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Microfinance, Efficiency and Agricultural Production in Bangladesh

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ACADEMIC DISSERTATION

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Abstract

The objectives of this study were to make a detailed and systematic empirical analysis of microfinance borrowers and non-borrowers in Bangladesh and also examine how efficiency measures are influenced by the access to agricultural microfinance. In the empirical analysis, this study used both parametric and non-parametric frontier approaches to investigate differences in efficiency estimates between microfinance borrowers and non-borrowers. This thesis, based on five articles, applied data obtained from a survey of 360 farm households from north-central and north-western regions in Bangladesh. The methods used in this investigation involve stochastic frontier (SFA) and data envelopment analysis (DEA) in addition to sample selectivity and limited dependent variable models.

In article I, technical efficiency (TE) estimation and identification of its determinants were performed by applying an extended Cobb-Douglas stochastic frontier production function. The results show that farm households had a mean TE of 83% with lower TE scores for the non-borrowers of agricultural microfinance. Addressing institutional policies regarding the consolidation of individual plots into farm units, ensuring access to microfinance, extension education for the farmers with longer farming experience are suggested to improve the TE of the farmers.

In article II, the objective was to assess the effects of access to microfinance on household production and cost efficiency (CE) and to determine the efficiency differences between the microfinance participating and non-participating farms. In addition, a non-discretionary DEA model was applied to capture directly the influence of microfinance on farm households‘ production and CE. The results suggested that under both pooled DEA models and non-discretionary DEA models, farmers with access to microfinance were significantly more efficient than their non-borrowing counterparts. Results also revealed that land fragmentation, family size, household wealth, on farm-training and off–farm income share are the main determinants of inefficiency after effectively correcting for sample selection bias.

In article III, the TE of traditional variety (TV) and high-yielding-variety (HYV) rice producers were estimated in addition to investigating the determinants of adoption rate of HYV rice. Furthermore, the role of TE as a potential determinant to explain the differences of adoption rate of HYV rice among the farmers was assessed. The results indicated that in spite of its much higher yield potential, HYV rice production was associated with lower TE and had a greater variability in yield. It was also found that TE had a significant positive influence on the adoption rates of HYV rice.

In article IV, we estimated profit efficiency (PE) and profit-loss between microfinance borrowers and non-borrowers by a sample selection framework, which provided a general framework for testing and taking into account the sample selection in the stochastic (profit) frontier function analysis. After effectively correcting for selectivity bias, the mean PE of the microfinance borrowers and non-borrowers were estimated at 68% and 52% respectively. This suggested that a considerable share of profits were lost due to profit inefficiencies in rice production. The results also demonstrated that access to microfinance contributes significantly to increasing PE and reducing profit-loss per hectare land.

In article V, the effects of credit constraints on TE, allocative efficiency (AE) and CE were assessed while adequately controlling for sample selection bias. The confidence intervals were determined by the bootstrap method for both samples. The results indicated that differences in average efficiency scores of credit constrained and unconstrained farms were not statistically significant although the average efficiencies tended to be higher in the group of unconstrained farms. After effectively correcting for selectivity bias, household experience, number of dependents, off-farm income, farm size, access to on–farm training and yearly savings were found to be the main determinants of inefficiencies.

In general, the results of the study revealed the existence substantial technical, allocative, economic inefficiencies and also considerable profit inefficiencies. The results of the study suggested the need to streamline agricultural microfinance by the microfinance institutions (MFIs), donor agencies and government at all tiers. Moreover, formulating policies that ensure greater access to agricultural microfinance to the smallholder farmers on a sustainable basis in the study areas to enhance productivity and efficiency has been recommended.

Key Words: Technical, allocative, economic efficiency, DEA, Non-discretionary DEA, selection bias, bootstrapping, microfinance, Bangladesh.

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List of original publications

This thesis is based on the following publications:

I Bäckman, S., Islam, K. M. Z., Sumelius, J. 2011. Determinants of technical efficiency of rice farms in north-central and north-western regions in Bangladesh. *The Journal of Developing Areas,* Vol. 45 (1), pp.73-94.

II Islam, K. M. Z., Bäckman, S., Sumelius, J. 2011. Technical, economic and allocative efficiency of microfinance borrowers and non-borrowers: Evidence from peasant farming in Bangladesh. *European Journal of Social Sciences*, Vol. 18 (3), pp.361-377.

III Islam, K. M. Z., Sumelius, J., Bäckman, S. Do differences in technical efficiency explain the adoption rate of HYV rice? Evidence from Bangladesh. *Agricultural Economics Review*. (Accepted).

IV Islam, K. M. Z., Sipiläinen, T., Sumelius, J. Access to Microfinance: Does it matter for profit efficiency among small scale rice farmers in Bangladesh? *World Journal of Agricultural Sciences*. (Accepted).

V Islam, K. M. Z., Sipiläinen, T., Sumelius, J. 2011. Influence of credit constraints on technical, allocative and cost efficiency in peasant farming in Bangladesh. *European Journal of Scientific Research*, Vol. 56 (2), pp.229-243.

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Authors' contribution

This thesis is the synopsis of five related articles that deal with the same broad topic, efficiency, but investigate different aspects and methods to measure that efficiency. The author is mostly responsible for the development of theoretical framework, empirical work, data collection and for writing the manuscripts. In article I, the actual model fitting was carried out by Stefan Bäckman along with the author. All authors contributed to writing of the paper. K.M. Zahidul Islam was responsible mostly for writing the manuscript with the guidance of the co-authors. Article II is a pure mathematical application performed under the framework of linear programming (LP). The author along with Stefan Bäckman constructed the variables for the model with the guidance of John Sumelius. All authors contributed to writing the paper; however, K.M. Zahidul Islam was responsible mostly for the texts and for the analysis.

Article III started as a collaboration among the authors. The theoretical part of the article was developed by John Sumelius and K.M. Zahidul Islam. Moreover, K.M. Zahidul Islam conducted the empirical work of the paper including processing, computations, reporting and interpreting the results. All authors jointly contributed to writing the texts. In article IV, the theoretical foundation and the empirical model fitting was performed in collaboration with K.M. Zahidul Islam and Timo Sipiläinen. All authors contributed to writing the text. The writing of the manuscript was mostly carried out by K.M. Zahidul Islam with the guidance of the co-authors.

In article V the empirical approach and model fitting was performed by K.M. Zahidul Islam and Timo Sipiläinen. K.M. Zahidul Islam was mostly responsible for analysis and writing the manuscript along with the advice of the co-authors.

Contents

1 Introduction

Efficiency measurements of the production systems among the farmers of less developed countries has received considerable attention in numerous studies since T.W. Schultz (1964) hypothesized that farmers in developing agriculture are ―poor but efficient.‖ Schultz argued that ―there are comparatively few insignificant inefficiencies in the allocation of the factors of production in traditional agriculture‖. Moreover, Schultz claimed that a ―community is poor because the factors on which the economy is dependent are not capable of producing more under existing circumstances.‖ This hypothesis has an enduring and far-reaching effect in the literature on development economics. After Schultz‗s hypothesis had been proved invalid, attention has been devoted to resource use efficiency as an alternative means of increasing productivity and efficiencies. Measuring efficiency might lead to substantial resource savings that may have important implications both for policy formulations and farm management (Bravo-Ureta and Rieger, 1991). The analysis of the productive efficiencies in agriculture may give pertinent information to the policy makers for promoting sound strategic decisions about formulating agricultural policies that affect farmers‗ resource allocations.

For a resource scarce country such as Bangladesh where opportunities to develop and adopt new technologies are rare, empirical investigations of efficiency are extremely important. Such studies help to determine the level at which farmers use existing technologies and also to explore the possibility of raising the productivity of farms by increasing the efficiency with available resource endowments and technologies. Output efficiency of a farm is measured by comparing its actual output against the feasible (frontier) output. Efficiency measurement relies on the specification of a production frontier that represents the maximum potential output that can be produced from a given input vector (Kumbhakar and Lovell, 2000). Technical efficiency (TE) is defined in the production economic literature as the ability of a farm to obtain the best production from a given set of inputs (output-increasing orientation), or alternatively as the measure of the ability to use the minimum feasible amount of inputs to produce a certain level of output (input-saving orientation).

The TE is a purely physical notion that is measured without price information and without having to impose a behavioural objective on producers. In this case we assume that waste avoidance objective of producers is the ultimate concern and they maximize outputs from any given set of inputs or by minimizing input use in the production attain at given levels of outputs. At a higher level, the objective of producers might entail the production of given outputs at minimum cost or the allocation of inputs and outputs to maximize profits. Thus, if information on prices is available and a behavioural assumption such as cost minimization or profit maximization is appropriate, then the performance of a farm can be devised which incorporates such price information and behavioural assumptions. In such a case it is possible to consider allocative efficiency (AE), in addition to TE. AE from input-orientated perspective is linked to the farmer‘s ability to allocate inputs in the cost minimizing way, given their prices, leading to additional cost reductions after technical inefficiencies have first been removed. Economic efficiency (EE) is simply the product of TE and AE when the efficiency analysis presents the efficiency scores as a ratio. It may be noted that in the case of cost minimization, cost efficiency (CE) can be treated as EE.

When farmers encounter different prices and have different factor endowments (in the short term analysis), it may not be appropriate to use a production function to measure efficiency (Ali and Flinn, 1989; Lau and Yotopoulos, 1971). Thus, the price variation condition has led to the application of stochastic frontier profit functions in the estimation of farm specific efficiency directly [1](Rahman, 2003; Kumbhakar and Bhattacharyya, 1992; Ali and Flinn, 1989; Kumbhakar, 1987; Lau and Yotopoulos, 1971). Profit efficiency (PE) is defined as the capability of a farm to achieve optimal performance with respect to profits for a given sets of prices and technologies (the level of fixed factors of the farm). The PE approach takes into account the effect of technical, allocative and scale inefficiencies in the profit relationship and also any deviations from the optimal production that would lead to lower profits for a given farm (Ali et al. 1994). From a profit maximizing framework, a farm is scale inefficient, when it does not produce an output level that equates the product price with the marginal cost (Kumbhakar et al. 1989). Lau and Yotopoulos (1971) popularized the use of the profit function approach by which farm specific prices and fixed factors are incorporated in the analysis of EE. In addition, we should note that when farms are price takers, their options to increase profitability mainly lie in their ability to improve their productivity and to allocate their resources optimally.

Several methods have been suggested and used in efficiency analyses. Among these, stochastic frontier analysis (SFA) (Aigner et al. 1977; Meeusen and van den Broeck 1977) and data envelopment analysis (DEA) (Charnes et al. 1978) are two important methods. The main difference between the two methods is that, since SFA is parametric, it takes into account both the inefficiencies and also white noise, whereas the DEA is nonparametric and it attributes all deviations from the frontier function to inefficiency. However, the common feature of all efficiency analyses is that performance is a relative measure. Consequently, performance is a comparison of actual output/input vs. maximal attainable output/input of a decision-making unit (DMU). Coelli (1995) provided a comprehensive overview of the strengths and weakness of SFA and DEA frontiers.

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[1] *In contrast with widespread application of frontier production functions, use of profit frontier approach is quite limited.*

In empirical applications in which sample partitioning is based on membership in a particular group, such as, participating in a microfinance programme, sample selectivity bias must be taken into account[2]. This entails that some households might decide to participate in the microfinance programme but others do not. Thus, the underlying selection process is postulated on the presence or absence of participating in a microfinance programme. Heckman's (1979) sample selection model has been used as a conventional approach to incorporate selectivity issue in the application of linear models (Greene, 2010). However, Greene (2006, 2010) claims that such a model is not appropriate in non-linear models (probit, tobit etc.). If the assumption of sample selection bias is valid in nonlinear models, then we have to apply a specific tobit model with sample selection for the determination of consistent and efficient parameters both for probit and tobit models. The sample selectivity models applied in this study rely upon Greene's (2006, 2010) model which provided a general framework for testing and taking into account the sample selection in the stochastic frontier function analysis. This model is a more recent approach to the formal extension of the method for nonlinear models. Similar models with respect to sample selectivity bias have also been used in DEA models in which the determinants of inefficiency were tested separately for a specific group of farms such as microfinance participating farms.

In efficiency analysis, it is equally important to measure the level of inefficiency and to identify the socio-economic and institutional factors that contribute to inefficiency. An analysis of efficiency based on the socio-economic and institutional factors indicates which aspects of farm households' human and physical endowments cause inefficiency. If these aspects can be recognized, investment policies that improve efficiency can be implemented by the government and donor agencies. Kumbhakar et al. (1991) and Battese and Coelli (1995) were the first who suggested determining the factors of inefficiency as an essential component of efficiency analysis. They related inefficiency to a number of factors considered to be determinants and measured the extent to which these determinants contributed to inefficiency. However, the approaches for the identification of these inefficiency factors may vary to some extent based on the applied methodology.

The most commonly followed procedure has been the determination of an inefficiency index as a dependent variable and then regress that dependent variable against a number of other factors considered to affect efficiency levels (Kalirajan, 1984; Bravo-Ureta, 1997; Bravo-Ureta and Evenson, 1994; Bravo-Ureta and Rieger, 1991; Sharma et al. 1999; Coelli et al. 2002). In the context of SFA, a number of authors (Kumbhakar et al.1991; Battese and Coelli, 1995; Wang and Schmidt, 2002; Huang and Liu, 1994) claimed that the determinants of inefficiency should be estimated simultaneously by noting that the

[2] *See more details in articles II, IV and V.*

two-stage procedures contains serious problems concerning the assumptions made for the non-negative random inefficiency term, u_i. In the second stage regression, the efficiency scores are assumed to depend on farm specific and other factors, which imply that inefficiency scores cannot be identically distributed when the coefficient of the dependent variables differ from zero (Coelli et al. 1998). Therefore, the two-stage estimation procedure is unlikely to provide estimates that are as efficient as those that could be obtained by applying a single-stage estimation procedure (Battese and Coelli, 1995). Similar concerns have been raised by Simar and Wilson (1998) with respect to two-stage analysis in the context of DEA. In the present study we applied a single-stage approach according to the model of Battese and Coelli (1995).

It is generally believed that smallholder farmers in many countries lack access to financial services, which would enhance their incomes and allow them to escape the vicious cycle of poverty. One of the principal reasons behind this lack of access is that formal banks require collateral, which is not compatible with the resources held by small-scale farmers in Bangladesh. Moreover, complex procedures, poor communication network and inadequate banking facilities restrict the availability of credit to the poor farmers in the rural areas. Such restricted access to credit is an important barrier in rural development in many developing countries where information asymmetry and other inherent problems are common in the credit allocation process (Hoff and Stiglitz, 1993). The outcome of these information problems and the lack of access to financial services lead to reliance on costly informal credits[3], which inhibits investment in agriculture and limits the opportunities to diversify income sources. Therefore, the importance of addressing the credit needs of these small scale farmers remains one of the major rural development challenges that face a government that attempts to improve farm productivity and efficiency.

In Bangladesh Khandker (1998) pointed out that the traditional formal financial institutions have failed to provide financial services to the poor due to the inefficiencies and insufficiencies. Moreover, these formal financial institutions, frequently overburdened with excess liquidity, do not consider agricultural lending a viable proposition. However, rural based small microfinance institutions (MFIs), with inadequate finance, are uniquely positioned to serve this rural credit market and have become more confident about lending to this sector. The mismatch between supply perspectives (mostly formal sector) and the demand factors (need of microfinance) may be minimized through effective linkage between the rural MFIs with liquidity constraints and mainstream banks with an excess of liquidity. Such effective complementary linkage would ensure greater access to microfinance for the farmers who are largely excluded or left untapped by the MFIs. Thus,

[3] *Informal credit is characterized by those sources of credits that originate from village money lenders, friends, relatives, shopkeepers, landlords and neighbours.*

the adoption of agricultural microfinance can play an important role in correcting some failures of formal credit to smallholder farmers that have failed in the past. Furthermore, by focusing on agricultural microfinance development policy can strengthen the links between financial development, agricultural productivity and efficiency. The broader research question thus posited is: Does agricultural microfinance contribute to production efficiency of rice farms in Bangladesh? The research question also indirectly links the contribution of microfinance to ensuring food security in the country through increasing efficiency of farms.

The MFIs play a significant role in improving the lives of the poor communities in the various countries of the world through smoothing out their consumption expenditures, increasing incomes, savings, and diversifying income sources (Khandkar, 1998, 2003; McKernan, 2002; Simonwitz, 2002); poverty alleviation (Khandkar, 1998), women's empowerment and welfare (Hashemi et al. 1996); sustainability and outreach (Khandker et al. 1995; Sharma and Zeller, 1999); group-based lending (Ghatak, 1999; Stiglitz, 1990) and achieving Millennium Development Goals (MDGs)[4] (Littlefield et al. 2003; Simanowitz and Bordy, 2004). However, empirical studies that concentrate on the interactions between the effects of access to microfinance, farm efficiency and agricultural productivity are scarce. To the best of our knowledge, this is the first study that investigates this linkage in Bangladesh. These issues are important since inadequate funding of poor farmers has a negative impact on agricultural productivity and efficiency of small farms (Petric, 2004; Färe et al. 1990; Foltz, 2004; Blancard et al. 2006). Therefore, estimating the influence of microfinance on farm productivity and efficiency and the extent to which microfinance can affect farms productivity and efficiency is important for guiding and designing appropriate policies of interventions in Bangladesh.

In particular, the basic motivation of this research is to make a detailed and systematic empirical comparison of the microfinance borrowers and non-borrowers of Bangladesh by disaggregating the sample on the basis of agricultural microfinance use status. A further objective was to examine how the efficiency measures are influenced by access to agricultural microfinance. The topic of the work is important since the government of Bangladesh is attempting to ensure widely accessible agricultural microfinance to the farmers in order to increase agricultural production to help circumvent the global food crisis, and the loss of domestic production due to floods and cyclones in 2008. It is expected that the findings of the study may have profound relevance for the policy makers

[4] *The MDGs are intended to (i) eradicate poverty and hunger; (ii) achieve universal primary education; (iii) promote gender equality and empower women; (iv) reduce child mortality; (v) improve maternal health; (vi) combat HIV/AIDS, malaria and other diseases; (vii) ensure environmental sustainability, and (viii) develop a global partnership for development.*

in formulating agricultural loan policies and programmes. We hypothesize that MFIs enhance productive investments and profitability of borrowers through the dispensation of their loans coupled with their skill- development training, information and provision of other inputs that contribute towards farm productivity and efficiency.

The thesis is organized as follows: Section two presents the background information on the economy of Bangladesh. In that section, issues related to microfinance, productivity and efficiency and credit constraints concept are outlined. Section three presents the objectives of the study. Section four contains a description of the data, discusses the methodological considerations and the rationale for choosing the models. Section five presents the study results. The concluding remarks and policy implications are given in section six. Section seven provides suggestions for further research.

2 General Background

2.1 Bangladesh and its economy

Bangladesh is a low-lying, deltaic flood plain that is almost entirely flat and criss–crossed by a large number of mighty rivers and their tributaries and distributaries. It is bordered by the Bay of Bengal to the south, India to the west, north and east and Myanmar to the south-east. It lies between geographic co-ordinates of $20^0 34^{'}$ and $26^0 38^{'} N$ and $88^0 01^{'}$ and $92^0 41^{'} E$. Its land area covers 147579 square km, in which an estimated population of 146.1 million lives (Bangladesh Economic Review, 2010). Total labour force (15 years +) is 53.7 million and agriculture accounts for 48.4% out of total labour force (Bangladesh Economic Review, 2010). Bangladesh has one of the highest population densities in the world–990 persons/km^2. About 88.4% of the population live in the rural areas (Agricultural Census, 2008) and the population growth rate is 1.32 (Bangladesh Economic Review, 2010) which has always been a constraint on the economic development of the country. Apart from high population growth rate, Bangladesh‘s economic development has also been impeded by a series of external shocks and frequent natural disasters such as floods and cyclones. With a gross national income of USD 684 per capita (Bangladesh Economic Review, 2010) Bangladesh ranks 146th out of the 178 countries in the United Nations Development Programmes Human Development Index (Human Development Report, 2010), thus Bangladesh is a poor country with 40% of its population living below the poverty line (Bangladesh Economic Review, 2010).

The economy of Bangladesh is heavily dependent upon agriculture. Agriculture is the single largest producing sector of the economy that accounts for 20.2% of GDP and 6.3% of export earnings (Bangladesh Economic Review, 2010). The net cropped area totals 7.85 million hectares and the cropping intensity is 180% (BBS, 2007). Cropping intensity is defined as the number of cropping from the same field during one agriculture year (BRRI, 2008). Rice, wheat, pulses, vegetates, oil seeds, sugarcane and potatoes are the major crops grown in Bangladesh. The major macroeconomic objectives such as employment generation, poverty alleviation, food security and human resources development are greatly influenced by the performance of the agricultural sector. In addition, the agricultural sector makes indirect contributions to other sectors of the economy apart from feeding 146.1 million people of the country.

During the last decade, significant changes took place in the agricultural sector that include, *inter alia*, new production structures, the introduction of high yielding varieties supported by fertilizers, pesticides, mechanized cultivation and irrigation. All these initiatives have contributed to increase food production in Bangladesh. Compared to the fiscal year 2003-04, food grains production in 2009-10 grew impressively by 25% even yet Bangladesh needed to import 2.57 million metric tonnes of food grains during the fiscal year of 2009-10 (Bangladesh Economic Review, 2010). This indicates that much still needs to be done to ensure further growth of the agricultural sector to combat the poverty on one hand and to ensure food security and sustainable development on the other. Given the importance of credit and its contribution towards increasing outputs, ‗farmers'-friendly' agricultural credit programme needs to be rigorously implemented that could contribute to the food supply and food security in Bangladesh.

2.2 Microfinance, efficiency and productivity concepts

2.2.1 Concepts of microfinance

Microfinance offers poor people access to basic financial services, such as loans, savings, money transfer services, micro insurance and other financial products targeted at poor and low-income people[5]. On the other hand, microcredit refers to very small loans for unsalaried borrowers with little or no collateral, provided by legally registered institutions. The aim that poor people are also bankable without the conventional collateral, thus micro credit was established. Bangladesh is the country that pioneered microcredit concept. It developed the unique innovation of credit delivery to enhance income generating activities (IGA) through a collateral-free group-based lending strategy (Yunus, 1999; Hulme and Mosley, 1996; World Bank, 1994).

The Grameen Bank (GB) led the way of microcredit that disburses credit with the social motive to eradicate poverty, empower women, support start-up self-employment in the form of IGA. MFIs generally make credit to that segment of the population, which is not tapped by the mainstream banks for not having collateral. MFIs disburse financial services to poor and low-income clients, especially women, through the methods such as group lending and liability, pre-loan savings requirements, gradually increasing loan sizes, and an implicit guarantee of ready access to future loans when extant loans are repaid fully and promptly (CGAP, 2010).

The majority of the world's poor live in rural areas and most of them are bereft of access to the range of financial services they need. The mainstream commercial banks and other financial institutions intending to work in rural areas face numerous constraints, which

[5] *Consultative Group to Assist the Poor (CGAP).*
Home page: http://www.cgap.org/p/site/c/template.rc/1.1.947/, accessed August 10, 2010.

include, among others, poor infrastructure, dispersed demand and collateral limitations. As a result the rural people depend on rigidly administered informal financial alternatives such as family loans, money lenders, shopkeepers, traders and in most cases they are obliged to pay very high implicit and explicit costs that force the destitute to entangle in a vicious cycle of poverty for generations (Qayyum and Munir, 2006). Due to the lack of formal credit, microcredit has become a popular means of providing credit to the economically active but financially constrained poor farm household as a powerful instrument of poverty reduction (Morduch and Haley, 2002).

It is assumed that the provision of microcredit to the poor would help them to increase their incomes, reduce poverty and improve the farm productivity on the other hand (Khandker, 1998). However, the MFIs in Bangladesh have not generally addressed the credit need of small and marginal farmers for some perceived problems. The problems include, among others, risk of investment in agriculture; seasonality of agricultural production; poor loan repayment performance of agricultural lending; and the technical nature of agriculture production (Hakim, 2004). Moreover, the short-term working capital loans are usually paid off with weekly repayments. Thus, the principal product of many MFIs may not be compatible to long-term seasonal agricultural activities nor the resultant seasonalities of the cash flows of resource poor rural households. Nevertheless, access to agricultural microfinance has the potential to make a difference in agricultural productivity and efficiency.

To ensure efficient, sustainable and widely accessible financial systems, Bangladesh Bank (the Central Bank of Bangladesh) has directed all nationalized, specialized, private commercial and foreign commercial banks to increase disbursement of agricultural credit in order to increase agricultural production in response to the global food crisis, and the loss of domestic production due to floods and cyclones in 2008. The result was evident and compared to the fiscal year 2008-09, the disbursement target of agricultural credit was set at Taka 115123 million which was higher by 22.8% in the fiscal year 2009-10 (Bangladesh Economic Review, 2010). The commercial banks and non-government organizations (NGOs) provide loan both in cash and kind for accelerating the agricultural production. In Bangladesh, the rural credit market is largely dominated by the GB (the pioneer of microcredit concept), Bangladesh Rural Advancement Committee (BRAC), and Association for Social Advancement (ASA) and these bodies collectively account for 93% of the rural credit market shares (GB and MRA, 2010). They cover a wide range of financial services including loans, deposits and payment services to the low-income households and micro-enterprises. From the year 2004, IFAD in collaboration with PKSF (a government apex funding agency for NGOs in Bangladesh) started disbursing agricultural microfinance under the ‗Microfinance for Marginal and Small Farmers Project' which targets 210000 small and marginal farmers[6] in Bangladesh.

2.2.2 Productivity and efficiency

Productivity and efficiency are the two most important concepts in measuring performance in economics which, are sometimes used interchangeably. However, although there are similarities and linkages between them, these two concepts are not identical. Productivity of a farm can be simply defined as the ratio of output (s) to input (s) that is, the amount of inputs (labour, materials, machinery, technology, etc.) used to produce the outputs (goods or services). When there is a single output (O) and single input (I), we can simply define productivity (P) as: $P = O/I$. Productivity change is then simply the increase or a decrease of this ratio. When we use all factors of production in multiple outputs and input settings, we use the term total factor productivity (TFP) (Coelli et al. 1998). On the other hand, partial productivity, covers separate input and output relations of the units under consideration such as labour productivity (output/labour input), land productivity (yield or output/land area) in farming. Partial productivity measures may be misleading with respect to TFP when they are measured in isolation (Coelli et al. 1998).

Output-orientated efficiency measurement relies on the specification of a production frontier that represents the maximum output that can be produced from any given input vector (Kumbhakar and Lovell, 2000) and hence reflects the current state of technology in a particular industry. From an input point of view, a farm may be called efficient if it can produce a given level of outputs using the minimum quantity of inputs. In the case of single output-multiple inputs, which we apply in the present study, the efficiency index is that of the output divided by summed weighted inputs (Färe et al. 1994). The best practice or frontier function (or production frontier) serves as a standard against which to measure the efficiency of a production unit. In other words, it shows the ability of a farm to produce maximum attainable output from a given amount of inputs.

The formulation of such a frontier (theoretical framework) allows us to consider efficiency from different perspectives. These depend upon whether we exploit only input and output quantity data (production frontier) alone or in combination with input and/or output price data and a behavioural assumption for cost, revenue and profit frontiers (Kumbhakar and

[6] *According to loan providing institutions in Bangladesh, marginal and small farmers operate land areas between 0.2 to1 hectares. (PKSK and IFAD, 2004).*

Lovell, 2000). The production frontiers have been applied without recourse to price information or by imposing a behavioural objective on producers in articles I and III. Articles II and V used cost frontiers by imposing the behavioural assumption of cost minimization. Consequently these cost frontiers allow the identification of the sources of cost inefficiency by decomposing the cost inefficiency into its two components, input-orientated technical inefficiency and input allocative inefficiency (excess input use and misallocation of inputs). This decomposition also enables us to determine the extent to which technical and allocative inefficiency constitutes the main source of cost inefficiency. Article IV applied a profit frontier (variable) by imposing behavioural assumption of profit maximization where land is assumed to be fixed in the short run and therefore not freely adjustable by producers.

Koopmans (1951) provided the formal definition of TE: ―A decision-making unit is fully efficient, if and only if, it is not possible to improve any input or output without worsening some other inputs or output (Cooper et al. 2007, p.45)". Debreu (1951) defined TE as one minus maximum equiproportionate reduction (expansion) in all inputs (output) that still allows the production process to continue. Farrell (1957), being greatly influenced by Koopmans's (1951) formal definition of TE and Debreu's (1951) measure of TE, proposed a method to decompose the overall efficiency (economic efficiency) of a production unit into its TE and AE components. According to Farrell (1957), a farm can be technically inefficient if it fails to obtain the maximum output from a given set of inputs. In contrast, a farm may be allocatively (price) inefficient if it fails to choose the optimum combination of inputs given their prices. Farrell (1957) defined the input-orientated measure of EE as: $E(y,x,w) = C(y,w)/C$, where $0 < E(y,x,w) \leq 1$, $C(y,w)$ is a well-defined cost frontier function, C is the observed total cost, y is the vector of output quantities, w is the input prices. Farrell's decomposition of efficiency (economic) can be represented as: $E(y,x,w) = T(y,x) \cdot A(y,x,w)$, where $T(y,x)$ and $A(y,x,w)$ are the input-orientated measures of TE and AE. By definition both $T(y,x)$ and $A(y,x,w)$ lie within the (0, 1] interval. Finally, if profit maximization as a behavioural objective is assumed, the profit frontier $\pi(p,w)$ and its associated system of profit-maximizing output supply equations $y(p,w)$ and input demand equations $x(p,w)$ will provide a similar standard against which we can measure the performance of a farm.

The differences between the definitions of efficiencies by Koopmans and Farrell-Debreu measures were described by Lovell (1993). As a comparison between the definitions of efficiencies made by Koopmans and Farrell, Farrell's (1957) definition implied a radial reduction[7] (input-reducing focus) in inputs that is possible to reach a frontier from an inefficient point. In contrast, Koopmans (1951) stated that a farm is technically efficient if it operates on the frontier and furthermore that all associated slacks are zero. It also suggested that there should be no opportunities to decrease further any inputs. This suggestion also holds for multiple outputs (Coelli et al. 1998, p.142). The discussion of efficiency measurement in this thesis relies upon Farrell's (1957) methodology[8] which greatly impacted on the development of DEA and SFA and which is now well recognized as standard methods to measure efficiency.

Assuming constant returns to scale (CRS; e.g. benchmark technology), Farrell (1957) described the technological set by the efficient unit isoquant (UU') that shows the combination of inputs per unit of output required to produce one unit of output. From input-orientation, the efficiency of the DMUs are calculated as the radial reduction in inputs to the inputs levels of the best performing DMUs to produce the same level of output. For example, point B which lies above the unit isoquant represents the combination of inputs x_1, x_2 actually used to produce output *Y*. Hence the distance *QB* along the ray *0B* measures the technical inefficiency of a farm located at *B*.

The technical inefficiency of farm *B* is *1-0Q/0B* which shows the proportion by which inputs (x_1, x_2) could be reduced, when holding the output constant. The TE of the farm under consideration would be given by the ratio *0Q/0B*. TE takes a value of between zero and one, and hence acts as an indicator of the degree of technical inefficiency of the production unit. A value of one indicates that the farm is fully technically efficient, such as when point *Q* lies on the efficient isoquant. Thus, the radial efficiency measures of TE hold the relative proportion of inputs (outputs) constant. These radial efficiency measures, which have been used in the present study, are unit invariants. This suggests that changing the units of measurement (e.g. measuring quantity of labour in person hours instead of person days) will not change the value of the efficiency measure.

[7] *Radial reduction aims at obtaining the maximum rate of reduction with same proportion, e.g. a radial contraction in the two inputs (for two inputs case) that can produce the current output.*

[8] *Under two inputs and a single output setting, Farrell (1957) illustrated his original ideas by assuming constant returns to scale to represent the underlying production technology. He also discussed the extension of his method so as to accommodate more than two inputs, multiple outputs, and non-constant returns to scale.*

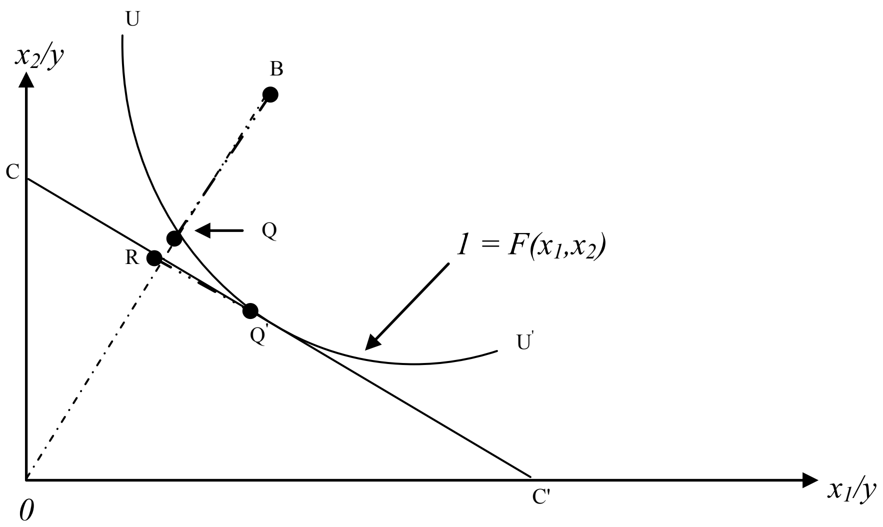

Figure 1: Technical and allocative efficiencies from input orientation

If input prices are available and if we assume that the behavioural objective of the farm is to minimize cost in such a way that the input price ratio is reflected through the slope of iso-cost line CC', AE can be obtained at the point where the slope of CC', the price line, is a tangent to that of unit isoquant UU'. The AE of the farm operating at point *B* is defined to be the ratio *AE = 0R/0Q*. Since the distance *RQ* represents the reduction in production costs that would occur if production were to occur at the allocatively (and technically) efficient point Q', instead of the technically efficient, but allocatively inefficient, point *Q*. Together with the concepts of TE and AE, Farrell (1957) described a measure of what he termed as overall efficiency and later he denoted it as EE which is given by EE = TE×AE = 0Q/0B × 0R/0Q = 0R/0B. Farrell‘s efficiency measure presented here follows an input-orientation measure. However, output-orientated efficiency measures that address the question: ‗by how much can output quantities be proportionately expanded without altering the input quantities used‘ can be found in Färe et al. (1985 and 1994). Input and output orientations are usually separated under the assumption of variable returns to scale (VRS) but they provide the same TE when CRS technology applies (Färe et al. 1994; Färe and Lovell, 1978).

The DEA models discussed above are based on CRS DEA models. The assumption of CRS is plausible as long as farms operate at optimal scale (Coelli et al. 2002). Various constraints such as imperfect competition, financial constraints, public sector central planning procedures or the goals of the owner may cause the farm not to operate at an optimal scale (Coelli et al. 2005). The use of CRS specification when all farms are not operating at their respective optimal scale will cause the TE measures to be influenced by scale efficiencies and thus the measures of TE will be biased by SE (Dimara et al. 2008). Consequently, to get pure technical efficiency (PTE) we must deduct scale effects from the TE scores. The use of VRS specification (i.e., best practice technology) enables us to calculate the TE score free of SE effects.

This shortcoming of CRS specification was corrected by Färe et al. (1983), Banker et al. (1984) and Byrnes et al. (1984), who considered a different set of assumptions to that of Charnes et al. (1978) and introduced an extension of CRS DEA model by adding the convexity constraint $\sum_{j}^{J} \lambda_j = 1$ that accounts for VRS DEA model. This VRS DEA model permits the constructed production frontier to have (local) increasing, constant or decreasing returns to scale (DRS) properties (Coelli et al. 2002). To investigate the nature of SE on farms' desired level of output, we estimated standard input efficiency scores, applying input-orientated DEA under the assumption of both VRS and CRS. We examined the scale properties in both the SFA and DEA approaches to investigate whether the farm had chosen the correct scale of inputs for the corresponding outputs it opts to produce.

The choice between input and output-orientated measures is a delicate matter and may depend upon the particular characteristics of the DMUs under consideration. For the DEA approach, we choose an input-orientated approach under the assumption that inputs are strongly disposable. It implies that by keeping the output constant it is possible to decrease some inputs without increasing the use of other inputs. Furthermore, we assumed that farmers have more control over their inputs than they do for their output levels and the input quantities seemed to be the primary variables for most of the farmers in the study areas that made input-orientation a better choice. From a behavioural perspective, when the objective is to minimize cost, then the input minimization and cost minimization go hand in hand. In addition, the inelastic demand of most agricultural products makes cost reduction a more effective means of increasing profitability than output growth and in many instances the choice of orientation has only a minor influence on the estimated efficiency scores specifically when the sampled farmers operate small farms (Konstaninos et al. 2006; Coelli et al. 2002; Coelli, 1996). A similar approach was used in other agricultural productivity studies (Konstantinos et al. 2006; Coelli, et al. 2002; Wadud and White, 2000).

Under the non-parametric DEA framework, we applied traditional two-stage regression. Several studies (Hoff, 2007; Banker and Natarajan, 2008) have compared the traditional two-stage approach with those of the bootstrapping method suggested by Simar and Wilson (2007; hereafter SW) and their estimation produced quite similar results for the tobit (Tobin, 1958) and SW. The two-stage approach calculates the efficiency scores with DEA (using only inputs and outputs) in the first stage and then regresses the efficiency scores against some farm specific and institutional factors in the second stage. In the first-stage we estimated efficiency scores by applying input-orientated DEA under the assumption of both CRS and VRS while the second stage applies a standard tobit regression that regresses the DEA VRS efficiency scores against some selected variables. However, the standard tobit regression (Tobin, 1958) does not adequately control for selectivity bias and therefore we estimated a tobit sample selectivity model that corrects for the selectivity bias when estimating the determinants of inefficiency for a specific group (e.g. microfinance borrowers or non-borrowers). An efficient estimation of sample selection requires being able to identify some explanatory variables that affect the selection process but not the outcome equation (Greene, 2006; Wooldridge, 2002; Maddala, 1983). Therefore, we included at least one or more variables in the selection equation which was not identical to the variables included in the structure /outcome equation.

2.3 Credit constraints concept

According to Jappelli (1990), Sawada et al. (2006) and Gilligan et al. (2005), there are two factors that determine whether or not a household will face credit constraints. The first factor is the demand for credit, which is the difference between a household‘s return on its resource endowment and the desired consumption. The second factor is the supply of credit by the formal financial institutions. A credit market also distinguishes between access to credit and the desire to participate in that credit market (Diagne and Zeller, 2001). Access to credit implies that a household has the potential to borrow from a particular source. In contrast, the household participates in the credit market, only when it actually borrows from that source.

Most of the empirical literature (Boucher et al. 2008; Duca and Rosenthal, 1993) defines households as credit constrained only when they demonstrate an excess demand for credit. Guirkinger and Boucher (2008) and Foltz (2004) argue that although this form of credit rationing may impact upon farm household productivity, two other forms of credit rationing should also be considered: transaction cost rationing and risk rationing. Transaction cost rationing arises when lenders factor in the transaction costs such as screening, monitoring and contact enforcement costs to the borrowers (Besley and Coate, 1995). Consequently, farmers with profitable investment opportunities may not be willing to borrow at the prevailing interest rates and thus remain credit constrained. In the presence of significant moral hazards, lenders may stipulate that the borrowers bear significant contractual risks. When this is the case, farmers prefer not to borrow even though the loan might raise their productivity (Boucher et al. 2005).

In the present study, farm households were classified as credit constrained or unconstrained based on different quantitative and qualitative questions. Households were asked the following questions: whether or not they had any information about credit from any institutional sources (both formal and semi-formal); whether they applied for credit or not from any source during the last 12 months prior to the survey; whether their applications for credit had been approved or not, and if so, the amount they obtained and whether demand exceeded the supply. As described by Guirkinger and Boucher (2008), households in this study were classified as credit constrained when the outcomes were: rejected applicants (constrained), those who did not apply for reasons such as long processing time, paper work, costly fees of application (constrained), and those who had no collateral or no chance of getting loan (constrained).

On the other hand, applicants were classified as credit-unconstrained when their demand were met in full or if they did not apply for credit because they had sufficient liquidity or they had no profitable investment opportunities. After defining the credit constraint status of farm households (credit constrained or credit unconstrained) based on the above responses, we used a binary probit selection criterion model together with a tobit regression in order to circumvent the problem of empirically identifying both the unobserved heterogeneity of the sample selection process in farm credit constraints status and that of its impact on production and cost efficiencies.

2.4 Efficiency estimation approaches

In the efficiency and productivity literature, there are two widely used methods of measuring efficiency: the non-parametric DEA and parametric SFA. However, the TFP index is most often used to aggregate time-series data and provides estimates of technical change equal to TFP. The background of both SFA and DEA originates from the index number methods including those described by Tornqvist, Laspeyres, Paasche, Fisher, and Malmquist. Coelli et al. (1998) provides a general overview of the index numbers and their developments. The TFP assumes that all farms are technically efficient, whereas the SFA and DEA provides measures of relative efficiency among the farms and does not assume that all farms are technically efficient. The main difference between parametric and non-parametric methods lies in the criterion used to distinguish between the two. Under the parametric approach, the functional form of the efficient frontier is pre-defined or imposed a priori, whereas in the non-parametric method neither a functional form nor an error term is pre-established. This later approach measures the relative efficiency of the

DMUs by estimating an empirical production frontier from actual input and output data for each farm.

Parametric models can be subdivided into deterministic models that assume all deviations from efficient frontier being under the control of DMUs, and stochastic models that capture also random effects outside the control of DMUs. In the stochastic frontier models, the random element, which includes measurement errors and other statistical noise, is assumed to be identically and independently distributed also with respect to the technical inefficiency component. Frontier models can be further classified based on the tools used to solve them, namely mathematical programming and econometric approaches (Murillo-Zamorano, 2004). The deterministic frontier functions can be solved either by using mathematical programming or by using econometric methods whereas stochastic specifications are estimated by econometric methods only. The choice of estimation method has been a contentious point as some researchers prefer parametric (Berger, 1993) approach and others a non-parametric approach (Seiford and Thrall, 1990). The non-parametric approach such as the DEA and the parametric approach such as the SFA have theirs advantages and disadvantages.

The parametric approach such as SFA deals with stochastic noise and permits statistical tests of hypotheses pertaining to the structure and degree of inefficiency. It allows separating random elements from farm specific aspects to some extent. Its main drawback is the assumption of an explicit functional form of the production technology and for the distribution of inefficiency especially in cross-sectional data. In contrast, non-parametric presentation like DEA, on the other hand, specifies the production set only in terms of desirable properties such as convexity and monotonicity, without imposing any parametric structure on the production set (Banker, Charnes and Cooper, 1984). Moreover, the DEA approach is feasible for calculating SE by combining CRS and VRS technologies and can handle multiple inputs and outputs. Its main drawback is that it does not consider random effects or measurement errors and attributes all deviations from the frontier as inefficiency.

It has been shown in the literatures that the production frontier approach has been extensively applied after Farrell‘s (1957) seminal work and interesting new approaches have been incorporated both in SFA and DEA models. However, in cross-sectional studies conducted in Asian countries (India and Philippines) especially on rice farming researchers have applied SFA and the traditional two-stage approach in the non-parametric frontier analysis (Thiam, 2001). Recent studies in Bangladesh (Rahman, 2003; Wadud, 2003; Wadud and White, 2000) have also used similar approaches. In practical applications, these simple two stage approaches in connection to the DEA analysis have produced similar results compared to more complicated approaches (Sipiläinen et al. 2009;

Banker & Natarajan, 2008; Hoff, 2007). For this reason, we used a (simple) two-stage approach when examining the determinant of DEA based TE, AE and EE.

An additional complication is related to the selectivity bias, which we took into account in the probit-tobit framework, when the effect of these potential determinants was evaluated. In SFA, the TE (PE) scores were computed by estimating parametric production frontier using the single-stage approach as described by Battese and Coelli (1995). The parametric production frontier makes it possible to estimate simultaneously the TE (PE) along with parameter values for background or farm related factors (*z* variables) that affect TE (PE). However, the model of Battese and Coelli (1995) cannot be used to assess possible sample selection bias while estimating PE. Therefore, we compared the results of the sample selectivity model which was jointly estimated with probit selection equation as described by Greene (2010) to that of the model of Battese and Coelli (1995). The comparison took place in the specified group, not simultaneously in the whole sample.

The DEA and SFA use quite distinct methodologies for frontier estimation and efficiency measurement and the choice of a particular method is contentious issue. In particular, the choice of one method may depend upon the particular characteristics of the DMUs under consideration or may be more preferred as a priori approach than the other method. Agricultural producers in developing countries in general and the smallholder farmers in Bangladesh in particular operate in an uncertain production environment and therefore it is plausible to apply SFA. On the other hand, DEA may become more appealing than SFA when taking into account the possibility of misspecification of the functional form or efficiency distribution. However, it has to be noted that in most cases the correlation between the efficiency scores of different methods is relatively high. Thus, the rankings are similar although the levels may differ. In addition, we have not applied SFA and DEA models to exactly similar research problems. This complicates these comparisons.

In the present study we applied both parametric and non-parametric frontier techniques since applying only one of these methods to improve efficiency may lead to incorrect measurements of increase outputs or reduce inputs since either method has its inherent limitations. This comprehensive approach allows us to suggest policy recommendations that contribute to formulating agricultural credit policies with the aim of attaining food security through increased production.

3 Objectives of the study

In this study, the objective was to analyze empirically the impacts of access to agricultural microfinance on rice farmers‘ production performance and efficiency in Bangladesh. Specifically, we studied whether small-scale agricultural microfinance offered at reasonable cost affects TE, AE, EE and PE of farm households. This thesis focused on five specific objectives which have been investigated in five papers. If efficiency varies among producers or through time, it is natural to seek the determinants of efficiency variation. Thus, the first paper of the thesis attempted to identify the determinants of TE and to explain the variation in efficiency of individual rice farmers operating in the north-central and north-western regions of Bangladesh. Further objective was also to assess various distributional assumptions made on the inefficiency component in the estimation of stochastic frontier models and to choose a production function that fits the data best on the basis of several hypotheses. This later objective was pursued since sample mean efficiencies are assumed to be sensitive to the distribution assigned to the one-sided error component, u_i.

In paper II the main aim was to assess the effect of access to agricultural microfinance on the TE, AE and EE of farm households. A non-discretionary DEA model was also used to access the effect of microfinance availability as a farm input (non-discretionary) and its effect on efficiencies. In paper III the purpose was to conduct a comparative analysis of farm level TE of hybrid variety (HYV) and traditional variety (TV) rice farmers in addition to finding out whether there are significant differences in TE between the two groups of producers. In addition, the factors contributing to the adoption rate of HYV rice or impending it were identified with special emphasis of farm level TE as a potential determinant of the adoption rate of HYV rice. The fourth paper (IV) measured the contribution of microfinance on PE and profit loss of rice farmers in Bangladesh and also identified the determinants of PE. The objective of the last paper (V) was to address the effects of credit constraints on TE, AE and CE. In addition, we also explored the possible determinants of credit constraints and identify factors that affect the efficiency indices.

4 Data and methods

4.1 Description of the study areas

The study areas covered two districts in north-central Bangladesh and four districts in north-western region of Bangladesh. The two districts in north-central regions (Mymensingh and Sherpur) are located approximately 135 km north of Dhaka (capital city) and the four districts in north-western regions (Rajshahi, Naogoan, Dinajpur, and Gaibandha) are located approximately 250 km to the west of Dhaka. The areas were chosen for the presence of IFAD funded ‗Microfinance for Marginal and Small Farmers Project' that specially addresses the agricultural credit needs of small and marginal farmers. The project consists of 14 districts including 117 *upazilas* (sub-districts). According to the IFAD (2004), the total population of the target districts is 28 million (of which 1.7 million households constitute the project target group) with 6.4 million small and marginal farmers. These areas have high levels of poverty (with 41% of the farmers living below the poverty line, which is set at $1 a day or less by the World Bank, 2004.) and good agricultural potential. The major agricultural products in these areas are crops (rice, jute, wheat, vegetables, and potatoes), horticulture, livestock (cattle, goat, and sheep), poultry and fisheries. The most commonly produced crop is rice and the average rice cropping intensity in these areas is 157.8% which indicated that the majority of farms grew two rice crops a year in the study areas.

Cultivation of three rice crops is rare but the farmers in both studied regions intensively cultivate the HYV Boro rice (winter rice) along with Aman (summer rice) and or Aus rice (spring) depending on topography and flooding conditions and on access to irrigation. In recent years, Boro rice cultivation has expanded at the expense of Aus rice in particular due to the development of irrigation and drainage systems in the study areas. In general, the climate of the study areas is mild during the winter with hot and dry summer with high humidity. Annual rainfall is fairly high and basically concentrates on monsoon climate characterized by rain bearing winds. Adoption of irrigation and the mechanization of cultivation through the use of power tillers such as hand tractors are common in the study areas.

4.2 Data collection procedures

The study used farm household survey data collected through a structured questionnaire. The researcher along with the five survey enumerators collected data from IFAD funded ‗Microfinance for Marginal and Small Farmers' project from 360 farmers in the north-central and north-west regions in Bangladesh during the 2008-2009 growing season. The data covered farm household information on crop and livestock production, consumption, savings, storage, off-farm income, access to credit and other borrowing activities, institutional constraints and demographic characteristics. The same data set has been used in writing all five papers. IFAD funded ‗Microfinance for Marginal and Small Farmers' project disbursed agricultural microfinance at a reasonable interest rate of 12.5% per annum. The farm households for both microfinance borrowers and non-borrowers were randomly selected from six districts.

Microfinance borrowers' data were collected using MFIs clients' lists which are used as a sampling framework. We interviewed 180 microfinance borrowers and 180 non-borrowers (control group) of microfinance. Non-borrowers were selected based on farming similar land holdings and socio-economic background to provide a control group for comparison with the borrowers group. A well-structured and field pre-tested comprehensive interviewing schedule was used before the data collection. Prior to the survey, one week of an intensive training programme was arranged to familiarize the enumerators with the content of the survey. The researcher along with enumerators interviewed the heads of the farm households at a convenient time. Constant supervision and day to day follow-up in the process of data collection ensured the validation of the responses. Discussions with the officials of the MFIs helped the enumerators to understand the language, culture and tradition of the study areas which minimized the barriers to communication and also external noise that impacted on the response behaviour of the surveyed households. Data were collected from the farmers that produced Boro, Aman, and Aus rice from the selected areas. As most farmers in Bangladesh are illiterate, the majority of them do not keep any vouchers or receipts of input prices nor do they maintain any written documents about input-output data. With a view to minimizing errors stemming from purely relying on farmers memories, data were collected immediately after the harvest in the months of June to August 2009.

In conducting the research, a multistage random sampling technique was used. The first stage was the purposive selection of two districts (Mymensingh and Sherpur) from north-central region and four districts (Rajshahi, Naogoan, Dinajpur, and Gaibandha) from the north-west region in Bangladesh. The second stage involved the identification of the farmers who had taken microfinance specially targeted for agricultural production. Two villages from each district were included in the sample. The respondents were primarily selected based on their land holdings and they included small and marginal farmers who farmed between 0.2 and 1.0 hectare of land. This land holding criteria was ascertained by the microfinance institutions at the time of granting agricultural microfinance to the borrowers. However, the land holding criteria was not very strictly followed while disbursing the loans. In addition to landholding criteria, farmers whose principal occupation was farming and the main source of household income came from crops were included in the sample both for microfinance borrowers and non-borrowers. Finally, a multi-stage proportional random sampling method was used to select 60 households (30 from microfinance borrowers and 30 from non-borrowers of microfinance) from each district, thus a total of 360 households were surveyed.

Map of Bangladesh and study areas

→ Study areas

Figure2. *Map showing the study areas*

Source: http://www.infoplease.com/atlas/country/bangladesh.html

4.3 Modelling procedures

The thesis consists of five articles. In the thesis, both parametric and non-parametric approaches are applied to estimate (calculate) efficiency. The parametric approach utilizes the SFA, where the estimation method relies on maximum-likelihood estimates (MLE) whereas the non-parametric approaches are based on input-orientated DEA models. Econometrics was used in article I, III and IV. In paper II and V the non-parametric applications, DEA were used. Since, the data used in this study were obtained from responses of farmers' reliance upon memory; it was justified to apply SFA over DEA to take into account such data noise. Therefore, SFA was applied in articles I, III and IV to investigate whether efficiency estimates were affected by external shocks and other noise that DEA does not take into account.

In each article, a specific analytical tool and descriptive statistics were used. In SFA, a single stage technique was applied where the production function and inefficiency effects model were estimated simultaneously with the estimation of the frontier function (Battese and Coelli, 1995). The estimation under SFA was performed by running the computer programs FRONTIER 4.1 and NLOGIT Version 4.0 (ESI, 2007) whereas the DEA based efficiency scores were calculated by computer program DEAP (Coelli, 1996). The computer program Frontier 4.1 (Coelli, 1996) yields maximum likelihood estimates for the frontier production function and TE (PE) measures for individual farm and utilizes the parameterization of total variance of the residual (the sum of variances of noise and efficiency terms) $\sigma_s^2 = \sigma_v^2 + \sigma_u^2, \gamma = \sigma_u^2 \div \sigma_s^2$ where γ lies between zero and one. The computer program NLOGIT Version 4.0 (ESI, 2007) applies maximum simulated likelihood in the estimation of efficiency model with selectivity which was applied to estimate PE following the model of Greene (2010).

It should be noted that the analysis of the effect of a specific treatment such as the participation to microfinance cannot be estimated directly by comparing participating and non-participating groups, if we assume the presence of sample selectivity bias. Therefore, to address the sample selection issues, we applied sample selectivity models in article II, IV and V. Greene (2000) and Wooldridge (2002) noted that if the correlation between the disturbances terms of selection equation and structural equation was not zero, ($\rho \neq 0$), then the estimation of the separate structure equation (equation of interest) leads to biased estimates of parameters. The conventional approach to deal with the selectivity issue as proposed by Heckman (1976) involves two steps. Fit the probit model for the sample selection equation in the first step. Fit the second step model (ordinary least squares or weighted least squares) by adding the inverse Mill's ratio (IMR) obtained from the first stage as an independent variable to correct the selectivity bias and test its significance.

Greene (2006, 2010), however, claims that such a specification is not appropriate in non-linear models (probit, tobit etc.). Thus, one cannot simply add the IMR into the tobit model, which was used when the determinants of inefficiency were tested for a particular group of farms (e.g. CCFH and CUFH; microfinance borrowing and non-borrowing farms). Instead, a specific tobit model with sample selection was applied. This used a maximum likelihood estimator in the determination of consistent and efficient parameters both for the probit and the tobit models in the presence of unobserved heterogeneity (correlation between the error terms of the two models). By applying the sample selectivity model, the unknown coefficients of the parameters of the probit model were estimated in the first stage. In the second stage, these estimates were used to eliminate the effects of sample selection in the equation of interest (structural equation) by applying a tobit model with sample selection. In the sample selectivity model, the estimation was run on the computer program NLOGIT Version 4.0 (ESI, 2007) and also by LIMDEP (Version 9.0) where the model parameters were based on MLE.

In the first article, the parametric SFA was used to estimate the TE scores and to identify the determinants of TE. The estimation was based on the single stage approach as described by Battese and Coelli (1995). In addition to identifying the sources of efficiency differentials among the rice farmers, several hypotheses were tested to choose both the appropriate functional form of the inefficiency component and a suitable frontier production function that fits the data best. Based on the results of hypotheses a logarithmic production function with second order terms (i.e., extended Cobb-Douglas) with an exponential inefficiency distribution was used to represent the underlying production technology and MLE was implemented to estimate the model.

The second article applied a DEA model (Charnes et al. 1978; Banker et al. 1984) to assess the impact of access to agricultural microfinance on farm households‘ TE, AE and EE. The reason for applying the DEA model is that it avoids explicit functional form of the production technology and the distribution of efficiencies and error terms and allows for ready compatibility with multiple inputs multiple output technologies. A non-discretionary DEA model was also used to investigate, if farms were constrained by credits, how did they perform compared to their counterparts? In this case, farm performances were compared in the presence of non-discretionary input(s). In addition, the possible sample selection bias was addressed by applying a sample selectivity model as described earlier. Moreover, the determinants of inefficiency are tested separately for the microfinance borrowing and non-borrowing farms. In the DEA models, the efficiency scores were initially calculated for the whole sample and the farms were subsequently divided into separate groups. Thus, the DEA model had a fairly different approach compared to Greene‘s (2006, 2010) SFA model.

The third article investigated whether there were significant differences in TE between TVs and HYV rice producers and investigated the determinants of adoption rate of HYV rice. The TE of TVs and HYV rice producers were estimated by using the SFA, where the estimation method is based on MLE, and a tobit regression analysis was used to identify the factors that affected the adoption rate of HYV rice. The role of TE as a potential determinant to the adoption rate of HYV rice was also investigated. It should be noted that this article addressed the variety adoption and microfinance was not explicitly accounted for in the analysis. However, access to microfinance as a determinant of the adoption rate of HYV rice was used in the analysis. Thus, microfinance was only indirectly linked in this paper.

The tobit regression model (Tobin, 1958) in this paper included both the adopters and non-adopters of HYV rice and this model permitted both the measurement of probability of adoption rate of improved variety and the intensity of adoption rate (Adesina and Zinnah, 1993). In Bangladesh, farmers who adopt HYV rice generally plant their entire land holdings under HYV rice, so the intensity measure takes a value of either 0% or 100%. Following the definition first described by Adesina and Zinnah (1993) and later by Doss and Morris (2001) the intensity of adoption rate of HYV rice was measured by the percentage of total rice area planted under HYV rice in Bangladesh. The tobit model on some farm–specific explanatory variables and institutional factors that might determine the adoption rate of HYV rice was regressed.

The fourth article measured the contribution of microfinance on the PE and loss of profit for rice farmers in Bangladesh by using a stochastic frontier profit function. A recently developed approach by Greene (2010, 2006) that provides a general framework for testing and taking into account the sample selection in the SFA was used. In addition, the determinants of profit inefficiency and estimated profit loss at the farm level separately for microfinance borrowers and non-borrowers were identified. The fifth article applied a binary probit selection criterion model together with a tobit regression in order to circumvent the problem of empirically identifying both the unobserved heterogeneity of the sample selection process in farm credit constraints and that of its impact on TE, AE and CE.

Limited dependent variable models (e.g. models in which the range of a dependent variable is constrained in some way) like tobit regression (Tobin, 1958) models were also applied in articles II, III and V where the TE, AE and EE estimates derived from DEA (article II and V) and SFA (article III) were regressed on farm-specific explanatory variables. The results of these standard tobit regressions (Tobin, 1958) which do not control for sample selectivity issues were compared with those of the sample selectivity models that correct for sample selection bias. It should be noted that in the DEA approach a significant proportion of the estimated efficiency scores were equal to one and that the OLS regression could predict the efficiency scores greater than one. Therefore, a tobit regression was used since it can account for truncated/censored data (McCarty and Yaisawarng, 1993). Our dependent variable, efficiency, lies between (0,1]. So, it was truncated from the left (below) and right (above). We may also think that the efficient unit (value =1) can be superefficient (their efficiency score could be larger and one). But in the case of standard DEA models we only observed a concentration at 1 and no larger values.

5 Results and discussion

The broader objective of this study was to provide answers to the questions related to the roles of agricultural microfinance on production performance and efficiency of farm households, especially in relation to rice farming in Bangladesh. All the articles deal with the same topic, efficiency, but from different aspects and by using different estimation methods. The articles aimed at answering separate but related questions in each of the five articles under the framework of general research questions. Since an identical data set was used for each article, discussions based on each article are interrelated with others. The purpose of this section is to summarize the answers to the research questions raised in each article, and to discuss the results, to present the contributions of each article in relation to the existing literature on productivity and efficiency and to provide general conclusions.

5.1 Determinants of technical efficiency of rice farms in north-central and north-western regions in Bangladesh (Article I)

Efficiency is an important factor of productivity growth especially for developing economies that has the potential of increasing productivity with existing resource endowments and technologies. Measuring farm level TE and its determinants may indicate the levels with which farmers use existing technologies. Moreover, TE may indicate the potential for increasing productivity through improved efficiencies and also which aspects of the farm households‘ characteristics and resource endowments might be addressed by public investment policies to improve productivity and efficiency. The first article begins with identifying factors, which cause efficiency differentials among farms in the study areas. A stochastic parametric frontier approach was applied to estimate farm level TE in addition to quantifying the contribution of each factor to inefficiency, with special focus on access to agricultural microfinance.

In this article we addressed the sensitivity of results with respect to its functional form and efficiency distribution. More specifically, we aimed to consider the effects on the measured efficiencies by varying the distributional assumption on the one sided error component (u_i) and the functional form. The testing and choice of the appropriate functional form are important since rotating the distributions (half-normal, truncated normal and exponential distributions) of the one sided error component (u_i) may greatly impact upon the efficiency estimates. This paper thus handled the sensitivity of the distribution assigned to the one-sided error component through choosing the appropriate functional form by applying likelihood ratio tests. In particular, the analysis of the production structure and TE of Bangladeshi rice farms through this finding may give better insights for the policy makers about farm level TE and formulate policies to enhance farm productivity and efficiency. This article incorporated the whole farm rice production in the analysis and identified the determinants of the whole farm rather than for a specific rice crop. In addition, a new explanatory variable named ‗access to agricultural microfinance', which had not been examined in the previous studies as a potential determinant of efficiency in rice farming was introduced. The paper also tested whether extension visits, experience, education, access to microfinance and regional variation explained the differences in the TE of the surveyed farms.

The results of the hypotheses test suggest that a quadratic frontier production function (i.e. extended Cobb-Douglas functional form) with the assumption of exponential distribution for the inefficiency component is suitable to analyze the production structure of rice farming in Bangladesh. The results of the efficiency revealed that TE scores of surveyed farms, estimated as e^{-u_i} , varied from 0.16 to 0.94 (mean 0.83). The result of the mean TE shows that the average farmers in the studied areas produced only about of 83% the maximum attainable outputs. It also indicated that there is substantial technical inefficiency in rice farming and there is some scope for increasing rice production by 17% if the average farmers were to acquire the same technical and managerial skills levels of their most efficient counterparts. In other words, the deviation of the observed output from the frontier output reflects the inefficient use of the factors which are under the control of the farms. Moreover, given the limited farming land resources in Bangladesh, the mean TE implies that there is still scope to improve production performance by improving the TE with an existing technology.

The results showed that there is some evidence that TE can be improved by ensuring the availability of financial resources; more specifically, when farmers have access to external financial resources such as access to microfinance. In the agricultural setting of Bangladesh, the well-administered agricultural microfinance offered at reasonable cost (12.5% per annum) may exhort the farmers to exert greater efforts through the actions of the lending institutions (e.g. MFIs) that may result in improving production efficiency in one hand and contributing to food security on the other. Frequency analysis of efficiency scores showed that 75% of the farms operated with an efficiency level 80% and above, whereas 3.6% had efficiency scores below 60% and the rest had efficiency levels between 61% and 79%. The likelihood ratio (LR) tests confirm the presence of inefficiency and indicate that the technical inefficiency effects were related to the variables specified in the inefficiency effect model.

The parameters of the explanatory variables (or determinants) in the inefficiency model were simultaneously estimated in a single-stage using computer program FRONTIER 4.1 in which the estimation was based on MLE. The computer program Frontier 4.1 (Coelli, 1996) yields maximum likelihood estimates for the production function and TE measures for individual farm and utilizes the parameterization of $\sigma_s^2 = \sigma_v^2 + \sigma_u^2, \gamma = \sigma_u^2 \div \sigma_s^2$ where γ lies between zero and one. The results show that factors such as age, education, off-farm income, number of plots, region and access to microfinance positively influenced technical inefficiency whereas experience and extension showed a negative relationship with inefficiency.

The significant negative impact of the experience on technical inefficiency might mean that rice farming in Bangladesh is highly dependent on the number years of rice farming experience. It also implies that long years of experience help the farmers to allocate inputs effectively thereby contribute to operating at higher TE. This finding suggests that extension education could be effective by tapping the experienced farmers and targeting the younger farmers‗ lack of experience by good extension education. The significant positive impact of the number of plots operated by the farm households on technical inefficiency meets the priori expectation that the more plots the farms have, the less productive are the farms‗ production operations. This can be explained due to the fact that fragmented lands may create problems to the harnessing of modern technologies, and better farm practices such as irrigation or the optimal use of machinery and labour. Consolidation of individual small plots into larger unified plots might ensure economies of scale thereby increasing output in addition to increasing TE.

As expected, having access to microfinance tended to improve TE of farm. The results suggested that access to microfinance reduces the technical inefficiency of the sample farms. Estimated results show that microfinance borrowers had significantly higher TE than their non-borrowing counterparts. The survey results show that, on average, microfinance borrowing farms obtained agricultural finance of Taka 16673 whereas their demand for loan was Taka 39383. These binding liquidity constraints may obligate the farms to use a level of inputs that may deviate from optimal levels and thereby inhibit the optimum production. In this sense, the marginal contribution of access to microfinance may bring the input levels closer to the optima, which would increase yields and outputs. Therefore, it is essential to explicitly address the issue of ensuring access to microfinance to a larger segment of productive population in Bangladesh. From this perspective, several policy guidelines may be formulated that may bring about the relaxation of the liquidity constraint and improve producer access to inputs which may lead to improving food production in Bangladesh.

The first step is to address the features of agricultural microfinance by taking into account that farmers are heterogeneous in their demands for credit and the ‗one basket fits all' concept of credit supply is inadequate. Thus policies leading to substantial modifications to conventional operational methodologies of agricultural microfinance in addition to the seasonality of crops and farm incomes should be considered when the loan repayment schedule is being formulated. Such modifications may match the heterogeneous demands of households and enable farmers to afford finance by devising flexible repayment schedules. Second, the establishment of ‗poor-friendly' microfinance banks to improve the access of farmers to finance without collateral and at reasonable cost is suggested. Third, the delivery of tailor-made agricultural microfinance backed up by direct support from the government through regulatory framework and institutional innovations may improve access of farmers to microfinance. Therefore, relaxing credit constraints through ensuring access to microfinance as a policy instrument, merits further attention particularly in Bangladesh.

Fourth, only ensuring access to microfinance *per se* may not be enough to improve production efficiency of rice farms. Therefore, providing technical guidance on farm management in addition to supervision of the end use of loan for the right purposes and also advice on marketing the agricultural produce are essential when measures to take. It is important to note that there is a time lag between when the inputs are purchased and when the output is marketed. If farms could borrow the optimum amount of finance such that liquidity does not constrain profit maximization of farms and repay the loan costs after the output is marketed, it may lead the farmer to mobilize more working capital during the production period. This, in turn, may create at least some positive cash flows after taking the loan costs into account. If such measures are devised, it might lead to more efficient allocation of resources and increased production through improved efficiency which may, in turn, contribute to ensuring food security in Bangladesh.

5.2 Technical, economic and allocative efficiency of microfinance borrowers and non-borrowers: Evidence from peasant farming in Bangladesh (Article II)

Most policies and research interests regarding rural credit markets perceive that poor households in devolving countries lack access to credit. Consequently this affects their technology adoption rate, risk behaviour, agricultural productivity and overall household welfare. On the other hand, access to credit alleviates the capital constraints on farm households, increases the ability to acquire needed agricultural inputs, encourages households to adopt labour-saving technologies, which raises agricultural productivity and efficiency (Delgado, 1995; Zeller et al. 1997). Empirical evidence is therefore required for assessing the role of access to finance for production performance and efficiency of farm households. In article II, the effects of microfinance on TE, AE and EE of rice farms in Bangladesh were calculated and factors that affected these were identified. The potential endogeneity of the access to microfinance in the explanation of efficiency was examined according to the model of Greene (2006, 2010).

Article II contributes to the literature on efficiency by bringing insights in which farms performances are influenced by the presence of non-discretionary institutional variable (access to microfinance). We assumed that farm may not be able to alter the amounts of microfinance they obtained from MFIs at least in the short run. More specially, the paper used a non–discretionary DEA model to investigate the effect of strictly monitored and administered microfinance programme for farms‘ production and CE of farms. Moreover, the study used an internally consistent method of incorporating ‗sample selection' through a tobit model in the determination of consistent and efficient parameters for probit and tobit models for the presence of unobserved heterogeneity.

The results showed that under both CRS DEA and VRS DEA models, microfinance participants had significantly higher AE and EE. However, the two groups did not differ significantly in terms of TE. If we consider physical output *per se*, the computed mean of TE of the microfinance participating farms under CRS DEA was 64.5%, and ranged from 20.3% to a maximum 100%. On the other hand, for the non-participating farms the computed mean of TE under the CRS DEA was 62.2%, and ranged from 24.1% to 100%. Given the present state of technology and input levels, these findings imply that microfinance participating and non-participating farms produce 64.5% and 62.2% of the maximum attainable outputs respectively. These findings suggest that the microfinance participating and non-participating farms in the study areas may increase their production by as much as 33.5% and 37.8% respectively.

The results also showed that under the VRS DEA frontier microfinance borrowers and non-borrowers could reduce their input usage by 27% and 28% respectively, if they were to acquire the necessary technical and managerial skills of their most efficient counterparts and they could bring down the costs of production by 52% and 54 % respectively. The efficiency measures obtained under the VRS DEA model were consistently higher than those derived under the CRS DEA model for both groups. Consequently the VRS DEA envelops the data more tightly than the CRS DEA frontier. The DEA analyses revealed substantial productive inefficiency in the study areas for both groups. For the inefficient farms of both groups, the causes of the inefficiencies may be attributed to either in inappropriate scale of operations or a misallocation of resources. Inappropriate scale indicates that the farms do not take advantage of economies of scale and thus fail to determine the optimum size of resources, whereas a misallocation of resources suggests inefficient input combinations. The scale efficiency is 0.89 for the microfinance borrowers and 0.87 for the non-borrowing farms, which indicates that adjusting the scale of operation may improve the efficiency by 11% and 13% for the microfinance borrowing and non-borrowing farms respectively.

The reason for applying a non-discretionary DEA models is to ensure fair comparison in performance assessment such that DMUs that face unfavourable conditions, which they cannot influence are not penalized for producing less outputs or consuming more inputs than their counterparts. This model was modified by adding the credit constraint that the microfinance borrowers were compared only to those farms with the same level of debt as is suggested by Coelli et al. (1998). This model not only facilitates the comparison of efficiencies with discretionary inputs but also with the level of debt. The results demonstrated a direct link between the access to microfinance and the level of efficiency of the households. The DEA estimates showed that the microfinance borrowers, under CRS assumption, had 3%, 15%, and 13% higher TE, AE, and EE compared to their peers of non-borrowers of microfinance. These indices are higher by 3%, 7%, and 8% respectively under VRS assumption. The results of the pooled model and the non-discretionary DEA model are quite different.

Comparing the results of a non-discretionary model with a formulation that only accounts for discretionary inputs (pooled DEA models) show that efficiency estimates improve in the presence of external non-discretionary factors. In general, when the effect of the external environment is taken into account, microfinance participants increased their relative TE, AE and EE by 7%, 2% and 7% respectively under VRS DEA model. If we simulate the result considering physical output *per se*, the computed average for TE for CRS DEA of microfinance participating farms under the non-discretionary DEA model is higher by 6.5% compared to the pooled model. This model estimates that for the microfinance participating farms, the value of output per hectare of land could be increased by Taka 5060 (e.g. 77838×6.5% = Taka 5060). Given that the mean value of output per hectare land was Taka 77838 for the microfinance participating farms, this represents a potential 6.5% increase in productivity. Given their liquidity constrained status, we expect that increasing the access and amounts of microfinance could increase their productivity further, which may contribute to improving food security in Bangladesh.

It can be deduced that non-discretionary factors in relative efficiency analyses are factors-that although uncontrollable by the DMUs, still impacts on the relative efficiency rankings. It is thus evident that borrowers of microfinance are more efficient in terms of all efficiency indices compared to the non–borrowers of microfinance. The microfinance borrowers are more efficient at using the resources in a technically efficient way and they are also more able at allocating the inputs in a cost minimizing way compared to their non-credit borrowers counterparts. This result is understandable when the repayment obligations of the credit borrowers are taken into account. Such an obligation encourages borrowers to increase their efforts to minimize waste of production. Therefore, access to credit increased their efficiencies and this result corroborates those of previous studies (Binam et al. 2004; Zavela et al. 2005; Komicha and Öhlmer, 2006).

Results also reveal that factors that influence TE, AE and EE under the standard tobit models that did not address selectivity bias are different from those that took into account the selectivity bias. The results demonstrated that after effectively correcting for the selectivity bias, household size, land fragmentation (e.g., number of plots) access to on–farm training, household wealth and off-farm income share are the main determinants of efficiency. Given these results, it can be concluded that the allocative inefficiency is the dominant inefficiency component in overall economic inefficiency compared to technical inefficiency. As a consequence allocative inefficiency indicates the inability of the surveyed farms to allocate inputs in the most cost minimizing way rather than using the inputs in a technically efficient way. Thus, the allocative inefficiency of the farm households in general and more of the non-borrowers of microfinance in particular need to be addressed to improve productivity and efficiency since allocative inefficiency constitutes the more serious problems than technical inefficiency. Moreover, increased production through improving technical efficiency may at least theoretically ensure higher revenues that compensate the producers for high production costs.

Finally it is noted that inefficiency is not just the outcome of the amounts of inputs used. Environmental and also institutional factors also have effects on efficiency. Thus, it requires co-ordination through well-organized education, access to finance, policies to reduce land fragmentation, ensuring on-farm training and appropriate courses of action for future research and development programmes. To improve efficiency the study results highlights that the need for the improvement of efficiency of rice farms should be the first logical step of the government to increase the production in the study areas. Such a step would be expected to ensure food security in Bangladesh on a sustained basis. With rising input prices (fertilizers, pesticides, diesel, electricity, irrigation) the provision of finance to the marginal and small farmers still remains elusive in Bangladesh. From policy standpoint, providing loans to the rural needy and untapped farmers in ways that would ensure high rates of repayment at minimum interest costs are suggested. Consequently, streamlining the microfinance to the credit constrained farmers would be a vital factor in increasing the rice production in Bangladesh. In our view, government in collaboration with non-government organizations (NGOs), commercial banks and donor agencies can address the availability of flexible agricultural microfinance, which could improve efficiency of the farmers.

It is evident from these results that access to microfinance does have a positive influence on production performance and CE in that the indebted farmers face repayment obligations that encourage them to minimize waste and increase production. Therefore, the success and experience of the Grameen Bank, the pioneer of the microcredit concept, may be emulated on a sustainable basis in pursuing the goal of increasing production efficiency that may also contribute to ensuring food security in Bangladesh.

5.3 Do differences in technical efficiency explain the adoption rate of HYV rice? Evidence from Bangladesh (Article III)

In article III, we estimated the TE of rice producers for traditional variety (TV) and high-yielding-variety (HYV) in Bangladesh. We also investigated the effect of TE on farm households�GÇÿ adoption rate of HYV rice. The motivation of writing this article came from the observation of a low adoption rate of HYV rice (38.6% of total rice area, BBS, 2006) in spite of its less vulnerability to flood, favourable government policies emphasizing the adoption rate of HYV rice through seed market reform, measures to introduce better soil, emphasis on availability of irrigation water, fertilizer subsidies and other inputs, adaptive research and extension. The contributions of the third article are generally empirical. First, it identifies the possible redistribution of resources in the event of opting for more HYV and less TVs. Second, by comparing the differences between TVs and HYV rice producers, the study proposes TE as a potential determinant of adoption rate of HYV rice. The results also reveal that TE *per se* as an explanatory factor may contribute significantly to the adoption rate of HYV rice.

Following the definitions of the ‗intensity of adoption‘ by Rogers (1962), Adesina and Zinnah (1993) and Doss and Morris (2001) as the conceptual framework, article III used the same data set to estimate technical efficiencies of TVs and HYV rice producers by a stochastic frontier approach. The cropping systems and varieties that were chosen for analysis are Aus' (spring) crop, the 'Aman' (summer) crop and the 'Boro' (winter) crop. The first two varieties are traditional, rain-fed crops, whereas the Boro crop is the HYV. A tobit regression (Tobin, 1958) model was used to investigate whether the differences in TE of HYV rice producers could explain the adoption rate of HYV rice along with other determinants. Estimation of the results between the functional forms (Cobb-Douglas vs. translog) revealed that Cobb-Douglas production function is the best representation of the underlying production technology for TVs and HYV. Results of the stochastic frontier indicate that mean level of TE are 86%, 91% and 89%, for Aus, Aman and Boro rice respectively. Therefore, suggesting substantial gains in outputs with available technology and resources could be made. The estimated value of σ_s^2 is significant at the 1% level of significance for all rice crops and indicates that the conventional production function is not an adequate representation of the data. The intercept values of the MLE estimates were greater than the OLS estimate for each rice crop which further shows that the frontier production function lies above the traditional average function.

In order to test the notion that TE is the same for all crops, separate stochastic frontiers were estimated for each cross-section. A paired-difference *t-test* for each pair of the crops compared was used to test the null hypothesis that the mean TE for each pair of crops, one pair at a time, was the same. These pair-wise comparisons supported the notion that mean TE of Aman rice was significantly higher for this sample. We also used Bartlett‘s Test to test for the homogeneity of variances among the TE indices of the three rice crops. The null hypothesis, that the variance was the same for all rice crops, was overwhelmingly rejected at the 5% significant level. It was concluded that there were significant differences between the variances among the cropping systems. This study also identified the determinants related to the availability of complementary inputs and the effect of TE of farm households on the adoption of HYV rice.

The results showed a positive and significant relationship between adoption rate of HYV rice and age, education, TE, access to microfinance, irrigation coverage, perception of yield of HYV rice, membership of village-local group, and number of agricultural workers in the family. On the other hand, the perception of input costs, price of HYV rice and farm size negatively affected the adoption rate of HYV rice. It was found that there was a significant positive correlation between TE and adoption rate of HYV rice but on the basis of cross-sectional data no clear direction of causality was determined between these two issues. The development and adoption of HYV variety plays a critically important role in improving productivity, ensuring food security and welfare for resource limited farmers. Therefore, an insight into the above issues especially as to how the technical efficiencies may be improved merits further attention to increasing the likelihood of adopting the HYV rice.

5.4 Access to microfinance: Does it matter for profit efficiency among small scale rice farmers in Bangladesh? (Article IV)

The fourth article used a recently developed approach described by Greene (2010) that provides a general framework for testing and taking into account sample selection in the stochastic profit frontier function analysis. In addition, the determinants of profit inefficiency and estimated profit loss at the farm level were identified separately for microfinance borrowers and non-borrowers. The contribution of this article is that it compares the results of a stochastic frontier model that was jointly estimated by the probit selection equation to that of the stochastic profit frontier with inefficiency effects model of Battese and Coelli (1995). The later does not address sample selectivity issues. The comparison was made on a specified group, not simultaneously in the whole sample. The paper thus contributes to the efficiency literature by showing the effect of access to microfinance on the PE of farms while adequately controlling for sample selection bias.

The use of a sample selection model is appropriate as the effect of a specific treatment such as the participation to microfinance cannot be estimated directly by simply comparing participating and non-participating groups when there is sample selectivity. By using an extended Cobb-Douglas stochastic frontier profit function the PE and profit loss of rice farmers in Bangladesh was assessed. Model diagnostics and the results reveal that serious selection bias exists that justify the use of sample selection model in stochastic frontier models. After effectively correcting for selectivity bias, the mean PE of the microfinance borrowers and non-borrowers were estimated at 68% and 52% respectively. This result suggests that a significant share of profits were lost due to profit inefficiencies in rice production. The results also suggest that the average PE of microfinance participants in the selectivity bias correction model was 7.7% ($p<0.01$) lower than in the conventional model described by Battese and Coelli (1995).

It is evident that the direct estimation of single- equation stochastic profit frontier models for only microfinance borrowing farms seems to have understated the inefficiency levels. The mean difference between the efficiency scores of these two models (selectivity vs. conventional model) is significantly different under both groups. In addition to that, the *t*-ratio for the mean difference between the two groups (selectivity bias corrected) was also highly statistically significant at 1% significance level. This result indicates that under the selectivity model, microfinance participants had significantly higher PE compared to their non-participating counterparts and access to microfinance had a significant impact on the PE of these farms. It is thus evident that ensuring access to microfinance can contribute to improving farms productivity and profitability in Bangladesh.

The estimation of profit-loss per hectare, given the technology, prices and fixed factor endowments of this study revealed that the microfinance participants incurred significantly lower profit-losses per hectare and had significantly higher PE compared to the non-participants. The results from the inefficiency effect model obtained from the stochastic profit frontier using the inefficiency effects model of Battese and Coelli (1995) showed that age, extension visits, off-farm income, region and the farm size are the significant determinants of inefficiency for households. The results of inefficiency analysis suggest that farmers with more experience in farming, located in north-central region, and having more interactions with extension agents tended to be more profit efficient. On the other hand, increasing off-farm income share and farm size tended to lower PE. Given the variation in actual profit, PE and profit-loss, it was observed that there is substantial potential for both groups to improve profit efficiency and to minimize profit-losses with greater scope especially for the non-borrowers.

5.5 Influence of credit constraints on technical, allocative and cost efficiency in peasant farming in Bangladesh (Article V)

Improving access to finance to the resource scarce and cash-starved poor farm households was considered to induce growth and employment. Economic theories also supports the notion that alleviating the liquidity constraints of the poor farm household by enhancing their access to capital will lead to increased production, more efficient allocation of resources and improve their overall economic welfare (Singh et al. 1986).The negative impacts of access to credit on farm household' efficiency have been amply documented in development literature (Guirkinger et al. 2007; Foltz, 2004; Carter and Olinto, 2003; Parikh et al. 1995; Feder et al. 1990). To address the influence of credit constraints on farm household efficiency, article V distinguished between credit constrained farm households (CCFH) and credit unconstrained farm households (CUFH) as described by Guirkinger and Boucher (2008). In addition, a binary probit selection criterion model was used to address the sample selection bias in article V. In the second stage, the efficiency scores obtained from the VRS DEA models were regressed against some selected variables that were assumed to influence efficiency.

The results suggested that credit constraints have direct effects on farm efficiencies. It was also evident from the findings that the TE and SE were quite high, whereas the AE and CE were somewhat lower under both CRS and VRS DEA models for both the CUFH and CCFH groups. Given the available technology, both groups could reduce their physical input use equi-proportionally by 28% whereas they could bring down the costs of production by 52% for CUFH and 55% for CCFH in the pooled VRS DEA models. The results in the pooled model and the separate DEA models for the two-subsamples differ.

For instance, the separate DEA models for both groups show that CCFH had mean TE, AE and CE of 5%, 6% and 7% less than those of the CUFH under CRS. The results of the confidence intervals determined by bootstrap method for both samples indicated that the differences in average efficiency scores of CCFH and CUFH were not statistically significant although the average efficiencies were higher in the CUFH group. However, the results are quite similar in the pooled sample.

When the relationship between productivity and credit constraints is empirically compared it was estimated that the CCFH would increase their physical output by 311 kg[9]. (e.g. 6211×5% = 311 kg.) per hectare if credit constraints were eliminated. This represents an increase of 5% over the observed productivity of the CCFH. It could be deduced that based on the above simulated result formal credit constraints have a negative effect on the productivity of the surveyed farms. If this result were to be applied to the aggregate figures it would mean that 8.69 million CCFH (Bangladesh Agricultural Census, 2008) would increase the physical production by 2.70 million metric tonnes[10] a year. This suggests that increasing the volume of credit to the farms by all tiers of the government especially to the CCFH group would probably improve production and cost efficiencies in one hand and contribute to ensure food security in Bangladesh on the other.

Model diagnostics revealed that a selection bias exists that necessities the use of a sample selection model to obtain unbiased estimates of the determinants of inefficiency. It is also evident that after correcting for the selectivity bias, household experience, number of dependents, off-farm income, farm size, access to on–farm training and yearly savings were the main determinants of inefficiencies. Given the negative impacts of credit constraints on farm production and CE, there is some scope for increasing efficiencies by ensuring access to credit for all farms in general with a greater potential for improvement for the CCFH. The study also shows that the majority (59%) of the farms are credit-constrained which indicates that the credit needs of the farms are not adequately met. As a consequence, increasing the volume of credit to the farms by all tiers of the government especially to the CCFH may improve production and CE. The broad policy and legal measures that may be devised should include, *inter alia*, ensuring access to formal loans for the farms, developing rural infrastructure, motivating the small and marginal farmers to consolidate their lands through creating larger viable farm holdings and ensuring on-farm training for the farm households.

[9] This comparison of productivity per hectare is based on the similar sets of farms (CUFH) and we assume that CCFH could reach the average efficiency levels of their counterpart (CUFH) at least theoretically when the credit constraints were eliminated.

[10] Note that credit constrained farms would increase, on average, their physical output per hectare by 311kilogram if all forms of formal credit constraints are removed. Increase in aggregate food supply is calculated as: total number of credit constrained farms × per hectare increase in output.

6 Conclusions and policy implications

The objective of the study was to analyze the efficiency of microfinance borrowers and non-borrowers in Bangladesh and to examine how the efficiency measures are influenced by access to agricultural microfinance. This study employed both parametric and non-parametric frontier techniques to investigate differences in efficiency estimates between microfinance borrowers and non-borrowers. The study also handled sample selection bias by incorporating sample selection procedures in both parametric and non-parametric frontiers. This is of importance since using observations from a particular group (be it microfinance participating or non-participating farms) alone is likely to produce biased estimates of the production (profit) function, which will be carried over to biased estimates of production (profit) efficiency. Farm level cross-sectional data obtained from a survey of 360 farm households from north-central and north-western regions in Bangladesh was used in the study.

This thesis is based on five articles. Each article relied upon the same data set and attempted to answer separate but related research question and therefore the issues raised in each article are closely related to each other. In article I, a stochastic production frontier analysis was used to estimate TE and its determinants in which the maximum likelihood procedure was implemented to estimate the efficiency scores and the parameter values. Article II, applied a non-parametric method that used an input-orientated DEA framework. A tobit model with sample selection which used a maximum likelihood estimator in the determination of consistent and efficient parameters both for probit and tobit was also applied while estimating the determinants of inefficiency. In addition to that, a non-discretionary input-orientated DEA model directly captured the influence of microfinance on production and CE of farm households. In Article III, we investigated farm level TE of the TVs and HYV rice producers using Cobb-Douglas production functions in which the maximum likelihood procedures were implemented to estimate the models. A tobit regression was used to assess the impact of TE on the adoption rate of HYV rice.

In article IV, we used an internally consistent method of incorporating ‗sample selection' in a stochastic frontier framework that had a maximum simulated likelihood in the estimation of selectivity-efficiency model. The results of the stochastic production for selectivity bias were compared with that of the conventional stochastic production frontier with profit inefficiency effects model. In article V we used an input-orientated DEA framework to calculate TE, AE and CE of the CCFH and CUFH groups. We also used a binary probit selection criterion model together with a tobit regression in order to circumvent the problem of empirically identifying both the unobserved heterogeneity of the sample selection process in farm credit constraints and that of its impact on production and cost efficiencies.

The main results and conclusions are summarized as follows:

a) There exist substantial production inefficiencies among the sampled farms and a potential to improve TE without requiring the introduction of new technology. Technical efficiencies of farms were generally low and the microfinance borrowers displayed significantly higher TE compared to the non-borrowers.

b) Farms faced binding liquidity constraints that have a negative impact on the efficiency of the surveyed farms.

c) The empirical evidence suggests that both microfinance borrowers and non-borrowers could reduce their input use levels and bring down the costs of rice production, if they could operate on the efficient frontier. Allocative inefficiency has been the main contributor of lower EE for rice farmers in Bangladesh. This suggests that additional efforts should be devoted to improving the AE as a means of improving overall EE.

d) The results showed that access to microfinance has significant positive influence on TE, AE and EE of farm households and it helps the microfinance participating farmers in their use of inputs in a cost minimizing way. It is also evident that when the effect of a non-discretionary factor was taken into account, microfinance participants increased their relative TE, AE and EE. Indeed, the results suggest that farmers with debt obligations are induced to greater efforts to make repayments of their lending intuitions such as MFIs thereby resulting a positive relation between farm debt and production efficiency.

e) It is deduced that non-discretionary factors in relative efficiency analyses are uncontrollable by the DMUs, despite impact on the relative efficiency rankings.

f) Results indicated that in spite of its high yield potential, HYV rice production was associated with lower TE and had a greater variability in yield than the TVs. Empirical findings also indicated that TE had a significant positive influence on the adoption of HYV rice. However, on the basis of cross-sectional data no clear direction of causality could be determined between these two factors.

g) The model diagnostics reveal that serious selection bias exists that justifies the use of a sample selection framework. It is also evident from the results that inputs are vital factors to profitability in rice farming and that rice farms do not use their inputs efficiently. The results suggest that the mean PE of microfinance borrowers was significantly higher than that determined for the non-borrowers of microfinance. Consequently there exists substantial scope to increase profits by improving efficiency for both groups. Special attention is needed for the non-borrowers since they have greater potential to increase PE and to reduce loss of profit.

h) In general when the overall credit constraints status of farms including that of the access to microfinance data were considered, differences in mean efficiency scores of the CCFH and CUFH were not statistically significant although the mean efficiencies were higher in the CUFH group. Given that a majority (59%) of the farms were credit-constrained implies that the observed TE gap indicates a considerable loss of output. This further suggests that if we in Bangladesh want to keep our 150 million people fed, we need to take our agriculture seriously and help the farmers to improve their productivity. Ensuring the provision of credit to the farms at affordable interest rates by all tiers of the government is suggested.

i) Irrespective of the methods used in the investigation, land fragmentation, farming experience, provision of on-farm training, access to microfinance, higher off-farm income and access to extension services are some of the determinants among other that are robust in explaining inefficiency of the farms. Therefore, a broader policy agenda is imperative that not only addresses the rice production but also identifying the factors affecting the farming efficiency.

Policy Implications

Results of this study clearly revealed that farm production performance and efficiency in Bangladesh are influenced by the availability of financial resources. More precisely, when a farm has access to finance it incentivized to improve productivity and efficiency. Therefore, efforts directed at expanding finance specifically that of microfinance merits further attention. Such financing may contribute to improve access to buying inputs, which may lead to improving food production in Bangladesh. Several policy relevant conclusions that potentially would enhance farm productivity and efficiency can be drawn from the present study.

First, our results suggest that currently the MFIs do not fully meet the credit demands of the farms in Bangladesh. Therefore, the MFIs should initially identify the effective credit demand of a farm before determining the loan sizes since farmers are not necessarily homogenous in their demand for credit. Instituting a banking system that can supply microfinance to the marginal and small farmers without collateral and at a low interest rate may prove fruitful in meeting the credit needs of the farms. In this regard, an effective linkage between the rural MFIs with their liquidity constraints and mainstream banks with excess liquidity may minimize the demand-supply gap and ensure greater access to microfinance for those farmers who are largely excluded or untapped by the MFIs. The ministry of agriculture, along with the ministry of finance should work in collaboration with the nationwide network of MFIs to ensure access to finance at a reasonable cost so that it contributes to attaining food security in Bangladesh. This in turn, may lead to the more efficient allocation of resources and increased production through improved efficiency.

Second, the result suggested that farming efficiency improves in the presence of non-discretionary factor more specially within the agricultural setting, because farmers with strict repayment obligations are impelled to greater efforts to meet repayment obligations to the lending institutions such as the MFIs. This leads to a positive relationship between debt and production efficiency. The study results thus highlight the need for the Bangladesh government to improve the efficiency of rice farms as the first logical step in increasing the production in the study areas. Such a measure should contribute to ensuring sustained food security in the country. From a policy standpoint, providing loans to the rural needy and untapped farmers in ways that ensure high rates of repayment with minimum interest costs are suggested. Consequently, streamlining the microfinance to the credit constrained farmers would be a vital measure in increasing the rice production in Bangladesh. In our view, the Bangladesh government in collaboration with non-government organizations (NGOs) and MFIs can replicate the IFAD funded agricultural microfinance programme more rigorously on a sustainable basis in pursuance of the goal of increasing production efficiency. This step, would also contributing to ensure food security in Bangladesh.

Third, the results indicate that majority of the farm households in the study areas were so credit constrained that it resulted in considerable loss in output. For a land scarce country like Bangladesh where the per capita land is only 0.06 ha (BBS, 2006) such loss in production poses a substantive threat to food security in the country. A policy response aimed at increasing rice production through improving the TE of the farmers in general but more specifically in CCFH group should be addressed. This is partly due the relative impact of credit constraint on productivity is higher among the CCFH farmers. The well-being of the huge population of Bangladesh is strongly associated with the improvement in the performance of its agricultural sector including food security. It is therefore imperative for greater institutional and policy support to eliminate credit constraints of the farms and increase food security, standard of living and employment prospects.

In article (V) it was seen that 61% farmers borrowed at an exorbitant interest rate of 148% per annum both for farming and consumption purposes from the informal sector. The results also suggest that farmers are increasingly able and willing to pay commercial banks' interest rates including those that are charged by MFIs for small loans. The policy makers may think of expansion of opportunity space for the farming community by letting the agriculture credit to follow market-based interest rates for small loans. This should create a niche for other formal lenders and increase the overall availability of funds. Through such expansion, formal lenders such as commercial banks may tap into many more rural farmers and increase the total lending market volume. The increased loan volume, in turn, may reduce the unit cost of lending and thereby make the formal loans more profitable. A cohesive policy should be formulated to identify the extent of credit constraints, determine the effective demand for credit, create a balance between the formal sector competitive interest rates in the rural credit market and which of those farmers are willing and able to pay interest rates and, most importantly, the timely availability of credits to farms.

Fourth, the results suggest that TE of HYV rice producers is quite high and long experience of HYV rice farming helped the farmers to allocate inputs effectively, which enables them to operate at a higher TE. However, the adoption rate of HYV rice in Bangladesh is only 38.6% of the total rice growing area (BBS, 2006), which indicates that some bottlenecks exists in affecting and adopting new technologies. Our results provide the obvious message to policy makers to improve the adoption rate of HYV rice through the timely supply of agricultural inputs at affordable prices, ensure sufficient access to microfinance, ensure fair price of rice, greater co-ordination between the government, NGOS and private sector to develop and release new rice varieties toward improving farm production. These policy and technology developmental interventions may improve farm production, farm income and contribute to ensuring food security in Bangladesh.

Finally, it is noted that inefficiency is not just the outcome of the amounts of the inputs used. Farm specific and institutional factors also have effects on efficiency. Our key findings on the factors that affect efficiency closely agree with those of Wadud (2003), Rahman (2003), Coelli et al. (2002), Wadud and White (2000), Sharif and Dar (1996), Ali and Flinn (1989) and Wang et al. (1996). Our results suggest that irrespective of the study methods applied for investigation, land fragmentation, farming experience, the provision of on-farm training, access to microfinance, higher off-farm incomes and extension services are some of the determinants, among others that robustly explain inefficiency of the farms. Therefore, a broader policy agenda is imperative that not only addresses the rice production but also identifies the factors that affect the farming efficiency.

The land fragmentation problems in Bangladesh may be addressed by amending the law of inheritance of parental property, developing the land market and by tracing the causes of such fragmentation. The broad policy and legal measures that may be devised include, *inter alia*, revising the laws of inheritance and land tenancy, motivating the small and marginal farmers to consolidate their lands through creating viable farms, encouraging farmers to buy and enlarge contiguous plots by selling discrete distant plots and formulating national land use policy that may restrict such fragmentation.

The results suggested that farmers who had contact with extension services operated at a higher TE, AE, EE and PE. More specifically, the significant positive influence of extension services to improve farm PE makes a strong case in favour of strengthening the extension services to promote farmer welfare in Bangladesh. Therefore, a realistic package that increases the number of farmers reached by the extension contacts and also training of the extension personnel of all categorise may be used as a vital step towards sustainable agricultural production in Bangladesh. The poor performances of farms attributed to the greater scope to off-farm income for impoverished farmers strongly indicates that farming is becoming less important to the farmers since it is incapable of providing sufficient returns. It is therefore imperative to reinforce agricultural marketing and to ensure fair price for farmers to keep their farming activities viable.

7 Suggestions for further research

This study used cross-sectional data to measure and explain efficiency differentials among microfinance borrowers and non-borrowers. Efficiency literature suggests that by using cross-sectional data it is possible to present a static analysis of efficiency and caution is warranted to explain the results of cross-sectional data. Dawson (1985) pointed out that efficiency measures obtained from cross-sectional data might be distorted by period specific abnormalities. If these distortions are significant, then the resulting efficiency measures might not be accurate. To overcome this potential problem, recent developments in stochastic frontier models have received much enthusiastic attention in the efficiency study literature. Based on cross-sectional data it can be concluded that a particular farm is inefficient in any one year when it invests in new farm capital that may lead to subsequent efficiency gains in the longer term. This is a recognised limitation of this study. To know what is happening to efficiency levels of the producers over time, good panel data are needed to assess the nature of the variables over time. The panel data also helps us to know the dynamic changes in the behaviour of microfinance borrowers and to trace the impact of the technology adoption on productivity and efficiency.

The use of longitudinal or panel data sets thus allows multiple observations on each individual in the sample and we can trace the variations within and also between years. Panel data estimation does not rely on strong distribution assumptions of error components. Moreover, it relaxes the assumption of independence of technical inefficiency error components from the regressors. It can also estimate the TE of each producer consistently by adding more observations for each producer. Therefore, further research on generating panel datasets that may enable us to study the fixed effects and random effects in the estimations are needed. Farm efficiency and other forms of managerial skills are dynamic in nature and they may change over time. An insight into why some farmers with similar assets are more likely to obtain microfinance whereas others are not should be investigated to assess the risk attitude of farmers towards microfinance. A detailed and conscientious study to estimate the optimum demand of microfinance and its effect on farm household production decisions and efficiency may of be of great interest and value. Attempts could also be made to formalize the credit (or liquidity constraint) and the microfinance component in the economic model. Upon adding the constraint we could get a formal presentation for the shadow price of it (the Lagrange multiplier). How the behavioural responses, welfare outcomes, risk bearing and perception of technology adoption rate change in response to availability of cheap agricultural working capital through MFIs of farm households need to answered.

In the present study the traditional nonparametric DEA models were used. The conditional efficiency model developed by Cazals et al. (2002) and Daraio and Simar (2005) allows the inclusion of contextual/environmental *z*-variable in the production process. Therefore, the conditional efficiency model can be applied in further research to examine how these variables affect the production process. The free-disposal hull approach (Fried et al. 1993; Lovell and Vanden Eeckaut, 1994; Deborger and Kerstens, 1996) that relaxes the convexity assumption maintained by the DEA models can also be applied in further research. Moreover, as a further development of nonparametric frontier techniques, an order-m efficiency procedure that estimate partial frontiers and allows some observations to be above the frontiers can be researched. Such a simple nonparametric estimator does not envelop all the data points and so, is more robust for outliers and/or extreme values (Florens and Simar, 2005).

The farm household efficiency differential based on credit sectoral choice may be estimated to test the viability of agricultural microfinance over other forms of credit. This study covered rice production in north-central and north-western regions only. Hence, the scope could be and needs to be widened to cover other locations to explain similarities and variations in productivity and efficiency between them. Finally, this study was confined to rice production issues only so it is pertinent that rice marketing and consumption issues also deserve further research.

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