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Measuring Economic Efficiency among Rice Farmers through Non-parametric Approach in Punjab Pakistan

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Abstract: The present study was conducted to analyze the technical, allocative and economic efficiency on input oriented basis between two groups of rice farmers i.e. with off-farm work and without off-farm work. To compute the efficiencies data envelopment analysis (DEA) approach was applied on the collected data from 400 rice farmers from Punjab province of Pakistan. The results revealed that both groups of the rice farmers are different in all efficiencies with respect to production. The mean technical efficiency score was 0.90 for with off-farm work while 0.82 for the group of without off-farm work. Calculated mean score of allocative efficiency was 0.88 and 0.76 for the groups with and without off-farm work respectively. Further, a group of farmers with off-farm employment had mean score of economic efficiency 0.83 while 0.74 was found for without off-farm work group. On the basis of results, suggestions and policies are presented.

Keywords: Off-farm work, economic efficiency, DEA approach, rice farmers, Pakistan.

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1 Introduction

Agriculture is crucial to human endurance and provides food, fuel and other ecosystem services. In Pakistan's economy, agriculture has an important role. This sector contributes 21 percent share in the country's GDP. About more than 60 percent population is living in rural areas and almost 42.5 percent country's labour force is involved in agriculture sector (GOP, 2016). While, the growth rate of agriculture has remained stagnant 2.9 percent in Pakistan during the year 2014-15. It is essential for the economy to improve agricultural sector, because it delivers a major proportion of raw material to the industrial sector.

Concerning food security in Asia, rice still has center of attention. Up till now, the role of rice production is vital in alleviating poverty and hunger. Gradually the poor consume more rice and are usually dependent on it. Despite the fact is that production and consumption of world's 90 percent rice is in Asia (FAO, 2009). Hence, its supply must increase at least by twofolds till 2050 to cope with the demand of growing population (Skamnioti and Gurr, 2009).

In Pakistan, rice is an essential cash crop, second staple food after wheat (Arshad et al., 2017; Nawaz et al., 2017). It earns foremost foreign exchange after cotton (Rehman et al., 2017). Although, during 2013-14 cropping period rice area was expanded and cultivated on 2.79 million hectares giving produce of 6.79 million tons (Khan, 2014; GOP, 2017). However, impressive yield of rice was not achieved under numerous uncertainties (Neumann et al., 2010; Ahmad et al., 2016).

The population of Pakistan has grown manifolds since its birth. Many scholars have predicted that population of Pakistan will be twice of the year 2010 by the year 2025 (Qasim, 2012). Thus, the existing gap is expected to increase up to adverse level between national supply and demand of food products (Ray et al., 2013). There are many hindrances i.e. low productivity in agriculture, unavailability of quality seed, improper usage of fertilizer, water shortage, unprecedented weather conditions, rigid behavior of farmers for using improved management practices etc.

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(Zhang et al., 2014). This entire situation supports the grounds that agricultural productivity can be improved with the existing resources by efficient farming techniques as a sustainable development option (Iqbal et al., 2001).

As rice is a staple food more than 60 percent population in the world and the majority of them are in Asia whose staple food is rice. Hence, efficiency in rice farmers got attention and investigated in this region particularly in South and South-East Asia. Rice has a greater part in the food security and economic development not only in Asia also in the world. Previous studies show the importance of rice crops in different areas (Balcombe et al., 2006; Coelli et al., 2002; Dhungana et al., 2004; Rahman and Rahman, 2009; Rahman et al., 2009; Rahman, 2010; Tan et al., 2010; Wadud and White, 2000; Yao and Shively, 2007).

On the other hand, off work is crucial phenomenon now days for the farmers all over the world due to low income in the agriculture sector. With the time passing, off-farm dependent ration of households is increasing. Many studies have been attributed of off-farm work importance to the rural households and income earned from the off-farm employment is from 20 percent to 75 percent (Adams, 2001; Benjamin, 1992; De Brauw et al., 2002; De Brauw and Rozelle, 2008; Xiaobing et al., 2007; Yu and Zhao, 2009). For instance, on the Agriculture Censes database in Taiwan, about 75 percent farm households were involved in off-farm employment. Similarly, in USA the share of rural households' in off-farm activities was found 65 percent according USA Agricultural Department (Fernandez-Cornejo et al., 2007). Jolliffe (2004) stated in his research that the proportion of engaging in off-farm activities was 74 percent in in Ghana.

In addition, the ration of off-farm income earned from the off-farm work is found 35 to 50 percent in developing countries (Haggbladeet al., 2010). Barrett et al. (2001) disclosed in his research that farmers are not only rely on agriculture sector but also rely on off-farm work which is growing trend particularly in developing countries. Babatunde (2013) revealed in his study that 50 to 90 percent income was earned from the non-farm activates in Kwara state of Nigeria. Moreover, among Sub-Sahara African households' income shared for off-farm income found between 30 to 42 percent on average (Daviset al., 2014). Similarly, in an earlier study the share of off-farm income for households in Latin American found 40 percent (Daviset al., 2002). Woldehanna (2000) stated in his study that 35 percent Dutch farmers were involved in off-farm activities. Ethiopian farmers were engaged 57 percent in 2008 and 73 percent in 2013 in different off-farm activities (Bedemoet al., 2013; Beyene, 2008).

To measure the efficiency of firms commonly two techniques i.e. parametric and non-parametric are used. A parametric technique depends on a specific form of function i.e. production function (e.g. cost or profit function) and econometric model is used to compute this function. Further, this parametric approach is called a stochastic function, and for calculation of the efficiency of firm random error term is used in this model. Hence, parametric constraints are imposed in this approach. For instance, in parametric approach Cobb-Douglas function of production is adopted as the alternate of unitary elasticity (Chavas and Aliber, 1993). Moreover, parametric approach is a challenge to calculate the efficiency as it needs to put all relevant input variables, and if some variables are highly correlated with each other for the production function also posses additional challenge.

On the other hand, the second approach to compute the efficiency of the firms is non-parametric and also known as data envelopment analysis (DEA) approach. The program in this approach is used is a mathematical model. This technique does not impose the parametric constraints and does not make any conflict for the correlated variables. According to Coelli (1995) and Krasachat (2004) data envelopment analysis (DEA) technique has main advantages. (a) It is free from the assumption of functional form to specify the relationship between inputs and outputs. (b) It does not require the assumption about the distribution of the underlying data.

Hence, this study approaches data envelopment analysis (DEA) technique to estimate the technical, allocative and economic efficiencies. DEA approach was also used by Sharma et al. (1999) measuring the efficiency among farmers in Hawaii. This technique was also used to examine the efficiency in developing countries by Bravo-Ureta and Pinheiro (1993) and they found farmers inefficient. Thibbotuwawaet al. (2012) conducted a study between irrigated and rain-fed Sri Lankan rice farmers by using DEA approach and found that in the irrigation area farmers were 88 percent efficient while rain-fed farmers found 82 percent efficient in average. He further stated that farm size, water security, seed quality, family labour and other factors had impact on farmers' efficiency. Poudel et al. (2015) conducted a study to analyze the TE, AE and EE between the groups of organic and conventional coffee farms and found different scores of efficiencies between the categorized groups.

For improvement of rice production practices and yield it is essential to understand the efficiency among rice farmers (Awan et al., 2015). Hence, the main goal of the present study is to examine the input-oriented technical, allocative and economic.

2. Materials and Methods

2.1 Data Sampling

To reach the goals of the study, a survey was conducted in 2015-16 to collect the farm level data from the rice-growing farmers in Punjab province of Pakistan. The reason to select this province is that rice is cultivated more than 70 percent of the country in Punjab province. A multistage cluster sampling technique was applied to collect the data. A well-structured questionnaire was prepared and 400 farmers were interviewed from five districts namely Gujranwala, Sheikhupura, Sialkot, Mandi Bahauddin and Hafizabad due to rice production area. The sample size was decided as described earlier (Fitz-Gibbon and Morris, 1987; McCall, 1980; Wunsch, 1986). Among them 200 respondents were without and 200 were with off-farm work which are involved at least since last two to three years to examine the efficiency between these two groups (Table 1).

2.2. Model specification

First time efficiency calculation was proposed by Farrell (1957) and according to him, efficiency is consists of three component i.e. technical and allocative and economic of any firm. Technical efficiency (TE) is the proportional reduction in inputs possible for a given level of output in order to obtain the efficient input use while allocative efficiency (AE) consist to the ability of a firm to produce at a given level of output using the cost-minimizing input ratios. Allocative efficiency is calculated as the ratio of the minimum costs required by the firm to produce a given level of outputs and the actual costs of the firm adjusted for TE. Economic efficiency (EE) is also called cost efficiency which refers to the capacity of a farm/firm to produce a quantity of output, determined, for the given level of technology at a minimum cost. Hence, according to Farrell (1957) a firm is economically efficient if it is efficient in both technical and allocative. Economic efficiency is computed as the ratio of the minimum possible costs and the actual observed costs of a firm.

To examine the technical, allocative and economic efficiency, data envelopment analysis model (DEA) is used. DEA model was proposed first time by Charnes, et al. (1978), and it was based on the earlier studies (Afriat, 1972; Boles, 1966; Farrell, 1957; Shephard, 1970). To investigate the efficiency, input-oriented technique is used first time by Charnes et al. (1978) with assuming the constant return to scale (CRS).

Subsequently Banker et al. (1984) relaxing the constant return to scale (CRS) assumption and presented a new model i.e. variable return to scale of DEA. A brief introduction of DEA model can be seen in Fare et al. (1994), Coelli et al. (2005) and Fried et al. (2008) experiments/ research outcomes. We review that DEA model in this paper to achieve the objective of our study. The DEA model is very suitable for the multiple inputs variables and single output. In our study data envelopment analysis model (DEA) is used with variable returns to scale (VRTS) technique. Return to Scale (RTS) explains the behavior of the rate of increase in output (production) relative to the associated increase in the inputs (the factors of production) in the long run. In the long run all factors of production are variable and subject to change due to a given increase in size (scale). Furthermore, RTS focus on the relation between input and output quantities. In addition, other studies also attempted of turning stochastic frontier methods to semi-parametric and non-parametric assessment methods which also allow flexible functional forms e.g Delis et al. (2014).

Table 1. Sampling Strategy

Province	Districts	Sample		Total
		With off-farm work	Without off-farm work	
Punjab	Gujranwala	40	40	80
	Sialkot	40	40	80
	Hafizabad	40	40	80
	Mandi Bahauddin	40	40	80
	Sheikhupura	40	40	80
	Total	200	200	400

By assuming that the number of firm's *n* is a single product *y* using inputs *k*. then for measuring the technical efficiency by input-oriented technique of firm *j*, we can solve the following linear programing model.

$$\min_{\theta,\{\lambda_1\}_{i=1}^{n}} \theta. \quad [1]$$

With subject to

$$\sum_{i=1}^{n} y_i\lambda_i \geq y_i, \quad [2]$$

$$\sum_{i=1}^{n} x_{ki}\lambda_i \leq \theta x_{kj}, \text{while } k = 1,2,\ldots,k \quad [3]$$

$$\sum_{i=1}^{n} \lambda_i = 1, \quad [4]$$

$$\lambda_i \geq 0, \quad [5]$$

Where,

θ = technical efficiency of j^{th} firm calculate the input-oriented inputs, y_i = output production quantity by i^{th} firm of applied inputs *k* and *i* is equal to 1, 2, …., j, …., n. While *n* represents the number of farmers (firms). x_{ki} = input quantity (k), used by i^{th} firm. Where, *k* denotes the input use in numbers by firms and *k*=1,2,….,*k*. While weights for the determination are denoted by $\{\lambda_i\}_{i=1}^{n}$.

By solving the model given in equations from 1 to 4 we can gain the optimal value of j^{th} firm and function is $\theta^*$and then we can measure the technical efficiency of the input oriented of the j^{th} firm and obtain the equation as under:-

$$TE_j = \theta^*, \quad [6]$$

Given equation of technical efficiency satisfies the conditions of $0 < \theta^* \leq 1$, Hence, if the value is 1 that's mean firm is fully efficient. To gain the $\theta^*$for j^{th} firm, the above issue is solved and *j* is equal to 1, 2… *n*.

To calculate the cost efficiency on input oriented base of the j^{th} firm, we establish the following equation;

$$\min_{\{x_{kj}\}_{k=1}^{k},\{\lambda_i\}_{i=1}^{n}} \sum_{k=1}^{k} w_{kj}x_{kj}, \quad [7]$$

With subject to:-

$$\sum_{i=1}^{n} y_i\lambda_i \geq y_j, \quad [8]$$

$$\sum_{i=1}^{n} x_{ki}\lambda_i \leq x_{kj}, \text{where } k = 1,2,\ldots,k \quad [9]$$

$$\sum_{i=1}^{n} \lambda_i = 1, \quad [10]$$

$$\lambda_i \geq 0, \quad [11]$$

Where, w_{kj} denotes the input price used by j^{th} firm. To gain the optimum solution of the j^{th} firm, the model solved from equation 7 to 11 then $\{x_{kj}^*\}_{k=1}^{k}$, and $\{\lambda_i^*\}_{i=1}^{n}$.

To calculate the economic efficiency of the j^{th} firm (*EEj*) is measure as under;

$$EE_j \frac{\sum_{k=1}^{k} w_{kj}x_{kj}^*}{\sum_{k=1}^{k} w_{kj}x_{kj}}, \quad [12]$$

We can see that equation 12 states the ratio production minimum cost to the actual observed production cost.

The allocative efficiency of the j^{th} firm can be calculated by using equation 6 and 12 as under;

$$AE_j \frac{EE_j}{TE_j}, \quad [13]$$

To calculate the efficiencies for j^{th} firm, we solve the above problems *n* times. To achieve our objective we use DEAP 2.1 software (Coelli, 1996).

3. Results and Discussion

3.1 Descriptive statistics of used variables in the model

Table 2 describes the descriptive statistics of the variables used in this model. The information given in this table is distinguished between categorized groups of farmers. First variable in table is output i.e. yield in kg per acre. Labour input variable is noted as used man days to follow the Dhungana et al. (2004). Input variable machine and other farm equipment is observed by hours used per farm for the rice crop. Fertilizer and chemical are measured by bags used at farm level. These variables are used by considering that it is not possible without fertilizer to catch the food production aim to feed the world's growing population. Furthermore, the role of fertilizer in food production is 40 to 60 percent commercially (Roberts, 2009). Chemical variable is calculated in litters. Irrigation and seed input variables are specified in number of watering and kg per farm respectively. Water has a vital role among rice production input variables and irrigated area for the rice crop is represented by 59 percent in the Asia (FAO, 1999). Seed is calculated in kg on farm basis. Further, Land area was also calculated for the rice cultivation of both groups of farmers.

Table 2. Descriptive statistics of used variables

Variables	Characterization	With off-farm work		Without off-farm work	
		Mean	SD	Mean	SD
Output variable					
Yield	average(kg/acre)	2142.00	133.22	1892.2	153.29
Inputs variables					
Labour	used man days	170.52	104.28	170.16	101.44
Machine	agricultural equipment used in hours	81.34	52.23	65.86	45.97
Fertilizer (NPK)	fertilizer used in bags	2067.6	1325.1	1744.2	1124.2
Chemical	used chemical in litters	63.62	41.18	63.89	39.13
Irrigation	no. of irrigation	470.10	288.77	431.56	282.97
Seed	seed used in kg	114.78	72.84	112.04	79.11
Cultivated area	agricultural land (acres)	14.23	9.07	9.47	4.99
Inputs variables cost					
Labour cost	Rs. per farm	156696.0	96037.7	152494.3	99234.6
Machine cost	Rs. per farm plough	48429.35	29705.6	37168.8	24222.9
Fertilizer cost	Rs. per farm	114955.7	75054.7	95692.6	62250.9
Chemical cost	Rs. Per farm	35309.6	22536.3	31835.8	19601.4
Irrigation cost	Rs. Per farm	193301	118517.9	179708.7	116607.6
Seed cost	Rs. Per farm	12625.8	8012.17	12324.1	8702.4
Land cost	Rs. Per farm (rent price)	329939.5	217471.4	472557.5	326051.5

The yield on average was found 2142 kg and 1892.2 kg per acre for categorized farmers i.e. having off-farm work and not have off-farm work respectively which a huge difference. Farmers having off-farm employment has higher mean values for variables use of machine/agricultural equipment, fertilizer applied and number of irrigation have greater mean value then their counterpart. On the other hand, used of labour, chemical and seed quantities are almost the same by mean value and didn't have difference. Cost of all inputs is calculated on farm basis. Labour cost is calculated on the daily wages in the study area. It shows that the group with off-farm work is investing more for labour. The results indicate that farmers having off-farm work are hiring more labour than other group. Furthermore, results indicate that all inputs costs (average) except land cost are higher for the group of with off-farm work than without off-farm work group. The results divulge that land cost is lower for the group of having off-farm work. The reason is that without off-farm work has bigger farm in size than with off-farm work.

3.2. Descriptive statistics of measured efficiency among categorized groups of rice farmers

Table 3 divulges the descriptive statistics of measured technical (TE), allocative (AE) and economic efficiencies (EE) given of both groups (with and without off-farm work) of rice farmers. The results indicate that TE, AE and EE are different between the categorized groups. The results revealed that the mean technical efficiency is 0.90 for the group of having off-farm work while 0.82 for the group of without off-farm activities. Farmers with off-farm work have higher technical efficiency score and more efficient. It is because group of off-farm work have more income (due to off-farm work) and using more inputs quantities than their counterpart. Hence, the results show that farmers with off-farm work can minimize 10 percent of their input use to gain the same level of rice yield and without off-farmers can minimize their inputs use 18 percent and can produce the same level of rice production. Poudel et al. (2015) conducted a study regarding technical efficiency and used DEA technique. They also found difference among efficiencies between categorized groups of coffee farmers in Nepal. Their results revealed that the scores for technical efficiency found 0.89 and 0.83 for the organic and conventional groups of coffee farms respectively. Furthermore, standard deviation value is 0.06 and 0.07 for with and without off-farm work respectively. Minimum efficiency is 0.72 to the group of with off-farm work while 0.64 for the group with no off-farm work. Likewise, a study was conducted between two groups of rice farmers in Bangladesh (Coelli et al., 2002) and their study support to our findings.

Table 3. Frequency distribution of efficiency measure of categorized rice farmers

Efficiency range	With off-farm work			Without off-farm work		
	TE (%)	AE (%)	EE (%)	TE (%)	AE (%)	EE (%)
0.50-0.55	0	0	0	0	0	0.5
0.55-0.60	0	0	0	0	0	3.0
0.60-0.65	0	0	0.5	0.5	0.1	5.5
0.65-0.70	0	0.5	5.0	0.5	1.5	9.0
0.70-0.75	0.5	3.5	13.0	2.0	2.5	18.5
0.75-0.80	2.0	8.5	15.0	7.5	6.5	25.0
0.80-0.85	5.5	16.0	21.5	17.5	24.5	24.5
0.85-0.90	12.5	27.5	24.5	17.0	35	10.5
0.90-0.95	24.5	31.0	15.5	30.0	26.5	5.5
0.95-1.00	55.0	13.0	5.0	25.0	2.5	1
Mean	**0.90**	**0.88**	**0.83**	**0.82**	**0.76**	**0.74**
SD	0.06	0.06	0.08	0.07	0.06	0.08
Min	0.72	0.69	0.63	0.64	0.60	0.54
Max	1.00	1.00	1.00	1.00	1.00	1.00

AE, allocative efficiency ; EE, economic efficiency; TE, technical efficiency.

The results illustrate that mean value of allocative efficiency also varies between both groups i.e. 0.88 and 0.76 for the groups of with and without off-farm work respectively. These results indicate that farmers with and without off-farm work can reduce their production cost by 12 and 14 percent respectively. Many different studies were conducted earlier and their results revealed that farm are found inefficient and can reduce the cost to produce the same output (Debebe et al., 2015; Khan et al., 2016; Majiwa et al., 2016; Terin et al., 2017). In addition, minimum values of allocative efficiency are 0.69 and 0.60 for the groups with and without off-farm work respectively, but the standard deviation was same for both groups i.e. 0.06.

Lubis et al. (2014) analyzed allocative efficiency among pineapple farmers in Indonesia and stated that farmers were inefficient. Further, the group of farmers with off-farm employment has mean value of economic (EE) or cost efficiency 0.83, while 0.74 mean for was found for the group with no off-farm activities. The results further reveal that both groups of farmers can reduce their production cost ratio for rice crop to by using the optimal proportion of the given inputs with cost to gain the level of rice production. The results indicate that minimum value is 0.63 to the group with off-farm work while 0.54 is to the other group. The results of (Coelli et al., 2002; Lohano et al., 2011; Lubis et al., 2014) are overall supportive with our findings.

3.3. Frequency distribution of the measure efficiency between categorized group of rice farms

Table 3 indicates the frequency distribution of input oriented technical, allocative, economic/cost efficiencies. The results indicate that farmers range of the input oriented technical efficiency with off-farm work group of farmers is between 0.70 to 1.00 and for without off-farm work efficiency range lies between 0.60 to 1.00. Famers having non-farm activities are mostly efficient in the range between 0.95-1.0 i.e. 55 percent farmers and without off-farm work are between 0.90-0.95 i.e. 30 percent farmers. Range for the allocative efficiency between the groups is 0.65-1.0 and 0.60-1.0 respectively. Further, highest percentage of the farmers in the group of with off-farm work ranged from 0.90 to 0.95. While for the other groups of farmers' highest proportion ranged from 0.85 to 90. The results further reveal that economic efficiency (EE) range of farmers with off-farm work ranges from 0.60 to 1.00 and the farmers without off-farm work range 0.50 to 1.00. The findings illustrate that farmer's output oriented technical efficiency ranges between 0.70 to 1.00 for with off-farm work group while 0.60 to 1.00 to the group of farmers having no off-farm work. likewise results were revealed by Coelli et al. (2002) between two groups of rice farmers in Bangladesh. Other previous studies also revealed the same results regarding technical, allocative and economic efficiency (Debebe et al., 2015; Khan et al., 2016; Majiwa et al., 2016; Terin et al., 2017).

4. Conclusion

The present study was conducted to analyze the technical, allocative and economic efficiency on input oriented basis between two groups of farmers (i.e. with and without off-farm work) in Punjab province of Pakistan. To measure the efficiencies, data envelopment analysis (DEA) was applied on collected data from 400 rice farmers. The empirical results of the study revealed that both groups of rice farmers have disparities in all efficiencies with respect to farm. Technical efficiency (TE) was found higher score i.e. 0.90 for the farms with off-farm work while 0.82 for farms without off-farm work. In addition, study concluded that mean value of allocative efficiency was also varying i.e. 0.88 and 0.76 between the groups with and without off-farm work respectively. Further, group of farmers with off-farm work had mean value of economic efficiency (EE) 0.83 while 0.74 mean score was calculated for the group of with no off-farm work. Based on the results it is suggested that extension workers should visit the farmers to guide them regarding best management inputs practicing and consequently, technical, allocative and economic efficiency will enhance of the rice farmers. This would increase the production and yield to meet the food security as which is the most important issue of the world. Farmers should be provided with the new technologies and off-farm work opportunities to enhance the income level so that they can invest more in agriculture sector, consequently rice production will increase.

List of abbreviations: AE, allocative efficiency; DEA, data envelopment analysis; EE, economic efficiency; RTS, return to scale; TE, technical efficiency; VRTS , variable returns to scale.

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Author Contribution: MR envisioned and planned the study, data collected, entered and analyzed, wrote manuscript. Professor ZD Supervised the work and critically discussed the data processing and manuscript writing. RO, UIA and GG were involved in data handling and analysis and AN edited the manuscript. UIA was involved in data handling and analysis. GG critically discussed the manuscript. All authors read and finalized the manuscript.

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