efficiency of small farmers, however, has been triggered by Schultz's (1964) popular *'poor-but-efficient hypothesis'*; the idea that peasant (small) farmers in traditional agricultural settings are reasonably efficient in allocating their resources and respond positively to price incentives. As the choice of development strategy, even if not fully, at least partly rests on the policy makers' conceptions of farm/ farmer-level performances; the level of efficiency of peasant (small) farmers indeed has important implications for choice of development strategy. If farmers are reasonably efficient, then increases in productivity require new inputs and technology to shift the production possibility frontier upward. But, on the other hand, if there are significant opportunities to increase productivity through more efficient use of farmers' resources and inputs with current technology, a stronger case could be made for productivity improvement through overcoming factors causing the inefficiency. The majority of the empirical works, however, appear to be supporting Schultz's hypothesis which presumably led to increasing emphasis by policy-makers on investments in new technologies and inputs rather than efforts aimed at improving the efficiency of less efficient farmers. Nevertheless, the extent to which peasant farmers in traditional agriculture settings behave consistently according to basic economic rationale still appears controversial (Woldehanna, 2000:1).

In Ethiopia agriculture still plays a major role in the economy of the country and considerable resources are invested on modern inputs and technology packages delivery under the agricultural extension program especially during the last two decades. Nevertheless, empirical evidence on farmer-level efficiency is very scanty and little work has been done in that respect in Ethiopia. Belete et al (1993), Admassie and Heidhues (1996), and Hailu et al, (1998) appear to be among the few to mention. Belete et al (1993) and Admassie and Heidhues (1996) both pertain to central highlands of Ethiopia. Belete et al (1993) tried to explore the possibilities for improving production and income of small farmers through better allocation of resources under alternative animal cultivation (work oxen acquisition) practices. The study, however, considered a deterministic setting. Such a specification ignores the fact that output can be affected by random shocks outside the control of the farmer. The problem with this approach is that the entire shortfall of observed output from maximum feasible output is attributed to technical inefficiency.

Admassie and Heidhues (1996) tried to separately determine and compare the level of technical efficiency of two groups, one representing modern technology users and the other consisting of relatively traditional farmers that do not use modern technology using a stochastic frontier production function. The fact that both Admassie and Heidhues (1996) and Hailu et al, (1998) used stochastic frontier approach gives them similarity. Hailu et al, (1998) was different from the former two in a sense that it tried to investigate the level of inter-farm technical efficiency gap for sample smallholder farmers representing eastern highlands (Oromia region) of Ethiopia. However, both of these two works failed to determine the factors of inefficiency. Moreover, despite that peasant farmers in Ethiopia and elsewhere in the developing world are constrained by a host of factors including capital shortage, problem of draft power, as well as small and fragmented land holding; Belete et al [1993] considered only the problem of draft power. It would be more appealing, however, when all these factors are incorporated into the model and let the model determine as to which of these host of factors are most important ones.

The motivations of this paper are, therefore, twofold: one, to measure technical efficiency of peasant farmers in northern Ethiopia using stochastic frontier approach; and, two, to determine factors causing inefficiency. The novelty in here is that, firstly, it broadens our knowledge about farmer-level technical efficiency by providing insights from northern Ethiopia. Secondly, it tries to analyze both technical efficiency and factors of inefficiency simultaneously which happen to be a rare case in the literature. The rest of the paper is organized as follows. The next section reviews the role and performance of the agricultural sector in Ethiopia. Section three presents the theoretical framework employed in the study. Section four empirical procedure and data. Section five provides empirical results. Section six draws some concluding remarks.

2. AGRICULTURE IN ETHIOPIA: ROLE AND PERFORMANCE

Ethiopia is typically an agrarian country. Agriculture contributes over 40 percent of GDP, about 80percent of employment, over 80 percent of commodity export earnings and 70 percent of raw materials supply for agro based industries. Except for the lowlands and nomadic areas, mixed crop-livestock farming appear to be the dominant farming strategy in the country. Eighty-one percent of the peasant farmers particularly in the Ethiopian highlands practice mixed farming. Crop production contributes over 50 percent to agricultural GDP and the rest comes mainly from livestock sub-sector. The bulk of the agricultural output, i.e., well over 90 percent of the total agricultural output, comes from individual peasant / smallholder farmers. Cereals mainly *teff*, maize, sorghum, wheat, and barley are the most important crops in the country in terms of land area allocated. For example, they accounted for over 75 percent of the total area under crops in 1997 (see Appendix A1).

Similarly in Tigrai, agriculture and allied activities (crop, livestock and forestry) have the largest contribution to regional GDP (Gross Domestic Product). Its average share for the last five years, i.e., during fiscal years 1995/96 to 1998/99, has been 57% in real terms. Within the agricultural value added, crop and livestock constitute the greatest share; with nearly 95 percent in the regional agricultural GDP and 54 percent in the total regional GDP. Within the overall regional GDP crop and livestock constitute 40 and 14 percent, respectively. Crop production in the region is cereal dominated. Cereal crops account for 84 percent of the cultivated land, while oil crops and pulses constitute 9 percent and 7 percent, respectively. Perennial crops constitute less than 1 percent of the cultivated land. Regionally speaking, sorghum, barley and teff are the three most import cereal crops in terms of area coverage (Table 9). However, the role may differ or be the other way around depending on area specific conditions.

In spite of its importance the performance of the country's agricultural sector, however, has been low and its growth failed to keep pace with the growing population particularly since the last four decades of the twentieth century (See Appendix A2). Per capita food production is still low. Some of the important indicators of the performance of agriculture sector in the country has been provided in Appendix A3. As a result, domestic supply problems and food aid dependence has been the typical manifestations of the country. Average land productivity over the past decades was 1.2, 0.6, and 0.5 tons per ha for food grains, pulses and oil seeds, respectively, which is low by many standards. The fact that agriculture is largely traditional and rain fed, that weather conditions play an important role could be one reason for the low performance. However, it might also be the case that efficiency differences among peasant farmers emanating from various influences also contribute to the poor performance of the sector.

3. THEORETICAL FRAMEWORK

Several different methods could be applied for measuring and computing technical efficiency.[4] However, the two most important approaches to the measurement of technical efficiency are: the output-oriented approach (often referred to as primal approach) and input-oriented approach (often referred as dual approach). In the primal approach the interest is by how much output could be expanded from a given level of inputs, hence known as output-shortfall. Whereas in the input-oriented approach the concern is the amount by which all inputs could be proportionately reduced to achieve technically efficient level of production, hence, known as input

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[4] See e.g. Fried, Lovell and Schmidt (eds), 1993 for an overview.

over-use. We prefer the primal approach because output short-fall is most characteristic for agriculture in developing countries.

Consider a situation where we have observations on I peasant farmers indexed i=1,..., I, with $x = (x_1,...,x_N) \geq 0$ vector of inputs used to produce an aggregate output $y \geq 0$. Then, the stochastic production frontier model could be specified as

$$y_i = f(x_i;\beta).e^{\phi} \tag{1}$$

where $f(x_i;\beta)_i$ and e^{ϕ}, respectively, represent the deterministic part and stochastic part of the production frontier, ϕ represents the random error term, and β is a vector of parameters to be estimated.

Besides allowing for technical inefficiency such stochastic production frontier models also acknowledge the fact that random shocks outside the control of the farm operator can affect output. But more importantly, the stochastic production frontier models provide a great virtue that the impact on output of shocks due to variations like in weed infestation, etc can at least in principle be separated from the contribution of variation in technical efficiency (Kumbhakar and Lovell, 2000).

The total error term in (1) could be decomposed into its respective two components as:

$$\phi_i = v_i + u_i \tag{2}$$

where v is the symmetric error term accounting for random variations in output due to factors outside the control of the farmer such as weather, disease, plain bad luck, measurement error, etc. Where as u represents the technical in/efficiency relative to the stochastic frontier and assumes only positive values.

The distribution of the symmetric error component v is assumed to be independently and identically as $N(0,\sigma_v^2)$. Such normal error term provides the production frontier to be stochastic and, hence, allows the frontier to vary across or over time for the same producer. However, the distribution of the one sided component u is assumed to be half normal. That is, it is assumed to be identically and independently distributed as $N^E(0,\sigma_u^2)$ and it follows that:

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

where σ^2 is variance of the composed error term ϕ and it says that the variance of the composed error term is the sum of the variances of symmetric error term v and the one sided component u.

Following Kumbhakar and Lovell (2000), the *stochastic* production frontier in (1) could also be rewritten as

$$y_i = f(x_i;\beta).\exp\{v_i\}.TE_i \tag{4}$$

where the stochastic production frontier $[f(x_i;\beta).\exp\{v_i\}]$ consists of two parts: a deterministic part common to all producers and a producer specific part *exp{v_i}*, which captures the effect of random noise or shock on each producer. Therefore,

$$TE_i = \frac{y_i}{f(x_i;\beta).\exp\{v_i\}} \tag{5}$$

defines technical efficiency as the ratio of observed output to maximum feasible output in an environment characterized by $\exp\{v_i\}$. Equation (5) implies that y_i achieves its maximum feasible value of $[f(x_i;\beta).\exp\{v_i\}]$ if and only if $TE_i = 1$. Otherwise, $TE_i < 1$ provides a measure of the short-fall of observed output from maximum feasible output in an environment characterized by $\exp\{v_i\}$ which varies across peasant farmers and β, as in above, is vector of parameters to be estimated.

Assuming that $f(x_i;\beta)$ takes the log-linear Cobb-Douglas form, then the stochastic production frontier model in Equation (1) could be rewritten as

$$\ln y_i = \ln f(x_i;\beta) + v_i - u_i \tag{6}$$

where $\phi_i = v_i - u_i$ is the composed error term (Aigner et al, 1977) which is asymmetric. The two-sided 'noise' component v_i $(v \sim N(0,\sigma_v^2))$ and the one-sided efficiency component $u_i \geq 0$ with half-normal distribution $(u \sim |N(0,\sigma_u^2)|)$ are assumed to be independent of each other. Once the model is specified, maximum likelihood estimation of Equation (6) or using the Corrected Ordinary Least Square (COLS), yields estimators for β and λ, where β is as defined earlier, $\lambda = \sigma_u^2 / \sigma_v^2$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$ as defined in Equation (3).

As it could be envisages, the parameter λ is an indicator of the relative variability of the two sources of variations. If λ is closer to zero the symmetric error term dominates the variation between the frontier/ maximum attainable level of output and the observed level of output. Or put differently, a value of λ close to zero implies that the discrepancy between the observed and the maximum attainable levels output is dominated by random factors outside the control of the producer. Otherwise, the more λ is greater than one the more the production is dominated by variability emanating from technical inefficiency.

Once the parameters of the stochastic frontier model are estimated using ML, or OLS, then the Jondrow et al (1982) decomposition technique/ estimators can be used to obtain farmer-specific estimates, $\hat{u}_i$. That is, following Jondrow et al (1982), the above mentioned assumptions on the statistical distributions of v and u would allow us to generate the conditional mean of u_i given ϕ_i as:

$$E(u_i / \phi_i) = \sigma * \left[\frac{f * (\phi_i \lambda / \sigma)}{1 - F * (\phi_i \lambda / \sigma)} - \frac{\phi_i \lambda}{\sigma} \right] \qquad (7)$$

where $F*(.)$ and $f*(.)$ respectively, are the standard normal cumulative and standard normal density functions, evaluated at $\phi_i \lambda / \sigma,$ for λ as defined in above. So that, Equations (6) and (7) provide estimates for v and u after replacing $\phi,\ \sigma, \text{and}\, \lambda$ by their estimates and using equation (2).

As the motive in here is also to determine factors contributing to inefficiency besides understanding farmer-level technical efficiency, we need to take explicit account of these factors in our model. Now let's assume that $z = (z_1, ..., z_Q)$ represent the vector of exogenous factors affecting technical inefficiency, which might include extension contact, involvement in off-farm employment, age, and gender in the case of peasant farmers we are interested in.

Generally, the two-step approach[5] and the 'direct' or ‘single step’ approaches appear to be the two major approaches that could be pursued to determining or identifying the factors affecting technical inefficiency in agricultural production. We followed the second approach, that is, the ‘direct’ or ‘single step’ approach. In the ‘direct’ or ‘single step’ approach the exogenous factors affecting technical inefficiency are included directly in the production function, and specified as

$$\ln y_i = \ln f(x_i, z_q; \beta) + v_i - u_i \tag{8}$$

If we assume that the z_q variable is measured in log, the marginal effect of a z variable on output could be determined as

$$\frac{\partial \ln y}{\partial \ln z_q} = \gamma_q \tag{8a}$$

which also implies

$$\frac{\partial y}{\partial z_q} = \gamma_q \frac{y}{z_q} \tag{8b}$$

In this approach z will, presumably, have two effects: one, it shifts the production technology, upward or downward, depending on the sign of γ; two, it increases or decreases output through reducing or increasing technical inefficiency.

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[5] The two-stage approach often involves a two step procedure. In the first step, the model like Equation (6) is estimated under the assumptions that hold with no z variables included and, then, Jondrow et al (1982) estimators used to obtain farmer-specific estimates, $\hat{u}$. In the second step, $\hat{u}$ is regressed on the vector of z variables. That is, run OLS $\hat{u}$ on an intercept and some z variables to obtain estimates of γ. Unfortunately, this approach has serious drawbacks: Firstly, it is assumed that the elements of z_q are uncorrelated with the elements of x_i. ML estimates of $(\beta, \sigma_v^2, \sigma_u^2)$ from Equation (6) under such assumption are biased and inconsistent, unless the x and z variables are true orthogonal. Secondly, in the first step, (as in assumption (8a) below), the mean of u is assumed to be zero and there appears no z variable. But in step two, the attempt is to explain u using a set of z variables which is a contradiction. (Kumbhakar and Lovell, 2000)

4. EMPIRICAL PROCEDURE AND DATA

4.1 Empirical procedure

A Cobb-Douglas functional form which includes both the conventional inputs and exogenous factors affecting inefficiency was the one considered in our analysis. Despite its restrictive assumptions, we found the Cobb-Douglas functional form to better fit the data. The specific model estimated was:

$$\ln Y = \beta_0 + \beta_i \ln L + \beta_2 \ln R + \beta_3 \ln X + \beta_4 M + \beta_5 Oxen + \gamma_1 Age_2 + \gamma_2 Age_3 + \gamma_3 Age_4 + \gamma_4 Crd + \gamma_5 Gen + \gamma_6 Off + \phi \,. \tag{9}$$

As it could be clear from Equation (9), three categories of variables have been considered in the model; output variable, *x*-variables or the conventional inputs and *z*-variables or exogenous factors assumed to affect inefficiency. The details of the variables considered and their measurement has been provided in Table 1, below.

Farm labour input (L), area of land cultivated (R), modern inputs (X), value of owned farm implements (M), and number of oxen (Ox) were the variables considered as regards to the conventional inputs. Considerable resources are being committed through the extension program, to increase modern inputs (fertilizer, seed, pesticides, etc) utilization of peasant farmers, with more emphasis given to improving production through increasing fertilizer consumption rate of farmers and credit provision. Hence, it would be worthwhile to assess whether these efforts would bring about the desired outcome. Following the arguments behind the variable modern inputs was hypothesized to be positively related to output, although the issue is debatable (Taylor and Shonkwiler, 1986). Extension contact was assumed to be implicit in the variable X (modern inputs), in the use of modern inputs such as fertilizer and, hence, excluded from consideration to avoid co-linearity. Number of oxen was hypothesized to have positive effect on efficiency. Considerable number of peasant farmers in the area do not own ox. Most often, farmers who have one ox plow their fields by joining hands with others / peer. It could be envisaged that lack of adequate draught power leads to delay and poor land preparation, inefficient farm operations and late planting with a major depressing effect on yield.

Access to credit, age of farmer, gender, and involvement in off-farm employment constitute z-variables considered in the model. The choice of such particular z-variables was largely based on economic arguments. Access to credit offers a characterization of the degree of market development or competitiveness.

Consideration was also made only for age of farmer and education of farmer was excluded from consideration because of the absence of significant difference in level of education among the peasant farmers considered. The effect of age of farmer on efficiency was anticipated to be either positive or negative; as age increases there is an experience effect which is efficiency increasing (potentially). However, as the old age is approached the capacity to do work might decrease. Old aged farmers are also less receptive to new technologies, implying negative relationship. To capture these different effects, four categories of age of farmer were specified (Table 1). The effect of age was measured visa-vis those with less or equal to forty years. Gender of farmer as specified in the model was anticipated to be negatively related to efficiency. It might appear that nothing could be done to influence gender per se. However, differences in resource endowments along gender lines and discriminatory cultural traditions might be expected to induce differences in efficiency across gender, for which an appropriate intervention could be designed. The argument is that, firstly, women in the area do not carry on plowing by themselves. The practice is either they rent out their land for sharecropper or look for somebody/ relative who does the plowing operation, which affect timely operation and/ or size of harvest. Secondly, women might have constrained access to credit and modern inputs for various reasons which also confer the negative relationship.

The effect of involvement in non-farm activities on efficiency might possibly be mixed, that is, both positive and negative. By acting as a residual sector that absorbs the workers who cannot be readily absorbed in agriculture, the rural non-farm sector might contribute to improved farm productivity of peasant households, through its income effect, by relaxing their capital or liquidity constraint and allowing the purchase of inputs such as farm labor, seeds, fertilizer and pesticides (Woldehanna, 2000). That is, in situations of the existence of surplus or unused labor and wage income from off-farm employment being, at least partly, reinvested in agriculture, a positive effect on efficiency might be anticipated. On the other extreme, when there is no surplus or unused labor and involvement in off-farm activities competes with labor for agriculture, it could be the case that it has negative effect on efficiency. On the balance, the net effect of involvement in non-farm activities was hypothesized to be either positive or negative, depending on the relative magnitude of the two effects.

Once the model is specified in such a way, as in Equation (9), then Coelli's Frontier package (Coelli, 1996) could be used to carry on the estimation and derive the parameter estimates $\beta \text{ and } \gamma$ as well as farmer-specific technical efficiency. The very reason that we followed this second approach is to come by the aforementioned drawbacks of the two-stage approach. We used STATA, frontier models for Maximum Likelihood estimation and OLS estimation. To take care of the zero value for some of the right hand-side (RHS) variables, a nearly zero positive decimal number was considered.

4.2 Data Description

The dataset used in this paper come from a random sample of peasant farmers in northern Ethiopia. A two period (two production year) data from 201 cross-sections of peasant households was obtained. However, 25 cross-sections were excluded due to zero values of left hand-side (LHS) variable. The data set refers to 1996 and 1997 production years and farmers in the sample are located particularly in *Enderta* and *Hintalo-Wajerat* districts of the Tigrai region. The description of the dataset has been provided in Table 2. About 13 percent of the households considered were females.

Peasant households in the area are involved in farm and off-farm activities. About 36 percent of the peasant households were found to be involved in off-farm activities. Mixed crop-livestock farming is the dominant system in the area. Crops grown by peasant farmers include lentils, vetch, linseed, and vegetables with barley, wheat, teff, and sorghum being the four most important crops in order of importance. Most of the peasant agriculture is practiced under rain-fed condition.

5. EMPIRICAL RESULTS

The maximum likelihood parameter estimates of the stochastic Cobb-Douglas production frontier (i.e., equation 9) are presented in Table 3. OLS estimation results have also been provided for comparison. The ML estimates of β parameter show that from among x-variables (the conventional inputs) the variables land, modern inputs, and value of owned farm implements were found to be significant, all with positive signs whereas labor and number of oxen turned out to be insignificant. Given that coefficients could be interpreted as elasticties, due to Cobb-Douglas specification, our results imply that a 1 percent increase in land input/area by, ceteris paribus, increases output about 0.42 percent.

The value of λ, i.e., the ratio of the variances of v_i and u_i for peasant farmers in the study area, reported as 0.591 (which is <1) shows that the symmetric error component dominates the one sided error term. This implies that the discrepancy between the observed level of output and the maximum attainable level of output is dominated by random factors outside the control of the farmer rather than technical inefficiency.

ML estimates of the γ parameters also showed that among all the variables considered the variables age and involvement in off-farm activities were significant. Whereas the variables access to credit, and gender of farmer found to have no significant impact on inefficiency. Also the sign of parameter estimate for gender turned out to be positive contrary to what was expected. The parameter estimate for the variable off-farm activities was significant but negative. Although up to expectation, this was in a way contrary to earlier finding (Woldehanna, 2000).

6. DISCUSSION AND CONCLUSIONS

In Ethiopia agriculture still plays a major role in the economy of the country and considerable resources are invested on modern inputs and technology packages delivery under the agricultural extension program especially during the last two decades. Nevertheless, empirical evidence on farmer-level efficiency is very scanty and little work has been done in that respect in Ethiopia. Belete et al (1993), Admassie and Heidhues (1996), and Hailu et al, (1998) appear to be among the few to mention. Belete et al (1993) tried to explore the possibilities for improving production and income of small farmers through better allocation of resources under alternative animal cultivation (work oxen acquisition) practices. The study, however, considered a deterministic setting. Such a specification ignores the fact that output can be affected by random shocks outside the control of the farmer. The problem with this approach is that the entire shortfall of observed output from maximum feasible output is attributed to technical inefficiency.

Moreover, despite that peasant farmers in Ethiopia and elsewhere in the developing world are constrained by a host of factors including capital shortage, problem of draft power, as well as small and fragmented land holding; previous studies (cf., Belete et al 1993) considered only the problem of draft power. It would be more appealing, however, when all these factors are incorporated into the model and let the model determine as to which of these host of factors are most important ones.

This paper attempted to derive farmer-specific technical efficiency and simultaneously determine the socioeconomic factors affecting inefficiency for a sample of peasant farmers from northern Ethiopia using a stochastic frontier approach. The analysis was performed for the aggregate value of annual crop output. The coefficient estimates of the β parameters showed that the parameters for the variables land, modern inputs, and value of owned farm implements are significant among the conventional inputs, all with positive signs whereas labor and number of oxen turned out to be insignificant. Given that coefficients could be interpreted as elasticity, due to Cobb-Douglas specification, our results imply that a 1 percent increase in land input/area, for example, ceteris paribus, increases output by about 0.42 percent. Increasing modern inputs use by 1 percent would also, ceteris paribus, improve output by 0.012 percent.

The value of λ, i.e., the ratio of the variances of v_i and u_i for peasant farmers in the study area, reported as 0.591 (which is <1) shows that the symmetric error term dominates the one sided error term, which implies that the discrepancy between the observed level of output and the maximum attainable level of output is dominated by random factors outside the control of the farmer rather than technical inefficiency.

ML estimates of the γ parameters also showed that among all the variables considered the variables age and involvement in off-farm activities were significant. However the interpretation may not be as straight forward as in the variables specified in logs. Whereas the variables access to credit, and gender of farmer found to have no significant impact on inefficiency. That is, technically speaking gender of farmer was found to have no significant effect on inefficiency. This could probably be because share cropping arrangements in the study area are reasonably efficient. Involvement in off-farm activities was found to have significant negative effect on farm production. May be because, on the balance the labor competing effect of involvement in off-farm activities outweighs the liquidity relaxing (income) effect.

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Table 1: Definition and measurement of variables considered in equation (9)

Variable category	Variable name	Measurement method
Output[6]	Aggregate crop output (Y)	Value of crop output in *Birr*
x-variables (conventional inputs)	(i) Labour (L)	Quantity of farm labour hours worked
	(ii) Land cultivated (R)	Area in '*tsimdi*'[7]
	(iii) Modern inputs (X)	Value in *Birr*[8]
	(iv) Farm implements (M)	Value of owned implements in *Birr*
	(v) Number of oxen (Ox)	Number of owned oxen
z-variables (exogenous factors)	(i) Access to credit (Crd)	As a dummy variable having a value of 1if yes, 0 otherwise
	(ii) Age category of farmer	
	Age$\leq$40 (Age$_1$)	As a dummy variable having a value of 1if yes, 0 otherwise
	Age>40$\leq$50 (Age$_2$)	Same as above
	Age>50$\leq$60 (Age$_3$)	Same as above
	Age>60 (Age$_4$)	Same as above
	(iii) Gender of farmer (Gen)	As a dummy variable having a value of 1if female, 0 otherwise
	(iv) Off-farm activities (Off)	As a dummy variable having a value of 1 if the farmer is involved in off-farm activities including food for work, 0 otherwise

Table 2: Description of the data set (n=352)

Variables	Mean	Std. Dev.	Min	Max
Age of household head	48	11.83	25	76
Labour	1897	592	0	4880
Area of land cultivated (in *tsimdi*)	7.06	4.7	0.8	24
Value of owned farm implements	237.62	185.71	8	1,427
Total livestock wealth	3,616	5,298	0	63,700
Value of modern inputs	72..99	147.85	0	1075
Number of oxen owned	1.55	1.09	0	6
Value of crop output	1,962.04	1,911.46	350	15,000

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[6] We considered/ concentrate only on crop output

[7] *tsimdi* is a local area unit 1*tsimdi*=0.25ha

[8] *Birr* is Ethiopian currency currently 1USD=8.66*Birr* and 1USD=7.00 *Birr* during the period the data was collected.

Table 3: Estimation results (standard error in parenthesis)

Variable	*Estimator*	
	OLS	***MLE***
Labor	*0.093* *(0.157)*	*0.104* *(0.141)*
Land	*0.498**** *(0.072)*	*0.419**** *(0.066)*
Modern inputs	*0.006* *(0.006)*	*0.012*** *(0.005)*
Value of owned farm implements	*0.237**** *(0.069)*	*0.225**** *(0.062)*
Number of oxen owned	*0.066* *(0.072)*	*0.074* *(0.064)*
Access to credit	*-0.004* *(0.036)*	*0.010* *(0.032)*
Age category of farmer		
Age$\leq$40		
Age>40$\leq$50	*-0.040* *(0.044)*	*-0.040* *(0.039)*
Age>50$\leq$60	*-0.006* *(0.045)*	*0.014* *(0.041)*
Gender of farmer	*0.053* *(0.130)*	*0.053* *(0.117)*
Off-farm activities	*-0.186**** *(0.040)*	*-0.165**** *(0.036)*
Intercept	*2.013**** *(0.559)*	*2.178**** *(0.504)*
R^2	*0.445*	
σ^2		*0.070* *(0.088)*
σ_u^2		*0.026* *(0.088)*
σ_v^2		*0.044**** *(0.004)*
λ		*0.591*
F-value	*14.89*	
Prob>F	*0.000*	
Wald chi2 (11)		*180.23*
Prob>chi2		*0.000*
Log likelihood function		*28.333*

****, and ** means significant at 0.01 and 0.05 level (or better).*

Appendix A1 Estimates of area under all crops by size of holding for individual peasant holders in 1997/98 ('000 ha)

Size of holdings (ha)	Cereals								Pulses (total)	All annual crops	All perennial crops	All crops
	Teff	Barley	Wheat	Maize	Sorghum	Millet	Oats	Total				
Under 0.10	84.47	83.99	50.36	151.02	67.50	18.32	7.48	463.14	123.52	710.57	216.10	926.67
0.10-0.50	1,081.72	428.52	473.18	647.15	522.91	183.61	27.96	3,365.05	561.82	4.255.23	266.97	4,522.20
0.51-1.00	433.99	127.31	195.26	194.92	244.22	65.70	3.58	1,264.98	99.82	1,456.76	43.22	1,499.98
1.01-2.00	116.12	32.28	64.13	67.67	95.32	19.96	**	395.84	18.81	436.94	20.56	457.50
2.01-5.00	18.03	9.74	4.68	22.22	18.56	**	-	75.36	**	84.74	5.95	90.69
5.01-10.00	2.52	-	-	3.13	4.10	-	-	9.75	-	9.75	5.41	15.16
10.01 and above	10.30	-	-	13.75	1.77	-	-	25.82	29.19	54.79	-	54.79
Total	1,747.13	681.84	787.61	1,099.87	954.38	289.73	39.38	5,599.94	837.34	7,008.74	558.22	7,566.96

Source: CSA (1998)

Appendix A2: Average annual growth rates per period 1961-1999 (in %)

	1961-70	**1970-80**	**1980-91**	**1991-99**
GDP	4.4	1.9	1.6	4.1
Agriculture	2.2	0.7	0.3	2.4
Industry	7.4	1.6	1.8	4.2
Services	4.5	3.9	3.1	5.8
population	2.4	2.7	3.1	2.2

Source: Mekonen (1998), and World Bank (2001)

Appendix A3: Some indicators of agricultural performance during 1993-99

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**Average annual %age growth 93-99**
Food production index	98	98	108	125	126	116	123	4.3
Food production per capita index	90	87	94	106	104	94	97	1.7
Volume of food output, by major food crops ('000 metric tons)								
Sorghum	628	703	1,414	1,808	2,040	1,083	1,304	0.3
Maize	1,456	1,396	1,990	3,164	2,987	2,344	2,840	0.3
Barley	787	875	986	1,125	953	983	970	0.1
Sugarcane	1,700	1,200	1,200	1,582	1,490	1,650	2,200	0.2

Source: World Bank (2001)