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Influence of credit constraint on technical efficiency of farm households in Southeastern Ethiopia[*]

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Abstract

Credit constraint not only affects the purchasing power of farmers to procure farm inputs and cover operating costs in the short run, but also their capacity to make farm-related investments as well as risk behaviour in technology choice and adoption. These, in turn, have influence on technical efficiency of the farmers. Although credit constraint problem has been recognized in economics literature, especially in those dealing with developing countries, little emphasis has been given to its effect on productive efficiency of farmers. In light of this, explicitly considering credit constraint, this paper estimated technical efficiency of credit-constrained (*CCFH*) and unconstrained farm households (*CUFH*) by employing a stochastic frontier technique on farm household survey data from Southeastern Ethiopia. The *CCFH* had mean technical efficiency score of 12% less than that of the *CUFH*. Given the largest proportion of *CCFH* in Ethiopian farming population, this gap implies considerable potential loss in output due to inefficient production. Improving technical efficiency of all farm households in general but more of particularly the *CCFH* is desirable. Additional sources of inefficiency differential between the two groups were also identified, and education level of household heads, land fragmentation and loan size significantly affected technical efficiencies of both groups. Besides, wealth and experience affected the *CCFH*, and household size affected the *CUFH*. In general, the results have important implications for credit, education and land policies in developing countries.

Keywords: Credit market, stochastic frontier, technical efficiency, smallholders.

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1. Introduction

Credit is one of the components of financial services considered fundamental in all production circuits and networks – material and service products (Dicken, 2007). However, theories of production and finance developed along separate paths as if production and financial decisions could be precisely separated (Blancard et al., 2006), with little focus on their interactions. Recently, there has been a growing interest in understanding the impact of financial structure on production (e.g., Barry and Robinson, 2001). In some technical efficiency studies, production inputs and corresponding prices are assumed constant, which means that technical efficiency is independent of input use (Alvarez and Arias, 2004; Färe et al., 1990; Lee and Chambers, 1986; Farrell, 1957). Among others, this unrealistic assumption precludes the effect of technical efficiency on input demands (Alvarez and Arias, 2004) because it assumes away relative differences among producers in terms of resource endowments and possible constraints in acquiring additional inputs, which indirectly affect the capacity of producers to attain desired level of technical efficiency. In addition, short-term efficiency indices are estimated within a framework of a given production technology. This also ignores the fact that the capacity of farmers to choose appropriate and more efficient technologies can be constrained by bounds of their resources (e.g., Alene and Hassan, 2006), one of such bounds being credit constraints. However, it is a common knowledge that asymmetric information and incentive compatibility problems lead to capital market imperfections, which in turn bring about credit constraints faced by borrowers (Blancard et al., 2006; Stiglitz and Weiss, 1981). Given underdeveloped infrastructure, inadequate institutional environment, and less competitive market situation in developing countries, credit market imperfections are common phenomena. Of course, credit constraint is not only a problem of developing countries. As evidence from various studies (Blancard et al., 2006; Gloy et al., 2005; Jappelli, 1990; Tauer and Kaiser, 1988; Lee and Chambers, 1986) shows, farmers in developed countries, especially small farmers, also face credit constraints, since developed countries' credit markets are yet not as perfect as often assumed in standard economic theories. For example, Blancard et al.(2006) observed that 67% of the farmers in their sample of 178 French farmers were financially constrained in the short run. In light of this, the presence of credit constraints is less debatable than its extent in the literature (e.g., Pal, 2002; Bali Swain, 2002; Kochar, 1997). This is mainly because access to credit market may not be translated automatically into one's participation in the credit market, given considerable information asymmetry and incentive compatibility problems (Diagne and Zeller, 2001; Barry and Robinson, 2001), and taking loans may not also lead to automatic solution to credit constraints (Guirkinger and Boucher, 2005; Freeman et al., 1998). For example, Barry & Robinson (2001) argue that access to external financing resources being limited, farmers' operations and investments heavily depend on internal financing. Farmers in developing countries are internally also constrained due to meagre resources they command.

As much as credit is fundamental to the operation of all production circuits and networks (Dicken, 2007), on the contrary, credit constraint can have direct and indirect effects on, for example, farm production. Directly, it can affect the purchasing power of producers to procure farm inputs and finance operating expenses in the short run and to make farm-related investments in the long run; and indirectly, it can affect risk behaviour of producers (Guirkinger and Boucher, 2005; Eswaran and Kotwal, 1990), thereby affecting technology choice and adoption by farmers. In this connection, for example, Binswanger & Deininger (1997) argue that an unequal distribution of initial endowments in environments where financial markets are imperfect and credit is rationed can prevent a large proportion of the population from making productive investments. Thus, a credit-constrained farmer is more likely to invest in less risky and less productive rather than in more risky and more productive technologies (Dercon, 1996). This risk behaviour affects technical efficiency of the farmers, thereby limiting the effort of the farmer in attaining maximum possible output. The notion that a credit constraint influences agricultural production has long been observed in the literature (e.g., Blancard et al., 2006; Petrick, 2005; Barry and Robinson, 2001; Färe et al., 1990; Lee and Chambers, 1986); however, empirical studies of its influence on efficiency are generally limited, scarce in most developing countries and particularly lacking in Ethiopia. In particular, most previous efficiency studies in Ethiopia (Haji, 2007; Haji and Andersson, 2006; Alene and Hassan, 2006; Gavian and Ehui, 1999; Admassie, 1999; Hailu et al., 1998) used a dummy variable for access to credit, measuring whether or not farmers took credit in producing outputs. This implicitly assumes that farmers who obtained loans would have their effective credit demand satisfied and would become credit-unconstrained. Obviously, this will not disentangle the difference between borrowing status and credit constraint condition (Diagne and Zeller, 2001; Freeman et al., 1998). Using a dummy variable in this way can only allow capturing whether or not the farmer had access to a credit facility or had obtained the credit. It does not show whether access to credit satisfies effective credit demand and alleviates credit constraints of the farmers or not. For example, Freeman et al. (1998) noted absence of relationship between farmers' borrowing and credit constraint status in Ethiopia, and suggested that significant proportion of those with some amount but inadequate loans still faced credit constraint in their economic activities. This also suggests that one needs to look into credit transactions and learn more from the borrowers in order to assess their credit constraint status (Boucher et al., 2005; Iqbal, 1986), and this paper used this approach.

In light of the preceding arguments, this study estimated technical efficiency of credit constrained (CCFH) and unconstrained farm households (CUFH) by disaggregating the full sample on the basis of credit-constraint status of the farm households, and identified factors additionally affecting their technical efficiencies. Results indicate that the CCFH had mean technical efficiency score of 12% less than that of the CUFH. Given the largest proportion of CCFH in Ethiopian farming population, the gap is a considerable potential loss in output due to technical inefficiency, which the country cannot afford to ignore because of the food deficit problem it has currently faced. The result suggests that improving technical efficiency of all farm households in general and more of the CCFH in particular is desirable. Beyond the country in focus, i.e., Ethiopia, the results have important implications for credit, education, and land policies in developing countries, where credit constraints are also widely observed. The rest of the paper is constructed as follows. Related theoretical and empirical literature is briefly reviewed in the next section. In section 3, the theoretical framework of technical efficiency is presented, followed by the empirical model in section 4. Describing the data in section 5, results and discussion are presented in section 6. Finally, conclusions and policy implications are suggested.

2. Credit constraint, access to credit market, and efficiency effect: review of literature

Credit market literature distinguishes between access to credit and participation in credit markets (e.g., Diagne and Zeller, 2001). A farm household has access to credit from a particular source if it is able to borrow from that source, whereas it participates in the credit market if it actually borrows from that source of credit. This implies that access to credit can be a constraint externally imposed on the farm households, while participation in a credit market is a choice made by a farm household. Thus, a household can have access but may choose not to participate in the credit market for such reasons as expected rate of return of the loan and/or risk consideration. In this connection, Eswaran & Kotwal (1990) argue that a non-participating household that has access to credit will still benefit if the knowledge of access increases its ability to bear risk, as it can be encouraged to experiment with riskier, but potentially high-yielding technology. The ability to borrow will also alleviate the need for accumulation of assets that mainly serve as precautionary savings, yielding poor or negative returns (Deaton, 1991).

Duca & Rosenthal (1993) argue that a farm household is credit constrained only when it would like to borrow more than lenders allow or if its preferred demand for credit exceeds the amount lenders are willing to supply. Stiglitz & Weiss (1992), on the other hand, describe credit constraints in two terms -- redlining and credit rationing. Redlining refers to excluding certain observationally distinct groups from credit markets, rather than offering them a contract that require higher interest payments and collateral guarantee. Credit rationing refers to a situation in which, among observationally identical borrowers, some get loans and others are denied.

Zeller et al. (1997) distinguish four groups of farm households in relation to credit constraints. The first, referred to as voluntary non-borrowers, are those who decline to borrow at will either because they have strong risk aversion and fear of getting into debt or because they are prudent and only would like to consume up to what they earn. Others who want to borrow less than their combined available credit lines from all lenders referred to as non-rationed borrowers. Rationed borrowers are those who want to borrow more than their available credit limit at a particular point in time. The last type of farm households, referred to as involuntary non-borrowers, are non-borrowers with no access to credit, or those who perceive that they are highly unlikely to get credit, so that the perceived borrowing costs outweigh the expected benefits of the loan.

On the supply side, quantity, transaction costs and risks are identified as relevant factors in the existing credit market literature (e.g., Feder, 1985; Foltz, 2004). First, farm households are credit-constrained if they face a binding supply constraint as limited by lenders' considerations. Second, as lenders may pass on transaction costs associated with screening, monitoring, and enforcing loan contracts to borrowers, as in the case of group lending scheme (Besley and Coate, 1995), farmers with investments profitable when evaluated at the contractual interest rate may not be profitable when transaction costs are factored in. Thus, they may decide not to borrow but remain credit-constrained. Finally, for households with access to credit, risk may reduce loan demand and hence productivity. For example, Boucher et al. (2005) analytically show that in the presence of moral hazard lenders require borrowers to bear some contractual risk, and if this risk is sufficiently large, farmers will prefer not to borrow even though the loan would raise their productivity and expected income. Lenders assess creditworthiness of their clients based on observable characteristics (Bigsten et al., 2003), and extend loans at certain interest rate. This means that borrowers are credit-constrained if, at specific interest rate, they would have liked to borrow larger amount than the lender supplied. In this case, the borrower exhausts this supply and then looks for another lender. However, the fact that this borrower exhausts its supply from one source, at specific interest rate, makes it a risky borrower for another lender.

Credit markets in developing countries are inefficient due to market imperfections such as interest rate ceilings imposed by governments, monopoly power often exercised by informal lenders (Bell et al., 1997), large transaction costs incurred by borrowers in loan acquisition, and moral hazard problems (Carter, 1988; Carter and Weibe, 1990). Stiglitz & Weiss (1981) argue that the problem where the lender bears risk of the transaction and the borrower obtains project benefits can be seen as an information problem. The asymmetries of information in credit market imply that first-best credit allocation is not possible, and this leads to the need for partial or full collateral. Then, inadequate collateral or lack of it implies that some individuals are denied credit, being otherwise identical to those who have the collateral and obtain the credits. In this connection, Banerjee (2001) argues that high-income individuals can borrow large amounts at low costs whereas low-income ones are able to borrow a small amount at high cost. This suggests that income or wealth level of borrowers has a direct relationship with the amount of available credit and an inverse relationship with cost of credit.

Moreover, lenders may not be allowed legally to charge above certain limits on loans, although informal lenders in practice may do so, as, for example, Emana et al. (2005) noted in Ethiopia. If the lender is not allowed to charge an interest rate at which the expected return is positive, then there will be credit rationing. Even if allowed to do so, lenders may be affected by adverse selection and/or incentive problems so that the expected return on a loan may not monotonically increase with interest rate. That is, lenders may try to avoid selection and incentive problems by rationing credit.

In general, the theoretical literature above shows that credit market failures give rise to heterogeneous resource allocation and different outcomes among farm households with varying characteristics. That is, a farm household that faces a binding credit constraint, ceteris paribus, will misallocate its resources and under-invest compared to its unconstrained peer. Availability of finance and its accessibility crucially affect production start-up and subsequent performances of the farmers. Barriers to access adequate loans will have adverse effect on technical efficiency of the farm households. Increased output production following improved access to credit is therefore evidence of binding credit constraint.

Most empirical literature reviewed below also support that credit constraints could affect resource allocations, risk behaviour and technology choice and adoption in production, which may lead to lower output of *CCFH* compared to the *CUFH.* For example, better access to credit resulted in higher income and consumption in Bangladesh (Diagne and Zeller, 2001) and in higher farm profitability in Cote d'Voire (Adesina and Djato, 1996), Malawi (Hazarika and Alwang, 2003) and in Tunisia (Foltz, 2004). Examining sources of efficiency differentials among basmati rice producers in the Punjab province of Pakistan, Ali & Flinn (1989) found significant effect of farmers' access to credit and later Parikh et al. (1995) also found that farmers with greater loan uptake were less cost inefficient than those with smaller loan size. Another study in Pakistan by Khandker & Faruqee (2003) reported formal credit's positive impact on household welfare outcomes. It was also found that formal credit increased rural income and productivity and that overall benefits exceeded costs of the formal credit system by about 13 percent in India (Binswanger and Khandker, 1995). Significant difference in productivities of credit-constrained and unconstrained households was observed in China (Feder et al., 1990; Feder et al., 1989). In Bangladesh, Pitt & Khandker (1996) examined the impact of credit from the Grameen Bank and other two targeted credit programs and found significant effects on household welfare, including education, labour supply and asset holding. Freeman et al. (1998) found that the marginal contribution of credit to milk productivity was different among credit-constrained and non-constrained farmers in east Africa.

More recently, studying the effect of credit constraints in Peruvian agriculture, Guirkinger & Boucher (2005) found that productivity of credit-constrained households depended on their endowments of productive assets and the credit they obtained from informal lenders. In Ethiopia, for example, Alene and Hassan (2006), studying the efficiency of traditional and hybrid maize production in eastern Ethiopia, found significant difference in farmers' technical efficiency due to differences in technology choice. The hybrid maize technology required adoption of a package of improved seed, chemical fertilizers, and cultural practices that farmers did not equally adopt, resulting in low technical efficiency differential. Part of the reason for the farmers' differential adoption of modern technology could be the credit constraints they face. Similarly, Holden & Bekele (2004) observed that households with access to credit compensated for increasing risk of drought by reallocating their production in such a way that crop sales were lower in good years to reduce the need to buy the crops in bad years. They argued that the households would be less able to do so without access to credit. Other efficiency studies in Ethiopia referred to earlier also identify access to credit as an important factor affecting efficiency of farmers.

It can also be seen that credit constraint is not only a problem of developing countries, where credit market imperfection is the norm rather than exception. The problem is present also in the developed world, where credit market imperfection is considered significantly lower (Blancard et al., 2006; Jappelli, 1990; Färe et al., 1990; Tauer and Kaiser, 1988; e.g., Lee and Chambers, 1986). For example, Blancard et al. (2006), studying short- and long-run credit constraints in French agriculture (where 67% of 178 sample farms were financially constrained in the short-run and nearly all farms face investment constraints in the long run) found that financially unconstrained farms are larger in size and better in economic performance than financially constrained small farmers, resulting in a difference of about 8.34% in profit. However, the nature and extent of credit constraints in developed countries are significantly different from those in developing countries, where the imperfection is also prevalent in other factor markets.

In general, although credit is mostly identified as one of the socioeconomic factors affecting different outcomes such as farm productivity and profitability, household welfare, and so on, only few studies have directly focused on the effects of credit constraints on technical efficiencies. The recent paper by Blancard et al. (2006) is directly related to ours but since it focuses on developed economy, it cannot represent developing countries' conditions. The generally limited studies explicitly addressing the effect of credit constraints on technical efficiency suggest that more studies are still desirable.

3. Theoretical framework

In economic theory, it is often assumed that producers maximize revenue, minimize cost or maximize profit. However, not all producers are equally efficient in this process. Given the same inputs and technology, some produce more outputs, more efficiently than others do. In the literature, there are different methods of estimating efficiency. At a broader level, one can find parametric, semiparametric and nonparametric methods, based on whether or not one can assume a functional form for an underlying technology and a specific distribution for the error terms. In the parametric family, one can also find deterministic and stochastic efficiency measures depending on whether or not random terms are accounted for. The stochastic estimation techniques attribute observed deviations from the efficient frontier to inefficiency and random errors, while in deterministic models, the deviations are attributed solely to inefficiencies, despite that random errors are present.

Moreover, productive efficiency literature (Farrell, 1957; Aigner et al., 1977; Bravo-Ureta and Pinheiro, 1993; Sharma et al., 1999; Wadud, 2003) distinguishes between technical, allocative and economic efficiencies. In this paper, we focus on technical efficiency, explicitly taking into account the credit-constraint status of the farm households affecting input use as given. Technical efficiency is defined as the ability to avoid waste by producing as much output as input usage allows, or by using as little input as output production allows (Farrell, 1957).

This study makes use of stochastic frontier analysis (SFA)[†], which requires a parametric representation of the production technology and incorporates stochastic output variability by means of a composite (two-part) error term. In particular, we estimate technical efficiencies of the sample farm households, given their difference in credit constraint status. Based on stochastic efficiency method, a general stochastic frontier model is defined as:

$$y_i = f(\mathbf{x}_i;\boldsymbol{\beta})exp(v_i - u_i); \qquad (i = 1, 2, \cdots, n) \tag{1}$$

where y_i represents the output of the ith farm household, n being the sample size, $\mathbf{X}_i$ a vector of variable inputs, β is a vector of technology parameters, $f_i(X_i;\beta)$ is the production frontier. The symmetric random error v_i accounts for random variations in output, which is assumed to be independently and identically distributed as $N(0,\sigma_v^2)$ independent of the u_i s; the u_i s are non-negative random variables, associated with technical inefficiency in production, which are assumed to be independently and identically distributed and truncations at zero of the normal distribution with mean, μ, and variance, σ_u^2, (i.e., $|N(\mu,\sigma_u^2)|$). The variance parameters of the model are parameterized as $\sigma^2 = \sigma_v^2 + \sigma_u^2$; $\lambda = \sigma_u^2 / \sigma^2$ and $0 \le \lambda \le 1$. Given the distributional assumptions of v_i and u_i, the estimate of u_i can be derived from its conditional expectation, given the composite error $\varepsilon_i (= v_i - u_i)$, applying the standard integrals (Jondrow et al., 1982).

$$E(u_i \mid \varepsilon_i) = \mu_i^* + \sigma_i^* \left[\frac{\phi(-\mu_i / \sigma_i^*)}{1 - \Phi(-\mu_i / \sigma_i^*)} \right] \tag{2}$$

where $\mu_i^* = (\mu\sigma_v^2 - \varepsilon_i\sigma_u^2) \big/ (\sigma_v^2 + \sigma_u^2)$, $\sigma_i^{*2} \equiv \sigma_v^2\sigma_u^2 \big/ (\sigma_v^2 + \sigma_u^2)$ and $\Phi(.)$ and $\phi(.)$ represent cumulative distribution and probability density functions, respectively. Therefore (1) provides estimates for v_i and u_i after replacing ε_i, σ_ε and λ by their estimates. That is, the output-oriented technical efficiency of the i^{th} farm household TE_i, given the levels of inputs, is defined as the ratio of observed

[†]Empirical efficiency studies usually utilize either Data Envelopment Analysis (DEA) or SFA. DEA is a nonparametric approach employing linear programming to construct a piecewise-linear, best-practice frontier for each economic unit (Färe, R., Grosskopf, S. and Logan, J. (1985) The relative importance of publicly owned and privately owned electric utilities. *Journal of Public Economics* **26:** 89-106.). Although, it does not impose a functional form on the data, it attributes all off-frontier deviations to inefficiency by assuming away the possibility of noisy data. SFA explicitly accounts for random shocks and is thus more appropriate in an environment such as our study area, where data can be noisy.

output to maximum feasible output in a state of nature depicted by $exp(-v_i)$ (Battese et al., 1996) as follows.

$$TE_i = \frac{y_i}{f(\mathbf{x}_i;\boldsymbol{\beta})exp(v_i)} = exp\{-(u_i \mid \varepsilon_i)\} \tag{3}$$

The distribution of u_i limits the estimated technical efficiency of a farm household i between 0 and 1. The inefficiency scores IE_i of credit-constrained and unconstrained farm households are defined as $1-exp\{(-u_i \mid \varepsilon_i)\}$ and are used as dependent variables in the estimated inefficiency effects models.

4. Empirical model

4.1 Econometric model specification

To assess farm household-specific technical efficiencies using parametric approach, the log-linear Cobb-Douglas stochastic production frontier[‡] is specified as

$$ln\,Y_i = \beta_0 + \sum_{k=1}^{6}\beta_{ik}\,ln\,x_{ik} + v_i - u_i \tag{4}$$

where y_i is the aggregated value of farm outputs of the i^{th} farm household in the sample, measured in Ethiopian Birr[§] and x_{ik} are the input variables, i.e., land, human labour, fertilizer, seed, herbicides and pesticides; the β s are parameters to be estimated; and v_i and u_i are as defined earlier in equation (1). To compare technical efficiencies of credit-constrained and unconstrained farm households, equation (4) is estimated using maximum likelihood estimator (MLE) separately for the two sub-samples, identified by a variable indicating their credit constraint status.

To investigate the effect of farm households' demographic, socioeconomic and institutional factors on technical efficiency, the inefficiency effects model in equation (5) is separately estimated for the two groups of farm households using least squares method.

$$IE_i = \delta\mathbf{Z}_i + \eta_i \tag{5}$$

where IE_i is inefficiency scores defined earlier; $\mathbf{Z}_i$ is a vector of proposed household demographic, socioeconomic and institutional variables affecting efficiency; and η_i is a random error term, assumed to be normally and independently distributed with mean zero and variance, σ_η^2.

[‡] The log-linear Cobb-Douglas specification was preferred to other alternatives such as the translog due to its convenience to interpret the estimates readily.
[§] The exchange rate was at 8.80 Birr =1US$ in January 2007.

4.2 Model variables and hypotheses

4.2.1 Dependent variable

It was hypothesized that the CCFHs would be more efficient than CUFHs. To test this, data collected from farm households were classified as credit-constrained and credit-unconstrained as reported by the sample farm household heads. Farm outputs were measured as annual farm revenues, by also accounting for the values of unsold and home-consumed outputs. Assuming same average output price in a season at which the farm households could sell their outputs, the revenues allowed aggregation of multiple outputs (Parikh et al., 1995), which otherwise was difficult to aggregate. Farm revenue per hectare was used as dependent variable in the estimation of the stochastic frontier production function, as used by other researchers (e.g., Alene and Hassan, 2006; Wadud and White, 2000; Feder et al., 1990). Assuming that production technologies are homogeneous within the sample and output prices are the same in a season, the difference in per-hectare revenue is believed to capture technical efficiency differential among credit-constrained and unconstrained farm households. In the inefficiency effects models of equation (5), the dependent variable is the inefficiency score defined earlier.

4.2.2 Independent variables and hypotheses

The independent variables for both the stochastic frontier production function and the inefficiency effects models are explained and their effects hypothesized as follows.

Production inputs

Land, labour, seed, fertilizer, herbicide and pesticide are inputs in the stochastic frontier production function specified in equation (4). The inputs are expected to have positive effect on the value of outputs in the production function. However, suboptimal use of some inputs may result in negative output effect and inefficient production. Land (*LAND)* is the total land area operated by the household, including that owned, rented in, contracted in and obtained through gift, and measured in hectare (ha). Labour (*LABOR*) is family labour force and external labour supply (hired, exchanged, or gift), measured in man-days. Fertilizer (*FERT*) is the quantity of chemical fertilizers called UREA and DAP applied to the crop, measured in kilograms (Kg). Seed (*SEED)* is the measure of improved and local seed varieties used by farm households, measured in Kg. Pesticides (PEST) and herbicides (HERB) are measures of the quantities of pesticides and herbicides, respectively, used by the sample farm households, both measured in millilitres (ml). The quantities and qualities of the inputs and the technical skills of the farm households to use the inputs properly determine technical efficiency of the farm households.

Land is an important input to agricultural production affecting farm output (Wadud, 2003), but the effect of farm size on efficiency is mixed. Some studies suggest that small farms are more efficient than large ones, but others oppose to this, justifying based on economies of scale and scope associated with larger sizes.

However, undoubtedly, one can see that use of external inputs increases with farm size, and economies of size may be attained as farm size increases. Moreover, larger farms may positively affect lenders' valuation of borrowers' creditworthiness (Khandker and Faruqee, 2003), as do farm outputs and income. Farm households with large farms would allocate resources more efficiently because they would have better access to credit and would better finance farm operations and on-farm investments.

Agricultural production in developing countries is a highly labour-intensive economic activity. In addition to its direct effect, farm labour supply may also have indirect effect on efficiency since it is complementary to other farm inputs. However, all farm households are not equally endowed with family labour. A farm household with inadequate family labour may wish to satisfy its farm labour demand externally, and to pay for this, will demand credit. Therefore, if the farm household is constrained in the credit market, it may also be constrained in the labour market.

The other variable inputs are often not family supplied, except *SEED* where farmers may use from their saved harvests; they are rather purchased from the market. Credit constraint will have direct effect on their use (Demeke et al., 1998) and their suboptimal use in turn will affect the use of land and labour inputs, and thus production efficiency. Farmers who are unconstrained in the credit market are more likely to choose optimal levels of these inputs than their credit-constrained counterparts are.

Inefficiency factors

After technical efficiencies are estimated for the two groups of farm households, sources of inefficiency differentials among farm households, besides credit constraint, are estimated using inefficiency scores as a dependent variable. As referred to earlier, the efficiency studies in Ethiopia and elsewhere (e.g., Coelli and Battese, 1996) show that several household demographic, socio-economic and institutional factors affect efficiency differentials among farmers. However, the effect of these factors varies in time and space, depending on specific situations in the study countries, making it imperative to test their effects also in this study area.

Demographic factors

Traditional farming has evolved over years through farmers' own experience of continuous experimentation and learning. Farmers develop and accumulate experiences including farm financing over time, and learn about farm technologies and subsequent productivity effects, market behaviours, and general physical and economic environments to make choices. Farmers may enhance their productive efficiencies, as they get more experienced, learn how to increase income-generating capacities and become able to use cost-effective strategies to cope with adverse shocks. For example, experience in borrowing may help farmers to use external sources effectively to smooth output and income fluctuations. Controlling for this, the age of the farm household head (*AGEH)* is hypothesized to increase productive efficiency. Previous studies also indicate positive effect of experience on farmer efficiency (Kalirajan and Shand, 1985; Stefanou and Saxena, 1988; Battese and Coelli, 1995; Battese et al., 1996).

Education is also expected to increase labour productivity by influencing managerial skills of farm operators, as skilled farmers are more likely to allocate resources more efficiently. Hence, education level *(EDUCL)* as measured in farm household head's years of schooling is included with a positive effect. Nevertheless, results from previous empirical studies are mixed. For example, while Bravo-Ureta & Pinheiro (1993), Ali & Flinn (1989), Parikh et al. (1995) and Battese et al. (1996) show that education has a positive effect on farmer's efficiency, others such as Kalirajan & Shand (1985) and Adesina and Djato (1996) found no significant effect.

Another factor possibly affecting technical efficiency of farm households is household size *(HHSZ).* Family labour is often an important source of labour supply in farm households in developing countries. In a situation where rural labour market is underdeveloped, which is also the case in the study area, coupled with credit constraint, farm households with inadequate family labour will experience farm labour deficit, others may experience idle labour surplus. Household size is expected to have a positive effect.

Socioeconomic factors

Here, household wealth and land fragmentation are included. Household wealth (*WEALTH*) captures the market value of total household physical properties such as farm implements, machineries and other stocks. Household wealth is expected to ease credit constraint in two ways. On the one hand, wealthier farmers are expected to own more assets, and will thus have more potential for equity financing, which in turn will generate more income. On the other hand, if equity finance falls short of total financial requirement, since wealthier farmers own more farm assets, this will increase their probability of obtaining external finance through its positive influence on lenders' valuation of creditworthiness. Thus, wealth is expected to have a positive effect on efficiency of particularly credit-constrained group, who often have smaller wealth.

Fragmentation of landholdings (*LANDFRAG*) is commonly regarded as a major obstacle to growth in agricultural production in developing countries (Tan et al., 2006). The more the number of plots per total operational holding of a farm household and the smaller the plot size, the higher the degree of land fragmentation and the less likely is the opportunity to apply new technologies (especially indivisible ones) such as irrigation facilities. Therefore, a negative effect is expected.

Institutional factors

Institutional factors are important determinants of productive efficiency (Fulginiti et al., 2004). One such factor is access to extension service (*EXACSS*). In this service, farm households often obtain information on improved crop varieties and breeds of animals. However, individual variations among farm households in accessing, searching and utilizing extension services are expected. As technology adoption depends on this service, those with access are expected to be more efficient. Based on results from previous studies (Bravo-Ureta and Pinheiro, 1993; Bindlish and Evenson, 1993; Parikh et al., 1995) a positive effect is hypothesized.

Efficiency may also be affected by farm households' access to credit information. A farm household cannot apply for loan without having information. Those with access to credit information (*CREDINFO*) will be in a better position to decide optimally on external financing and become more efficient than others, hence a positive effect is expected. A farm household may be quantity (loan size) rationed as the amount of credit obtained becomes inadequate for optimal choice of other variable factors of production, for desirable economies of scale require proportionate change in all factors of production. To see this, loan size *(CREDSZ)* is controlled for and a positive effect is hypothesized. Interest rate is a cost of capital to borrower farm households, and depending on choice of lenders, they may incur higher costs inefficiently. In this connection, for example, Gloy et al. (2005), studying the costs and returns of agricultural credit delivery in U.S., concluded that many large borrowers have access to credit rates that are more favourable. Therefore, we expect interest rate (*INTEREST)* to have negative effect on production efficiency. In Ethiopia, in general, and in the study areas, in particular, since communication and transportation infrastructure are less developed, access to available credit may be affected by physical proximity of the borrower to the location of the lender. To control for temporal and monetary costs of transportation, which are transaction costs to an individual borrower, distance to a credit facility *(DISCREDF)* is controlled for with expected negative effect.

5. Data

Ethiopia is one of the low-income developing countries where farmers and rural entrepreneurs operate under very poor infrastructure, with considerable adverse effect on their access to formal and semiformal lenders. Moreover, according to the existing land property rights law, farmers do not own land and this does not allow them to use land as collateral to obtain formal credit. This, among others, contributed to the rural credit market failure. The property rights problem, coupled with low level of the necessary infrastructure, entailed other forms of credit supply mechanism, such as third party guarantee scheme[**], joint liability of co-borrowers often used by microfinance institutions and inventory-based credit supply[††]. However, it is yet too early to observe the effect of these mechanisms in meeting the credit constraints of farmers, as they only have been implemented for a few years.

The data used in this paper were obtained in a farm household survey conducted during September 2004 to January 2005 in Merti and Adamitullu-Jido-Kombolcha (AJK) districts of Oromia region, Ethiopia. These study areas are located at about

[**] Regional states offer third-party guarantee to commercial banks against possible defaults, enforcing repayment through local administrative machinery.

[††] This is a credit delivery mechanism in which farmers, who face temporary liquidity problem at times of low output prices, can borrow against a deposit of farm outputs at a common storage facility until higher output prices can be received for products.

200 km and 160 km, respectively, to the southeast of the capital, Addis Ababa (Finfinne). The farm households were selected randomly from six Farmers Associations (FAs) in the two districts – four from Merti and two from AJK. Using FA-level list of farm households as a sampling frame, 240 sample farm households were randomly selected. Survey enumerators administered the questionnaire to heads of sample households by visiting them at their farmsteads. As shown in Table I, large fractions of the sample farm households grow several crops such as maize (61%), onion (38%), barley (36%), wheat (31%), teff[‡‡] (30%), haricot beans (25%), sorghum (19%), and faba beans (15%) while relatively smaller proportions also grow other crops such as rapeseed, tomatoes and green beans. The farm households grow multiple crops to diversify their outputs in light of minimizing risks in yields and prices. This risk behaviour of farmers is partly a reflection of the extent of the credit constraints they face. By diversifying their products, they limit their choice of best product mix in order to minimize the occurrence of risk involved, sacrificing the benefit of using high-yielding technologies.

Table I: Proportion of farm households growing different crops

Crop	Grower farmers (%)[a]	Crop	Grower farmers (%)[a]
Maize	61	Sorghum	19
Onion	38	Faba beans	15
Barley	36	Rapeseed	9
Wheat	31	Tomatoes	8
Teff	30	Peas	8
Haricot beans	25	Green beans	3

[a] Percentages are sample proportions of farmers growing a particular crop and do not add up to 100%, as most farmers diversify by producing multiple crops. Source: Own survey, 2004/05

In addition to the usual demographic and socioeconomic variables, farm household heads were interviewed on whether or not they had information about lenders, whether or not they applied for credit from any external source in the last 12 months prior to the survey, whether or not their applications were accepted, and if so, the amount they obtained and whether or not they were constrained after receiving credit. Moreover, information on location of the lender, interest rates charged, type of credit obtained and repayments were collected.

Based on descriptive results shown in Table II, the characteristics of credit-constrained (*CCFH*) and credit-unconstrained farm households (*CUFH*) are discussed. The overwhelming majority of the sample farm households (70%) reported being credit-constrained, which is not surprising, given the low level of rural credit market development in Ethiopia in general, and particularly in the study areas. Although there is no statistically significant difference between *CCFH* and

[‡‡] *Teff* (*Eragrostis tef*) is an annual cereal crop of grass family often used in production of *injera*, a major staple food in Ethiopia.

CUFH in terms of average age, household size and level of education, the two groups have significant differences in other characteristics, as the mean difference test statistics[§§] reported in the last column of Table II show. The *CCFHs* operate more fragmented farmlands than the *CUFHs*, as measured in the number of plots. The proportion of *CCFH* that applied for credit (65%) is significantly smaller than that of the *CUFH* (71%). Since there is no significant difference in terms of access to credit information between the two groups, this suggests that some *CCFH* did not apply for credit for reasons other than lack of credit information. This can possibly be due to farm households' fear of being rejected or consideration of transaction costs in application decisions. However, the absence of significant difference between the two groups' access to credit information does not imply that they both had adequate information. About 53% and 60%, respectively, of *CCFH* and *CUFH* had obtained loans and the difference is statistically significant (Table II). However, the statistical evidence of quantity rationing is not strong enough, as the difference in credit size between the two groups of farm households was statistically different from zero at only unconventional 11% level of significance. The fact that a considerable number of borrowers remained credit-constrained still makes the difference in credit size rationing between the two groups economically important to consider.

In terms of production inputs, there were significant differences between the two groups of farm households. The *CCFH* operated more land and used more labour but applied lower levels of seeds, fertilizers, pesticides and herbicides than the *CUFH*. Although land in Ethiopia is allocated to the farm households based on household size, the presence of informal land markets (Pender and Fafchamps, 2005) may cause difference in operational farm sizes among farm households with the same household size. In light of this, more land operated by the *CCFHs* are more likely due to larger household size, which is also the source of household labour supply. The variable inputs require more capital to purchase and it was observed that the *CCFH* applied them in lower levels than the *CUFH*. As a result, on the output side, the *CCFH* obtained less revenue per hectare of land than the *CUFH*. This pattern is similar to the finding by Feder et al. (1989), in which *CCFH* was observed to have used lower levels of inputs and obtained lower outputs than unconstrained farmers in China. Moreover, the *CCFH* had less wealth than the *CUFH*. This result also conforms with Banerjee's (2001) theoretical claim, where it is argued that wealthier farm households get more access to credit because they can afford fixed transaction costs, bear more risk and are less risky to lenders than less wealthy farm households.

Nevertheless, since these summary statistics are unconditional means, much more can be learned by conditioning the average figures on relevant demographic, socioeconomic and institutional characteristics of the farm households, which is the focus of the econometric estimation in the next section.

[§§] Independent t-test was used to test the null hypothesis of no difference between the means of the two groups, where the reported t-ratios were derived as $t = (\bar{x}_u - \bar{x}_c) / SE(\bar{x}_u - \bar{x}_c)$, and $\bar{x}_u$ and $\bar{x}_c$ are sample means of the variables for credit-unconstrained and constrained groups, respectively.

Table II: Sample descriptive statistics by credit constraint status

Variable name	Variable definition and measurement unit	Unconstrained	Constrained	Full sample	Mean difference test
		Mean§	Mean§	Mean§	t-ratio
AGEH	Age of household head (years)	42.23 (14.95)	43.69 (13.76)	43.25 (14.12)	-.734
HHSZ	Household size (No. of members)	7.58 (3.01)	8.02 (3.97)	7.89 (3.70)	-.863
EDUCL	Household head's education (years)	4.04 (4.13)	3.13 (3.44)	3.41 (3.68)	-.717
LANDWN	Total land owned (ha)	1.62 (1.17)	1.89 (1.34)	1.81 (1.29)	-9.615***
SEED	Crop seed used (kg)	141.10 (192.78)	137.63 (138.51)	138.68 (156.60)	-9.070***
FERT	Chemical fertilizer used (kg)	165.58 (259.40)	129.42 (217.19)	140.42 (230.90)	10.077***
PEST	Pesticides used (100ml)	66.64 (69.05)	6.49 (18.03)	24.79 (49.31)	10.491***
HERB	Herbicides used (100ml)	1.69 (3.86)	0.10 (0.23)	1.18 (3.31)	-3.750***
LABOR	Total labour worked (man-days)	127.45 (75.82)	132.62 (97.81)	131.05 (91.55)	2.449***
LANDSZ	Total land operated (ha)	1.73 (1.35)	1.83 (1.18)	1.80 (1.23)	-9.266***
OUTPVAL	Value of total farm output (100 Birr)	66.27 (82.03)	60.83 (83.62)	62.49 (83.01)	7.319***
WEALTH	Household wealth (1000 Birr)	26.23 (17.23)	9.56 (6.93)	14.63 (13.48)	6.705***
LANDFRAG	Land fragmentation (No. of plots)	2.65 (1.58)	3.13 (1.70)	2.98 (1.67)	-2.003**
CREDSZ	Size of credit obtained (Birr)	323.71 (596.22)	299.71 (573.88)	307.01 (579.62)	-1.529
CREDINFO	% of households with credit information	90	84	86	1.344
CREDAPPL	% of households applied for credit	71	65	67	-2.916***
CREDAPPR	% of households who obtained credit	60	53	55	-4.527***
EXACSS	% of households with extension visit	29	44	40	-8.432***

§Standard deviation of the means in brackets; sample means for dummy variables indicate fractions taking value 1 in the sub-sample. *** and ** indicate 1% and 5% significance levels, respectively, for test of mean difference between the two groups. Credit-constrained and unconstrained groups have sample sizes of 167 and 73, respectively.

Source: Own survey, 2004/05

6. Results and discussion

6.1 Estimated technical efficiencies

Maximum likelihood estimates of the parameters of the stochastic frontier production function specified in equation (4) are obtained using LIMDEP 7.0 software (Greene, 1995). The estimated values for the variance parameters, λ, in the stochastic frontier production model are significant, which indicate that technical inefficiency affects outputs of the two groups of farm households. The estimates for *CCFH* and *CUFH* are presented in Table III. In the case of *CUFH*, all input variables but *HERB* and *LAND* were statistically significant, and all but *LAND* and *SEED* showed the expected positive signs. *LABOR* had the highest input elasticity of production but *HERB* had the lowest, although the effect of *HERB* was not statistically significant. This implies that more farm revenue can be obtained by using more labour on the farm, as the production system in the study area is labour intensive. For *CCFH*, all variables except *HERB* were statistically significant and all but *LAND* and *SEED* had the expected positive signs. Capital-intensive inputs such as *FERT*, *PEST* and *HERB* had higher output elasticities for this group of farm households. The *CCFH* group used lower levels of capital-intensive inputs because of financial constraint, which is intuitive. Higher marginal effects of the limited capital inputs suggest that the *CUFH* could choose variable inputs more proportionally and this allowed them to have higher mean productive efficiency than the *CCFH*.

Table III: MLE estimates of stochastic production frontier

Variable	Credit-constrained	Credit-unconstrained
	Coefficient[a]	Coefficient[a]
Intercept	6.95 (12.51)***	5.61 (11.78)***
LnLAND	-0.34 (-1.66)*	-0.11 (-0.86)
LnFERT	0.13 (2.02)**	0.13 (4.47)***
LnSEED	-0.27 (-1.87)*	-0.19 (-2.77)**
LnHERB	0.04 (0.72)	0.02 (0.70)
LnPEST	0.07 (1.70)*	0.05 (2.24)**
LnLABOR	0.58 (4.15)***	0.69 (9.13)***
λ	0.76 (12.82)***	0.67 (11.16)***
σ	1.48 (11.43)***	0.90 (10.98)***
Log Likelihood	-351.15	-259.16

[a] Values in brackets are t-ratios; ***, ** and * indicate 1% , 5% and 10% significance levels, respectively. The dependent variable is the natural logarithm (ln) of the value of total farm output per hectare (in Birr). Sample size for credit-constrained and unconstrained groups is 167 and 73, respectively.

Policymakers are often interested in ranking firms in terms of their efficiencies to devise appropriate intervention policies (Dorfman and Koop, 2005). For this reason, frequency distributions of the farm household-specific productive efficiencies for both the *CCFH* and the *CUFH* groups are reported in Table IV and more vividly displayed in Figure I. It can be observed that productive efficiency varies widely among sample farm households in both groups. The mean technical efficiency score was 67% for *CUFH* and 55% for the *CCFH* group, suggesting a significant deterrent effect of access to credit on the efficiency of the farm households. The two groups, which mainly differ in their credit constraint status, had a 12% difference in average technical efficiency. Compared to other studies, this 12% is higher than, for example, the 8.34% profit loss difference between expenditure-constrained and unconstrained farmers Blancard et al., (2006) observed in France and the 8% Färe et al. (1990) observed in US. Since the proportion of *CCFH* in our sample is larger than the *CUFH*, improving credit access can significantly raise output. The average efficiency scores of 55% for *CCFH* and 67% for *CUFH* indicate not only the presence of significant efficiency gap between the two groups of farm households but also the presence of high level of technical inefficiency in both groups. The *CUFH*, on average, had potential loss of 33% in farm revenue due to technical inefficiency whereas the *CCFH* had about 45%, which suggests that both the gap in inefficiency between the two groups and the specific inefficiency of each group need to be reduced in order to produce at maximum possible technical efficiency levels.

Table IV: Frequency distribution of efficiency estimates

Efficiency Score (%)[§]	Credit-constrained		Credit-unconstrained	
	No. of farm households	Percent	No. of farm households	Percent
0<28	8	5	0	0
28-33	18	11	1	1
34-38	17	10	3	4
39-43	21	13	2	3
44-48	15	9	5	7
49-53	16	10	9	12
54-58	13	8	7	10
59-63	20	12	10	14
64-68	16	10	11	15
69-73	14	8	9	12
74-78	8	5	10	14
79<100	0	0	6	8
Mean	55		67	
Min	20		28	
Max	75		85	
SD	13		11	

[§]The mean, minimum, maximum and standard deviation of the efficiency scores are in percentages. Sample size for credit constrained and unconstrained are 167 and 73 respectively.

Not only the technical efficiencies were different between the two groups of farm households, but also there were differences in the distribution of the estimated technical efficiencies of the two groups of farm households. The minimum technical efficiency score for the *CUFH* was 28% but that of the *CCFH* was 20%. The maximum technical efficiency score for *CUFH* was 85% whereas for the *CCFH* was 75%. Moreover, about 65% of the *CCFH* had 58% and less technical efficiency scores but only about 30% of the *CUFH* had such levels of technical efficiencies, indicating more loss in potential farm revenue of the *CCFH* than the *CUFH*. Figure I depicts the cumulative distribution of the efficiency scores for the two groups. The technical efficiency scores of the *CUFH* group were skewed towards the highest efficiency scores whereas those of *CCFH* were skewed towards the lower scores. That is, the majority of the *CCFH* had lower technical efficiencies, resulting in large aggregate loss in output. Since knowing efficiency scores is not an end by itself, additional factors contributing to the differences in the technical efficiencies of the farm households are discussed below.

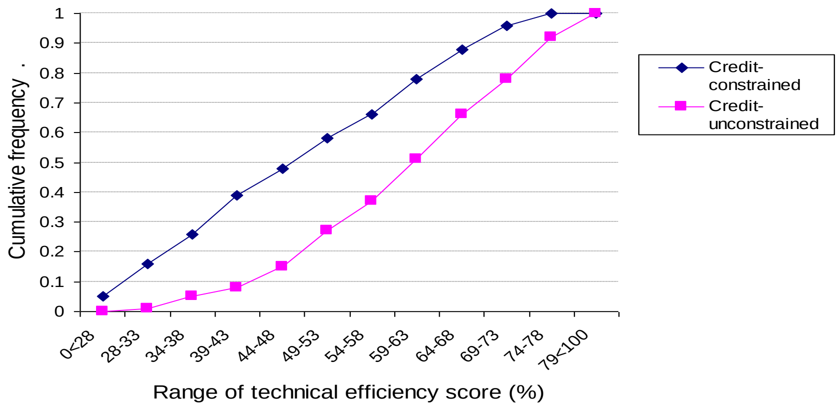

Figure I: Cumulative frequency of farm households by technical efficiency score

6.2 Factors affecting inefficiency

The parameter estimates of the relationship between technical inefficiency and farm households' demographic, socioeconomic and institutional factors are shown in Table V. High R^2 values show presence of a strong explanatory power of the covariates and thus a strong goodness-of-fit of the model to the data. The F-test for joint hypothesis that all non-intercept coefficients in the model were zero was also rejected, indicating that the observed inefficiency differential between the *CCFH* and *CUFH* groups was not due to mere chance but explained by the included covariates. The fourth column of Table V shows estimates for the full sample, where a dummy variable, indicating whether a farm household had obtained a credit or not, was included for comparison. This is similar to the way most previous studies in Ethiopia and elsewhere used dummy variables. However, this dummy variable shows whether farm household took a loan or not but does not identify whether the farm households were still credit constrained after taking the credit or not. The estimated coefficient of this dummy variable turned out to be statistically insignificant, suggesting that credit had no effect on technical efficiency of the farm households. For example, the study by Haji & Andersson (2006) had concluded in this way. However, such conclusion may be incorrect since taking a loan may not necessarily mean that the borrower had his/her credit constraint resolved. Since this variable does not show the credit-constraint of a borrower, one needs to go further and identify whether or not the farm household is still credit constrained after taking the loan.

The estimates in the second and third columns of Table V explicitly considered the credit-constraint status of the farm households, and the following discussions are based on these columns. It should be noted that technical inefficiency scores were used in the estimated regression model, and therefore when we interpret the coefficients a negative effect of the estimate on technical inefficiency equally means a positive effect on efficiency.

Table V: Parameter estimates of inefficiency effects model

Variable	Credit-constrained	Credit-unconstrained	Full sample
	Coefficient (t-ratio)	Coefficient (t-ratio)	Coefficient (t-ratio)
Constant	0.53 (1.82)**	0.73 (1.88)**	0.59 (3.55)***
AGEH	0.09 (2.25)**	0.05 (0.63)	0.06 (3.06)**
HHSZ	-0.05 (-0.61)	-0.07 (-2.33)**	-0.04 (-2.12)**
EDUC	-0.06 (-2.04)**	-0.03 (-2.04)**	-0.05 (-2.56)**
LANDFRAG	0.09 (3.11)***	0.07 (3.50)***	0.08 (3.17)***
EXACSS	-0.08 (-0.73)	-0.12 (-0.55)	-0.12 (-0.68)
CREDSZ	-0.10 (-2.11)**	-0.05 (-2.11)**	-0.07 (-2.32)**
WEALTH	-0.03 (-3.00)***	0.02 (0.44)	-0.03 (-2.71)**
CREDINFO	-0.07 (-0.44)	-0.04 (-0.27)	-0.05 (-0.93)
INTEREST	0.06 (1.20)	0.03 (0.90)	0.07 (0.67)
DISCREDF	0.07 (0.70)	0.05 (0.53)	0.05 (1.30)
CREDAPPR§			-0.24 (-1.56)
No. of observation	167	73	240
R^2	0.89	0.86	0.83

Notes: *** and ** indicate 1% and 5% significance levels, respectively. The dependent variable is inefficiency score (IE_i) as defined in the methodology part.

§This is a dummy variable taking value of 1 if the household obtained credit and 0 otherwise, included in the model using the full sample.

The age of the farm household head positively affected technical inefficiency of the *CCFH*, which is contrary to the hypothesis. For *CUFH*, age had not significant effect. A positive age effect for the *CCFH* means that older farmers were less efficient than younger ones. A possible explanation could be that the older farmers, although more experienced, might be more conservative and less receptive to modern technologies and farm practices that enhance technical efficiency than their younger peers. In Eastern Hararghe zone of Ethiopia, Seyoum et al. (1998) also observed a similar result in their study that compared technical efficiencies of farmers within and outside SG-2000 project, which was a pilot extension project later widely adopted in most agricultural regions of the country.

Household size significantly and negatively affected technical inefficiency of the *CUFH* group whereas it was insignificant for the *CCFH* group. This means that inefficiency decreases with household size of the *CUFH*. The *CUFH* could choose optimal levels of labour because they were not financially constrained. The insignificance of household size for the *CCFH* implies that labour supply did not matter for their efficiency, since because of credit constraint they could not proportionally choose optimal levels of other inputs. As expected, education level of the heads of farm households significantly and positively affected technical efficiency of both groups of farm households but with higher effect for the *CCFH* group. It means that technical efficiency of a farm household head increases with his/her formal schooling. Education, as a human capital, has multiple effects on the performance of the farm households, including acquisition, processing and utilization of information and farm managerial skills, which in turn can increase their technical efficiency. It suggests that public policy facilitating investment in farmers' education can increase farmers' technical efficiency. This result supports the effort Ethiopia has been putting on establishing farmers' technical training centres at the level of Farmers' Associations, the lowest rural administrative units.

Land fragmentation significantly and negatively affected technical efficiency of both groups of farm households, as expected. It means that fragmentation of a given fixed size of total farmland has inverse relationship with technical efficiency of the farm households. This may be explained in two ways. First, land fragmentation can deter optimal use indivisible technologies, such as irrigation equipment. Second, considerable amount of time and effort can be wasted in coordinating farm operations at different plots, especially as the distance between the plots increases. The result suggests that technical efficiency of the farmers can be improved by aligning farm plots allocated to a household. This has important relevance for land distribution policy in Ethiopia, where land is allocated to the farm households by the government. In a country where land markets function well, farmers may be advised to consider buying adjacent farm plots to reduce the negative effect of land fragmentation on their technical efficiency.

The amount of loan obtained significantly and positively affected technical efficiency of both groups of farm households, with the effect being more pronounced in the case of the *CCFH* group. The positive effect of the loan size can be seen in two ways. First, as the loan size increases, the unit cost of borrowing, including transaction costs, decreases because some of these costs are fixed regardless of the amount of loans and with increased loan size, the total cost thinly spreads over large loan size and reduces average unit cost. Second, as the amount of loan increases, farm households may be less constrained to acquire improved technologies and choose optimal levels of inputs, making them less inefficient than others. The result suggests that for the loan to bring about significant impact on the technical efficiency of a farm household, the loan size should be adequate to meet effective demand. A larger loan size will also have a cost reduction implication for lenders in that unit cost of credit delivery will fall with increased loan size per borrower, which can also make the lender more profitable. This in turn can create an incentive for the lender to reduce the lending interest rate with increased loan volume.

The wealth variable significantly and positively affected technical efficiency of the *CCFH* group but insignificant for the *CUFH*. This means that technical efficiency increases with the wealth of the *CCFH*. Intuitively, as wealth increases, credit constraint tends to ease from both the demand and supply sides. That is, farmers' capacity to self-finance internally may increase as they get wealthier, reducing demand for credit. However, if wealthier farm households expand their farm operations and demand additional external resources, they will be more creditworthy and less rationed in the credit market than their less wealthy peers. For the *CUFH*, the insignificant effect of wealth implies that their technical efficiency was independent of their wealth. That is the *CUFH* can still attain desired efficiency levels since they are not credit-constrained to choose optimal levels of inputs. The significant effect of wealth on the technical efficiency of *CCFH* means that within the *CCFH*, relatively wealthier farm households are more efficient than less wealthy ones. This implies that technical efficiency of a credit constrained household depends on its wealth level.

The effects of the variables extension visit, credit information, interest rate and distance to a lender turned out to be statistically insignificant, which suggests that these variables did not matter for both groups' technical efficiency. Some possible reasons for their insignificance are the following. Extension visit and credit information might be insignificant probably because farmers had only a few visits to extension offices and had limited credit information that maybe did not add much to his/her existing information base. It may also be that farmers' technical efficiency may not improve by mere increase in farmers' extension visit and credit information. In this connection, for example Alene & Hassan (2006) argue that poor communication skills of extension agents and low extension-agent-to-farmer ratio would pose a limit to the number of beneficiary farmers in extension service. Similarly, lack of organized credit market information and farmers' lack of it can also contribute to the insignificant effect of the variable. This in turn implies that better qualities, rather than mere presence, of these services can have better effect. The variable *distance to lenders* was perhaps insignificant because there was no considerable variation among farmers to equally inaccessible lenders. It may also suggest that distance may not matter if other components of the transaction costs (such as paper works, speed of loan processing and disbursement) can be significantly reduced. Similarly, some barriers other than the interest rates might be more important to improve the credit constraint condition of the farm households and reduce its efficiency effect.

7. Conclusions and policy implications

In this paper we estimated technical efficiencies of credit-constrained (*CCFH*) and unconstrained farm households (*CUFH*) using parametric stochastic frontier technique. We found that the mean technical efficiency scores for *CCFH* and *CUFH* were estimated at 55% and 67%, respectively, which means that the two groups of farm households, on average, had technical efficiency difference of 12 percent. Although the credit constraint was the focus of this study, additional factors were also controlled for. It was found that the technical efficiencies of both groups of farm households were significantly affected by farmers' education, land fragmentation and loan size. Besides, the efficiency of the *CCFH* was influenced by their farm experience and wealth, and that of the *CUFH* was affected by household size, as related to family labour supply. The results suggest that credit availability and loan size, farmers' education and landholding structure need to be improved for all farmers. Moreover, especially for *CCFH*, farm experience (as related to farm management skills) and household wealth (e.g., through better facilities and incentives to increase saving and capital accumulation) require improvement. The study enriches the existing empirical literature dealing with credit constraints by explicitly treating credit constraint of the farm households, which often enter in earlier studies merely as a dummy variable. The direct elicitation method used allowed explicit comparison of farm households based on their credit constraint status. In general, the study demonstrated that farmers are not homogenous in their demand for credit and subsequently in their credit constraints, and this has important effect on their technical efficiency. The study also suggests that in efficiency analyses, more could be learned by explicitly considering credit constraint of farm households.

An important policy concern in developing countries in general and particularly in Ethiopia is raising agricultural production, given limited resources, to meet the ever-increasing demand for food due to increasing human population. However, attaining maximum possible output using a given level of inputs, in which relative variation among farm households in resource endowments and access to credit results in efficiency differential, requires careful studies. Agricultural credit policies generally aim at alleviating credit constraints of farmers in order for farmers to be able to increase their output production by producing at maximum possible technical efficiency. In light of this, the results of this study suggest that for a loan to result in higher technical efficiency, it needs to satisfy the effective credit demand of the farmers adequately. Given the largest proportion of the *CCFH* in the Ethiopian farming population, the 12% gap between technical efficiencies of *CCFH* and *CUFH* suggests that there are considerable potential losses in output due to inefficiency. This calls for a policy measure that would address credit constraint problem of both groups of farm households in general, and those of the credit-constrained group, in particular.

On the one hand, a "blanket supply" of credit to all farm households without considering their difference in effective credit demand and constraint status would not guarantee that such a credit supply would result in alleviation of farmers' credit constraints. On the other hand, and more importantly, the credit-constrained group would be less efficient than the unconstrained ones, resulting in low level of outputs. This, in turn, will adversely affect the capacity of farmers to repay the debt. At the aggregate, this will also affect the effectiveness of credit supply.

The fact that the *CUFH* are more technically efficient than the *CCFH* suggests that a credit supply that is responsive to effective credit demand of farm households would result in higher outputs, which would also increase creditworthiness of the farmers. An increase in farmers' creditworthiness can raise lenders' incentive to extend more loans to the extent that can meet effective credit demand of the farmers. In other words, adequate credit reduces credit constraint and increases technical efficiency, farm outputs and creditworthiness of borrowers. On the contrary, it would be economically unattractive for farmers to receive a loan that cannot meet their effective credit demand, as they will remain credit-constrained and cannot increase their efficiency. This suggests that lenders should identify farmers' effective credit demand before determining loan sizes since farmers are not homogeneous in their demand for credit. In developing countries, government intervention in a credit system, as spurred by credit market failure, often becomes ineffective because it is delivered based on the implicit assumption that the farmers have similar demands for credit, thereby ending up in one-fits-all credit supply. This often does not match with effective credit demand of some farmers. This is evident from the fact that a considerable proportion of respondents who received credit also reported being credit-constrained. More often, significant credit defaults are reported in the formal credit sectors of developing countries. One possible cause could be that farmers cannot attain the necessary technical efficiency allowing debt repayment if the loans cannot meet their effective credit demand. However, ability to repay a credit, as related to higher output, could only be a necessary, not a sufficient, condition for debt repayment.

Another important implication of the results for credit policy is related to the cost of credit supply. The insignificant effect of interest rates on the efficiency of farmers suggests that factors other than the direct cost of borrowing may be important to consider. For example, some farmers may find monetary and non-monetary transaction costs (such as paper works, loan processing speed and speed of loan disbursement) higher than the interest rates. In this case, lenders need to consider the effect of such costs on the farmers' demand for credit and devise strategy to reduce such costs, by using information technology, for example, which can lower costs of credit transaction, monitoring and evaluation. In the absence of IT facility, lenders need to consider the proximity of branches of financial institution to borrowers.

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