DOI <https://doi.org/10.18551/rjoas.2017-02.25>

IMPROVING AGRICULTURAL FARM SPECIFIC EFFICIENCY AND WHEAT PRODUCTIVITY IN PERSPECTIVE OF MICROCREDIT: IMPLICATIONS FOR FOOD SECURITY IN PAKISTAN

Rasheed Rukhsana, Li Cui Xia, Ishaq Mazhir Nadeem*

College of Economics & Management, Northeast Agriculture University, Harbin, China

Latif Majid

Department of Agricultural Economics, Northeast Forestry University, Harbin, China

*E-mail: mazhir.nadeem@yahoo.com

ABSTRACT

Microcredit is considered to be an efficient tool for making direct or indirect improvements in farm production, income generation and poverty reduction. This study was conducted in four districts of Punjab province of Pakistan. The primary objective of this study was to explore the nature of relationship and the extent of influence of microcredit on farm efficiency, wheat production and food security. Primary data was gathered from field survey through a structured questionnaire. Stochastic frontier analysis (SFA), propensity score matching (PSM) technique and inefficiency effects model were applied for data analysis. Results of stochastic frontier analysis showed that in farm production, there exists substantial amount of inefficiency. Among farm inputs, fertilizer followed by irrigation and machinery were the dominating factors in explaining the variability on farm performance while labor and seed have relatively smaller effects. Outcomes of inefficiency effects model revealed that microcredit, education and farming experience help farmers a lot in efficient utilization of farm inputs. Microcredit borrowers had 1.56 percent higher level of farm efficiency as compared to non-borrowers. Results of propensity score matching confirmed a positive influence of microcredit on farm income. Average income of microcredit borrower was 8.32 percent higher than non-borrower. Overall the impact of microcredit on farm productivity and efficiency was positive which one hand improve farmers' income level and purchasing power, while one other hand, it contribute to strengthens the food security by increasing wheat supply.

KEY WORDS

Microcredit, farm productivity, efficiency performance, inefficiency effects, wheat production, food security, Punjab.

Food is the very basic need of human body. Food security can be defined as the existences of sufficient, safe and nutritious food available on sustained basis for all people in all times at prices commensurate with their income (Economist, 2012). In developing countries, the marginal and small farmers usually possess limited financial resources. To produce higher crop yield, these financial constraints restrict those farmers to use optimal level of farm inputs along with new production technologies. Such production constraints lead to lower the agriculture efficiency performance which become a reason for lower production of food crops such as wheat. Household lower income level reduce their purchasing power especially when there is less food supply (Islam and Maitra, 2012). Higher prices and inadequate stock of food in market influence the affordability of food which become a threat for food security. Therefore, planning for an efficient and sustained food production with affordability should be an imperative aspect for a long-term food security policy of any country.

Pakistan is an agriculture based economy and this sector the main supplier of food in the country. Wheat bread is the staple diet of 190 million human population of Pakistan. Food security can be attained by increasing the yield of food crops i.e. wheat and rice. Agriculture

farming in Pakistan is characterized by small and marginal farmers that hold less than 5 acres land area. These small farmers constitute 64 percent of total farms but cultivate only 19 percent of the total farm area (Economic survey of Pakistan, 2016). In order to obtain higher production of food crops, timely and adequate application of farm inputs are required which cannot be provided until farmers have sufficient funds. Hence, to perform necessary farm activities marginalized farmers need financial assistance either from formal or informal credit sources. Past studies (Stiglitz, 2000; Li, et al., 2011; Tu, et al., 2015) suggested that credit is a crucial factor to ascertain sustainable development in agriculture.

Agriculture productivity and farm performance can be enhanced by applying improved production technologies which lead to more food production and ensure food security. However, due to lack of collateral guarantee the small farmers have little access to obtain credit from institutional sources of credit i.e. commercial banks and agricultural banks. In Pakistan, group lending approach is practiced for providing small loans to the marginal or landless farmers. These small loans are collateral free and in case of loan default the members of a group are held responsible for each other. The conceptual framework developed for microcredit to act as developmental tool is displayed in Figure 1.

Figure 1 – Conceptual Framework

Golait (2007) conducted a study in India to discuss the performance of agriculture credit and the results revealed that credit flow to agriculture significantly increased the application of necessary farm inputs. He also suggested that credit services should be provided to a broader range of farmers through microfinance bank (MFBs), microfinance institutions (MFIs), NGOs, processors and input dealers on fair terms and low interest rate for sustainable agriculture performance. Akinsanmi and Doppler (2005) carried out a study in Nigeria to examine the aspects of agriculture resources and food security. They found that small farmers were crop oriented, retained little financial base, and had poor living standard. Large volume of their farm production was sold out but they spend less to meet food requirements. The incidence of food insecurity decreased if income and education of household is increased (Omonona and Agoi, 2007).

Javed, et al. (2006) concluded from a study conducted in Pakistan to examine the impact of microcredit on sugarcane and wheat productivity; that farm yield was increased and the living standard of farmers was also improved. They suggested that microcredit

facilities should be further expanded to agriculture community. Studies in literature (Vaessen, et al., 2014; Anang, et al. 2016; Osman, 2016) suggested that a double-edged impact on food security could be ascertained from microcredit. One impact of credit could be that it would facilitate the farmers to use the optimal level of inputs at the right time. This practice could help to produce maximum crop yield which increase supply of food (availability of food). The second impact of microcredit could be that extra crop-yield would increase farmers' income level which would improve their purchasing power (accessibility) for other food items.

To our knowledge, in Pakistan there is not a particular research that had studied the agriculture farm performance and factors of inefficiency linked to credit. In this study, we attempt to explore the existing farm inefficiencies on wheat production and its associated factors. Study evaluates that by incorporating microcredit, to what extent the farm inefficiency can be reduced. The specific objectives of this study were to: assess the impact of microcredit on wheat crop production; compare the levels of farm-specific efficiency between microcredit borrowers and non-borrowers; determine the nature of link between microcredit, farm efficiency and food security.

MATERIALS AND METHODS OF RESEARCH

Data source. Keeping in view the objective of this study, we collected primary data from wheat farmers living in the southern Punjab province, which was our study area. We selected 16 villages based on purposive sampling from four districts i.e. Vehari, Lodhran, Bahawalpur and Rahimyar Khan. These districts are highly concentrated with agriculture and livestock farming. Farmers of these 16 villages were our sampling frame, from which 231 farmers were included in the sample size of this study. From these 231 farmers, 118 were microcredit borrowers (treatment group) who had taken credit different sources for agricultural purpose and 113 were non-borrowers (control group). During sample collection, it was ensured that farmers having similar socioeconomic conditions should be included in the both control and treatment groups. A comprehensive questionnaire was developed to gather the relevant data in perspective of study objectives. Warwick and Lininger, (1975) approach was observed to collect reliable and valid data. Field survey questions were simple to understand that contained information about personal and agriculture farming. The personal information include such as their age, education, farming experience and family size. While the farming questions were concerned with farm input and output information such as land, seed, fertilizer, irrigation, labor, yield obtained, selling price and microcredit taken. Table 1 showed the sample distribution of farmers who were microcredit borrowers and non-borrowers across the four selected districts of Punjab province.

Table 1 – Name of Districts Surveyed and Number of Farmers interviewed from southern Punjab

Districts Name		Number of Farmers interviewed from		Aggregate
		Microcredit-borrowers	Non-Borrowers	
1	Vehari	29	26	55
2	Lodhran	30	28	58
3	Bahawalpur	32	31	63
4	Rahimyar Khan	28	26	54
Total		118	113	231

Source: Authors' field survey information, 2016.

Conceptual framework of Agriculture Efficiency Performance. Farrell (1957) first presented the concept of efficiency measurement. The distinctive feature of 'Farrel' efficiency measures were the assumption of constant return to scale (CRS) and less restrictive technologies. An economic efficiency consist of two parts: technical and allocative efficiency. In perspective of agriculture sector, technical efficiency deals with to achieve maximum level of farm production from a given level of farm inputs, keeping the production technology fixed. In agricultural production, farm-inefficiencies always exist due to certain factors such as; lack of improved technology, less information, limited access to capital lack of agricultural

extension services and inappropriate allocation of farm input resources. The concept of technical efficiency can be explained diagrammatically as in Figure 2. Assume that production activity of a farm by applying a linearly homogenous production technology produces a single output Y through a given set two inputs X_1 and X_2 . The frontier isoquant II' intersect the line 'OB' at point 'T' which represent a technically efficient combination of inputs ' X_1^T ' and ' X_2^T ' for this technology, as it lies on the frontier isoquant II' . The distance between point 'B' and 'T' represent the amount of technical inefficiency by producing the same level of output from both inputs. Usually, it is written in the percentage terms 'TB/OB'.

Measures of Technical Efficiency

Figure 2 – Graphical representation of Technical Efficiency

A farm producing at point 'T' is fully efficient because its production scale is found efficient and frontier isoquant II' . Farm technical efficiency at point B can be expressed as:

$$\text{Technical efficiency} = OB/OT$$

$$\text{Technical inefficiency} = 1 - TB/OB$$

Generally, the technical efficiency lies between 0 and 1 representing minimum to maximum level of output from given inputs with existing technology. Hence, $1 - TE$ represents technical inefficiency that is actually a gap between actual production and optimal attainable production.

Stochastic frontier production model (SFA). The model of stochastic frontier analysis has two components: the first part is concerned with measurement of physical inputs in a production structure while the second part deals with those factors that are not directly involved in production function but they are capable enough to affect the production activity. One such factor in our case is microcredit borrowing, as it is not a direct part of physical inputs (seed, fertilizers, pesticide) but may influence or facilitate agriculture production secondarily. Comprehensive reviews of SFA model had been provided by Green (1993), Fired et al. (1993) and Battese (1992). SFA model can be defined as:

$$Y_i = f(X_i; \beta) e^{\mu_i} \quad (1),$$

$$\mu_i = \xi_i - \zeta_i, i = 1, 2, 3 \dots \dots q,$$

Where: Y_i denotes the output level of i^{th} farms; X_i represents a vector of q inputs; β shows the parameters; μ represent error term of production function.

The error term is decomposed into two parts; stochastic symmetric random error (ξ_i) and asymmetric random errors (ζ_i). The stochastic error ξ_i take account the measurement of errors caused due to factors that are not under the control of the farmers; whereas, the ζ_i account for technical inefficiency for production technology. The ξ_i gives rise to the stochastic frontier while taking any real value when added to the deterministic frontier. However the value of ζ_i lies between 0 and 1, so when it is 0 then the production function will produce maximum level of farm production from available quantities of farm inputs; but, when $\zeta_i > 0$, then the farm production will be less due to the presence of technical inefficiency.

$$\varphi_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i, \beta) e^{(\xi_i - \zeta_i)}}{f(X_i, \beta) e^{\xi_i}} = e^{-\zeta_i} \quad (2)$$

The ratio of observed output of i^{th} farms produced from the given levels of the inputs to the corresponding frontier output will give the measurement of farm-specific technical efficiency (ϕ_i), which can be written as above in equation 2. Technical inefficiency (1-TE) of each farm can be measured as:

$$\varphi_i = \left[\frac{1 - \Phi\left(\frac{\sigma_i^* - (\mu_i^* / \sigma_i^*)}{\sigma_i^*}\right)}{1 - \Phi\left(-\frac{\mu_i^*}{\sigma_i^*}\right)} \right] e^{\left(-\mu_i^* + \frac{1}{2}\sigma_i^{*2}\right)} \quad (3),$$

Where, it is assumed that systematic error is distributed independently and identically along the mean zero and variance $e^{\sigma_i^2}$.

Technical inefficiency effects model. This model is very effective econometric tool to measure the efficiency performance. Technical inefficiency is estimated by modelling as a function of microcredit and certain other socio-economic factors such as farmers' education, farming experience, and level of land fragmentation. Potential differences existed in farm-inefficiencies among various farmers may be due to the variations presented in the household socio-economic characteristics. Exploring the influence of these characteristics for technical inefficiency provides some explanations regarding the nature of impact on efficiency performance. Hypothetically, technical-inefficiency is to be estimated by incorporating the variables such as: microcredit taken, farmers' education, farming experience and level of land fragmentation.

$$IE_i = \delta_0 + \delta_{1zi} + \delta_{2zi} + \delta_{3zi} + \delta_{4zi} + w_i \quad (4),$$

Where: IE represent farm inefficiency; z_i denotes factors of microcredit, education, experience, and land fragmentation; w_i shows stochastic random error that is assumed to be normally distributed.

This model quantify the factors (z_i) coefficients with a positive or negative sign to explain nature of influence on farm inefficiency. Analysis results recommends some policy implications to increase farm productivity which subsequently enhance food security through reduction of farm inefficiency.

Propensity Score Matching (PSM) technique. Impact assessment of microcredit intervention in agriculture production can be carried out by making a comparison between treated group (microcredit borrowers) and control group (non-borrowers). Microcredit impact assessment on the average incomes of farmers from both groups was evaluated by using Propensity Score Matching (PSM) technique. Matching the outcomes for the treatment and control groups to estimate causal treatment effects has become a popular approach (Heckman et al., 1997; Dehejia and Wahba, 1999). However in non-experimental studies, treatment effects between treated and controls differ due the presence of many other factors. Hence, the estimation of mean effect of participating in a treatment (e.g. microcredit borrowing) requires making a match of mean output if they had not been treated (control group). Matching procedure for PSM technique can be described as:

Let Y_1 is the outcomes of a microcredit-borrowers and Y_0 is the outcomes of the same microcredit borrower individual if he does not receive microcredit. So the $D = \{1, 0\}$ is a binary indicator ($D=1$ if borrowed microcredit, 0 otherwise). In our case to estimate the impact on average income of individual i , the match for observed household income would be:

$$Y_i = Y_{0i} + D(Y_{1i} - Y_{0i}) \quad (5)$$

Following this procedure we attempt to identify; average treatment effects (ATE)= $E(Y_1 - Y_0)$ which denotes the difference between the average incomes of two groups:

- $E(Y_1 - Y_0 | D=1)$ represents the average treatment effect on the treated that estimate the average income difference for the income which microcredit borrowers has earned and the income he would earned if not had borrowed credit.
- $E(Y_1 - Y_0 | D=0)$ denotes the average treatment effect (ATE) on the non-treated which measures the income difference between the potential income that a non-borrower did not earn ($D=0$) and the real income that he had earned Y_0 .

To estimate how microcredit borrowers would perform, if had not they received credit; propensity score matching (PSM) support this analysis by making a match for non-borrowing farmers.

RESULTS AND DISCUSSION

Table 1 showed the summary statistics of important farm indicators regarding the production of wheat. Five important inputs, seed, fertilizer, irrigation, machinery and labor were included in the empirical analysis. Average farm revenue was observed to be Rs. 35,720 (Pakistani Rupee). Coefficient of variations mentioned in Table 1, indicates variability of input/indicator use among sampled farmers. Irrigation cost represent 38.3 percent of average total variable cost (ATVC) which was major cost due to lack of irrigation water in the south region of Punjab province and farmers had to bear additional expenses for using ground water through tube wells or turbine water. Coefficient of variation for irrigation was 68.41. Second major cost was fertilizer that represents 33.6 percent of ATVC and C.V is 78.73. Machinery cost constitutes 16.50 percent of ATVC with C.A. of 81.23. Labor and seed costs showed 6.27, 5.84 percent of ATVC with C.V. of 81.87, and 62.94 respectively. Table 1 also presented the average amount of microcredit borrowing that was Rs. 7850/- with C.V. 95.64. The mean value of farmers' experience and schooling years was about 22 and 5 years respectively. The average land holding among farmers was 2.25 acre.

Table 1 – Summary Statistics of Farm Performance Indicators for Wheat Production

n/n	Mean	Coefficient of variation	Minimum	Maximum
Revenue earned (PKR)	35720	54.36	26000	51000
Irrigation	10284	68.41	7000	15000
Fertilizer	9022	78.73	3800	9510
Machinery	4430	81.23	3000	6200
Labor	1683	81.87	1300	2400
Seed	1568	62.9	850	1800
Amount of Microcredit borrowing	7850	95.8	0	30000
Farmers' experience	22	36.45	5	28
farmers, education	5	66.85	0	16
Land holding	2.25	66.75	0.5	5.5

Source: Authors' field survey results, 2016.

Findings of stochastic frontier model for microcredit borrowers and non-borrowers have been presented in Table 2. Results showed that the coefficients ' β ' of five indicators were positive and significant except that labor. It was found that fertilizer had dominant contribution followed by irrigation and then machinery. Labor had also positive sign but it was not statistically significant representing a low influence.

Table 2 – Results of Stochastic Frontier Analysis (SFA) Model

n/n	Microcredit Borrowers (n-118)			Microcredit Non-Borrowers (n-113)	
	Parameter	Coefficient	t-ratio	Coefficient	t-ratio
Constant	β_0	3.032	21.722	2.162	14.283
Land	β_1	0.116	4.364	0.160	2.018
Labor	β_2	0.089	1.685	0.109	2.106
Seed	β_3	0.907	3.258	-0.023	-0.953
Fertilizer	β_4	0.246	5.587	0.181	3.740
Irrigation	β_5	0.193	3.647	0.224	5.321
Machinery	β_6	0.1562	2.357	0.205	3.021

Source: Author's field data results, 2016.

Results of Table 2 also provided information for the findings relating to the microcredit non-borrowers. For microcredit non-borrowers all the coefficients ' β ' were positive and significant except that of seed that was negative but insignificant. Irrigation was found a dominating factors. Machinery and fertilizers were the second and third dominating factors (Table 2).

The results derived from inefficiency effect model are presented in Table 3. It was found that coefficients for microcredit borrowing, farmer's education and farming experience were negative which was expected.

Table 3 – Results of Inefficiency Effects model

n/n	Parameters	Coefficient	t-ratio
Constant	δ_0	0.192	12.2124
Microcredit taken	δ_1	-0.124	-1.1887
Farmer's Education	δ_2	-0.497	-1.145
Farmer's experience	δ_3	-0.435	-1.3875
Land fragmentation	δ_4	0.1263	5.314
R-Squared		0.0862	-
DW-statistic		2.8091	-

Source: Author's field data results, 2016.

Results validated that educated farmers with more experience had performed more efficiently as compare to those with less experience and low education. This demonstrated that by applying the present production technology, the farmers that had taken microcredit and also possess more education & experience were in better position to efficiently utilize the farm inputs to obtain higher production. Increased wheat production will ensure the improvement in food security. The outcomes showed that the variable of land fragmentation had positive sign and significant (Table 3). This concluded that an increased level of land division/fragmentation leads to enhance farm-inefficiency during crop production. The possible justification for this finding may be that, marginal and small farmers were not capable enough to utilize farm inputs efficiently along with new technology on their small land area.

Outcomes of Farm-Specific Efficiency Performance. Table 4 presented the results regarding the frequency distribution of farm specific efficiency performance. Findings revealed that for microcredit borrowers, the estimated farm specific technical inefficiencies displayed a substantial level of variability. The efficiency level varies between 33-94 percent while its mean value was 80.21 percent having a standard deviation of 8.62 percent. Majority of farms (32%) were between 81-90 percent technically efficient.

Results for microcredit non-borrowers presented in lower section of Table 4 indicates that variability of farm specific efficiency ranges 36-94 percent with a mean value 78.61 percent and standard deviation was 9.78 percent. Outcomes revealed that majority of farms (30 percent) were 81-90 percent technically efficient followed by 25% farms were between 71-80 percent technically efficient. Only 8 farms were performing between 91-100 percent efficiency but among them none was to be fully (100%) efficient. This analysis proved that in order to attain maximum technical efficiency and farm productivity, there is still a

considerable room for making improvements. Furthermore, the comparison of mean efficiency between microcredit borrowers and non-borrowers proved that, microcredit borrowers were 1.56 percent more technically efficient than non-borrowers. Although making an improvement of 1.56 percent in farm specific efficiency was not remarkable but it recommend that microcredit can be applied as potential tool to reduce farm-inefficiency. Reduction in farm inefficiency could lead to enhance wheat production and food supply.

Table 4 – Frequency Distribution of Farm Specific Efficiency Index

n/n	Microcredit Borrowers		
Efficiency Index	Number of Farms	Percentage of Farms	Cumulative of Farms
0-50	6	5	6
51-60	11	9	17
61-70	22	19	39
71-80	29	25	68
81-90	38	32	106
91-100	12	10	118
Mean efficiency	Standard Deviation	Maximum Efficiency	Minimum Efficiency
80.21	8.62	95	39
Microcredit Non-Borrowers			
Efficiency Index	Number of Farms	Percentage of Farms	Cumulative of Farms
0-50	7	6	7
51-60	12	11	19
61-70	24	21	43
71-80	28	25	71
81-90	34	30	105
91-100	8	7	113
Mean efficiency	Standard Deviation	Maximum Efficiency	Minimum Efficiency
78.64	9.78	94	36

Source: Author's field data results, 2016.

Propensity score matching (PSM) technique had been applied for making an assessment of microcredit impact. Pair of microcredit borrower (treatment group) were matched with a non-borrower from control group. The matched pair was similar to other pairs except of microcredit factor. PSM technique enable to create a balance between treatment and control groups for drawing a casual inference. PSM results have been presented in Table 5.

Table 5 – Outcomes of Propensity score matching and Effects Microcredit borrowing

Indicators	Coefficient	t-ratio
Education	0.165	3.547
Experience	0.148	2.457
Land Fragmentation	0.104	1.9245
Goodness of fit	0.614	
Log likelihood	-327.248	
Effects of Microcredit Borrowing		
Mean of income earned by matched treatment group	26670	
Mean of income earned by matched controlled group	24620	
Impact of microcredit borrowing	2050	

Source: Author's field data results, 2016.

Findings of PSM technique revealed that farmers with education and experience were more likely to borrow microcredit. Likewise, farmers with small land holdings would likely to receive microcredit rather than a farmer who owned large farm size. The overall impact of microcredit program was positive on farm productivity and income level (Table 5). For example, microcredit borrowers earned on an average 8.32 percent more than those of non-borrowers. This increased income level could improve the purchasing power of household to attain food security.

CONCLUSION

The primary objective of this study was to explore the relationship among microcredit borrowing and performance of farm-efficiency for wheat crop along with its link with food security. Results of stochastic frontier analysis (SFA) model demonstrate that the estimations of five farm inputs were positive and significant for output elasticities. For microcredit borrowers, fertilizer was dominating factor followed by irrigation and machinery. For non-borrowers, irrigation was dominating factor having ' β ' value of 0.224, second was machinery (0.205) and fertilizer (0.181). The outcomes of inefficiency effects models provided a sign of negative relationship among farm inefficiency and microcredit; farmer's education, and, farming experience. This implied that farmers taken microcredit and having good education and greater farming experience are more likely to operate farm activities in a better way to attain higher level of wheat production. Land fragmentation was positively correlated with farm inefficiency which disclosed that as the level of land fragmentation increased, farmer became less efficient to manage its farm resource to produce higher yield. Farm specific efficiency performance for microcredit borrowers ranged from 39 to 95, with mean efficiency level of 80.21 percent. For non-borrowers, range of efficiency lies between 36-94; with a mean efficiency level of 78.61 percent. Efficiency index revealed that microcredit borrower's farm efficiency was 1.56 percent higher than non-borrowers. Hence, microcredit program proved as to be effective tool for increasing farmers' efficiency that could lead to improve wheat production and subsequently ensure food supply/security.

The findings of propensity score matching (PSM) analysis confirmed that there exist positive influence of microcredit towards wheat production and income generation. Results exposed that farmers having smaller land holding but more education and experience were more likely to receive microcredit from different financial institutions to perform their farm activities at the optimal level. Microcredit borrowers on an average earned more Rs.2050/- (Pakistani rupees) as compared to non-borrowers. This increased in farm production and income level of marginal and small farmers would, no doubt, assist them to reduce their poverty conditions. The reduction in poverty would ensure food security and food affordability. Finally based on the findings of this study, it could be suggested that policies for the timely and low-cost delivery of microcredit should be introduced in south region of Punjab province. Such policies would help the marginal and small farmers to operate their farm activities efficiently. Reduction in agricultural farm inefficiency could lead to improve farm production which subsequently improve food availability and food security.

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