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Estimation of Technical Efficiency of Wheat Farms "A Case Study in Kurdistan Province, Iran"

Hamed Ghaderzadeh and Mahmoud Haji Rahimi

Department of Agricultural Economics, University of Kurdistan, Sanadaj, Iran

Abstract: The present study was conducted in the Saqqez city of Kurdistan province, Iran, in order to study technical efficiency of wheat farmers. The data were collected from both rainfed and irrigated farms in three different areas (mountain, semi-plain and plain), based on two stage cluster random sampling, for agricultural year 2003-2004. In total 210 farmers were interviewed. With respect to the coefficient of multiple determinations (R^2) of estimated transcendental production function for rainfed farms, the variables included in this model are able to explain 66.1% of variation in the average production of rainfed wheat per hectare. The variables such as seed, positively, area situation, negatively, nitrogen fertilizer, negatively and plant protection chemicals, positively, were significant. The estimated transcendental production function model for irrigated farms showed that the variables included in this model were able to explain 61.8% of variation in the average production of irrigated wheat per hectare. The variables such as seed and human labor were significant at the level of one Percent and positively related. The average of technical efficiency for rainfed farms in the mountain, semi-plain and plain areas was 0.668, 0.646 and 0.651 respectively. The average technical efficiency for the entire rainfed farms area was 0.655. This showed that rainfed wheat farmers were technically less efficient. In irrigated farms, the average of technical efficiency in mountain, semi-plain and plain areas was 0.704, 0.684 and 0.646 respectively and for the entire area was 0.676. This showed that irrigated wheat farmers in the Plain area were technically medium efficient and in other areas' farmers were technically less efficient.

Key words: Production function · Technical efficiency · Wheat farms · Kurdistan · Iran

INTRODUCTION

The Province of Kurdistan has been the cradle of animal husbandry in Iran and production of various horticultural and agricultural products. In 2005, the total cultivated area of the province was 940609 ha, of which 21247 ha (2.26%) was under horticultural trees and the rest was under agricultural crops. Wheat is the most important crop of the province. According to the annual statistical report in the agricultural year 2005-2006, by Iran's statistical center, total area under wheat was 459000 ha (i.e. irrigated area 43700 and rainfed area 415300 ha) with total output of 538302 tons. Accordingly total numbers of farmers engaged with wheat and other field crops were about 87527.

The study of efficiency, which focuses on the possibility of increasing output while conserving resource use, is very important especially in developing agricultural economies, where resources are meager and opportunities for developing and adopting better technologies have of lately started dwindling [1]. Efficiency can be defined in terms of producing the maximum amount of output, given a set of inputs; or producing a given level of output using a minimum level of inputs; or a mixture of both. Efficient farms either use less input than others to produce a given quantity of output, or for a given set of inputs they generate a greater output [2]. A frontier production function represents the maximum possible output for any given set of inputs setting a limit or frontier on the observed values of dependent variable, in the sense that no observed value of output is expected to lie above the production function. Any deviation of a farm from the frontier indicates the farm's inability to produce maximum output from its given sets of inputs and hence represents the degree of technical inefficiency [3]. Much of the literature on efficiency is based 'directly or indirectly' on the seminal work of Farrell [4] who argued that efficiency could only meaningfully be gauged in a relative sense, as a deviation from the best practice of a representative peer group of producers. He introduced the distinction between technical efficiency and allocative efficiency. From that time so far, the measurement of efficiency constituted a large portion of agricultural economic studies. For example, Dileep *et al.* [5] examined resource

Corresponding Author: Hamed Ghaderzadeh, Department of Agricultural Economics, University of Kurdistan, Sanadaj, Iran

use efficiency of contract farms and non-contract farms in tomato of Haryana State, India. Singh *et al.* [6] estimated technical, allocative and cost efficiencies of individual farmers and computed inter-farm and inter-regional variability in the efficiency measures to Haryana State, India by using the Data Envelope Analysis (DEA) approach. Mashayekhi [7] studied barley production and farm efficiency in Tehran province of Iran using translog frontier production function. He found the average TE for barley farms, to be 0.82 and included that about 52% of the differences between actual and frontier output had been due to technical inefficiency.

MATERIAL AND METHODS

We apply a parametric approach to estimate efficiency. The parametric approach is subdivided into two main classes of approaches namely deterministic and stochastic models. The main difference between these two broad categories is that deterministic models envelope all the observations, identifying the distance between the observed production and the maximum feasible production given the quantity of input used and identifying this distance as technical inefficiency. Stochastic models instead permit one to distinguish between technical inefficiency and statistical noise [8]. The stochastic frontier production function was selected for this study. A stochastic production frontier in general has the form [9]:

$$Q_i = Q(X_{ki}, \beta)\, e^{\varepsilon},\ i = 1, 2 \ldots n;\quad k = 1, 2 \ldots n \qquad (1)$$

Where
Q_i = Output of the i^{th} farm
X_{ki} = Vector of K inputs of the i^{th} farm
β = Vector of parameters
ε = Farm – specific error term

This stochastic frontier is also called a 'composed error' model because the error term is composed of two independent elements:

$$\varepsilon = V_i - U_i \qquad (2)$$

Where:
U_i = Non-negative term representing technical inefficiency
V_i = Symmetric component of the error term

The symmetric component, V_i, permits random variation in output due to factors outside the control of the farm such as weather and disease. It is assumed to be independently and identically distributed as N (0, σ_v^2). A one-sided component ($U_i \geq 0$) reflects technical inefficiency relative to the stochastic frontier, thus U_i = 0 for any farm's output lying below the frontier, representing the amount by which the frontier exceeds the actual output of farm i. It is also assumed to be independently and identically distributed as N (0, σ_u^2). That is half-normal distribution [10].

Let σ^2_u and σ^2_v be the variances of technical inefficiency parameter 'U' and statistical noise 'V' respectively then:

$$\sigma^2 = \sigma^2_v + \sigma^2_u \qquad (3)$$

The variance ratio γ, explaining the total variation in output from the frontier level of output attributed to technical inefficiencies, can be computed as:

$$\gamma = \sigma^2_u / \sigma^2 \qquad (4)$$

Where:
$0 \leq \gamma \leq 1$

Aigner *et al.* [11] defined λ as the ratio of standard errors in stochastic to symmetric disturbances as follows:

$$\lambda = \sigma_u / \sigma_v \qquad (5)$$

Estimation of stochastic frontier production function by maximum likelihood method gives the value of σ^2 and γ. The value of λ can be manually calculated by using the equations (3) and (4). From the equation (4), σ^2_u can be calculated as follows:

$$\sigma^2_u = \gamma \times \sigma^2 \qquad (6)$$

By substituting the value of σ^2_u in equation the value of σ^2_v is computed by:

$$\sigma^2_v = \sigma^2 - \sigma^2_u \qquad (7)$$

Then the square root of σ^2_u and σ^2_v are substituted in equation (5) to obtain the value of λ. In maximum likelihood technique, the estimates of λ and σ indicate the goodness of fit.

Individual firm measures of technical efficiency could be calculated from the error terms (ε_i) as follows:

$$\frac{s_u s_v f(e\lambda/s)}{s\left(1 - F(e_i\lambda/s) - \frac{e_i\lambda}{s}\right)} \qquad (8)$$

The specific model estimated in this study, based on above theoretical frame work, is as following:

$$LnY = Lna_0 + \sum^{9}_{i=1} a_i LnX_i + \sum^{9}_{i=1} b_i Xi + e_i \qquad (9)$$

Where:

Y = Output (Kg/farm)
X_1 = Labor (man-days/farm)
X_2 = Machinery (working hours/farm)
X_3 = Nitrogen Fertilizer (Kg/farm)
X_4 = Phosphate Fertilizer (Kg\farm)
X_5 = Plant protection chemicals (Litter/farm)
X_6 = Seed (Kg/farm)
X_7 = Manure (Kg/farm)
X_8 = Number of Irrigation
X_9 = Area situation (land situation)
bi = Linear coefficient of independent variables
a_i = Logarithmic coefficient of independent variables
α_0 = Intercept (constant term)
e = Residual term

Note: "N" in tables shows the number of farmers in each area and Ln of each variables considered in the model. The significant variables only reported in the tables.

Meeusen and Van Den Broeck [12] independently presented the Maximum Likelihood Estimates (MLE) to estimate a stochastic frontier production function.

Data: The present study was conducted in the Saqqez city of Kurdistan province. The study tried to calculate technical efficiency of wheat farmers both irrigated and rainfed farms. The sampling technique was based on two stage cluster random sampling. In the first stage, 10 major villages from each area (mountain, semi-plain and plain areas) were selected followed by random selection of sample farmers based on population of each village. The numbers of samples in each area is 70 and in total 210 farmers were interviewed. The data were collected for agricultural year 2003-2004 by personally interviewing the selected respondents. The Limdep software used to analyze frontier production function and calculate Technical efficiency.

RESULTS AND DISCUSSION

Dry land and irrigated land formed 78.04 and 21.96% of total cultivated area, respectively. The cropping pattern followed rainfed wheat, chick-pea, irrigated wheat, rainfed barley, Alfa-Alfa, rainfed sunflower and irrigated barley (Table 1).

Table 1: Cropping pattern in the Study Area

Crop	Particular	Kharif	Rabi	Total
Rainfed Wheat	Aggregate area (ha)	903.62		903.62
	Percentage	61.01		43.77
	Average area (ha)	4.61		4.61
	No of farm (%)	196 (93.33)		196 (93.33)
Rainfed Barley	Aggregate area (ha)	124.81		124.81
	Percentage	8.43		6.05
	Average area (ha)	1.41		1.41
	No of farm (%)	93(44.28)		93(44.28)
Rainfed Chick- Pea	Aggregate area (ha)		514.74	514.74
	Percentage		88.26	24.93
	Average area (ha)		3.26	3.26
	No of farm (%)		158(75.24)	158(75.24)
Rainfed Sunflower	Aggregate area (ha)		68.48	68.48
	Percentage		11.74	3.32
	Average area (ha)		3.28	3.28
	No of farm (%)		31(14.76)	31(14.76)
Irrigated Wheat	Aggregate area (ha)	274.62		274.62
	Percentage	18.54		13.3
	Average area (ha)	2.64		2.64
	No of farm (%)	104(49.52)		104(49.52)
Irrigated Barley	Aggregate area (ha)	64.01		64.01
	Percentage	4.32		3.1
	Average area (ha)	1.29		1.29
	No of farm (%)	48(22.86)		48(22.86)
Irrigated Alfa – Alfa	Aggregate area (ha)	114		114
	Percentage	7.7		5.52
	Average area (ha)	1.16		1.16
	No of farm (%)	97(46.19)		97(46.19)
Total		1481.06 (100)	583.22 (100)	2064.3 (100)

Percent figure in parentheses are percentages to respective sample size

Table 2: Estimated transcendental production function of rainfed wheat in Plain area

Particular	Coefficient	Standard error	t- value
Variable			
Intercept	3.435**	0.884	3.885
X_2 (Machinery hour)	0.687*	0.004	1.885
LnX_6 (Seed)	0.694**	0.148	4.675
LnX_5 (Plant Protection Chemicals)	0.17*	0.72	2.374
Model summary			
R^2	0.628		
$\bar{R}^2$	0.607		
F-statistic	30.351**		
N	66.00		

*Significance at 5% level and**Significance at 1% level

Table 3: Estimated transcendental production function of rainfed wheat in Semi-Plain area

Particular	Coefficient	Standard error	t- value
Variable			
Intercept	3.705**	0.129	3.281
X6 (Seed)	0.01*	0.000	1.967
X2 (Machinery hour)	-0.006**	0.003	-2.224
LnX6 (Log seed)	0.662*	0.202	3.275
Model summary			
R^2	0.754		
$\bar{R}^2$	0.737		
F –statistic	43.914**		
N	68.00		

*Significance at 5% level and**Significance at 1% level

Rainfed Wheat: The production function of rainfed wheat estimated for Plain, Semi-Plain, Mountain areas and entire study areas are presented in Table 2 and 4.

Table 4: Estimated transcendental production function of rainfed wheat in Mountain area

Particular	Coefficient	Standard error	t- value
Variable			
Intercept	3.676**	0.998	3.685
X3 (Nitrogen fertilizer)	0.01*	0.001	2.06
LnX6 (Log Seed)	0.638**	0.169	3.774
Model summary			
R^2	0.552		
$\bar{R}^2$	0.526		
F –statistic	20.95**		
N	62.00		

*Significance at 5% level and**Significance at 1% level

Table 5: Estimated transcendental production function of rainfed wheat for study area

Particular	Coefficient	Standard error	t- value
Variable			
Intercept	7784.00*	3831.75	2.031
X6 (Seed)	6.07**	0.526	11.556
X9 (Area Situation)	- 385.6*	216.238	- 1.783
X3 (Nitrogen Fertilizer)	-6.408*	2.66	-2.409
X5 (Plant Protection Chemicals)	145.637**	54.837	2.656
LnX3 (Log Nitrogen Fertilizer)			
Model summary	1836.85*	816.415	2.250
R^2	0.661		
$\bar{R}^2$	0.648		
F –statistic	52.935**		
N	196.00		

*Significance at 5% level and**Significance at 1% level

Table 6: Estimated transcendental production function of irrigated Wheat in Plain Area

Particular	Coefficient	Standard error	t- value
Variable			
Intercept	4.035**	0.692	5.832
X_3 (Nitrogen Fertilizer)	0.012**	0.001	1.793
LnX_6 (Log Seed)	0.507*	0.131	3.845
LnX_1 (Log Human Labor)	0.395**	0.103	3.838
Model summary			
R^2	0.755		
$\bar{R}^2$	0.73		
F –statistic	30.797**		
N	35.00		

*Significance at 5% level and **Significance at 1% level

Table 7: Estimated transcendental production function of irrigated Wheat in Mountain Area

Particular	Coefficient	Standard error	t- value
Variable			
Intercept	3.332**	0.855	3.899
LnX6 (Log seed)	0.564**	0.156	3.602
LnX1 (Log Human Lanlur)	0.492*	0.225	2.184
Model summary			
R^2	0.552		
$\bar{R}^2$	0.517		
F –statistic	16.003**		
N	42		

*Significance at 5% level and **Significance at 1% level

Table 8: Estimated transcendental production function of irrigated Wheat in Study Area

Particular	Coefficient	Standard error	t- value
Variable			
Intercept	5.89*	0.644	9.148
X6 (Seed)	0.002**	0.000	5.53
LnX1 (Log Human Labor)	0.584*	0.218	2.68
Model summary			
R^2	0.618		
$\bar{R}^2$	0.582		
F –statistic	16.987**		
N	104.00		

*Significance at 5% level and **Significance at 1% level

Plain Area: The estimated Transcendental production function model for rainfed wheat of Plain area farms showed that the Coefficient of multiple determination (R^2) was 0.628 indicating that the variables included in the model were able to explain 62.8% of variation in the average production of rainfed wheat per hectare. The F-value was high and significant at 1% level, which indicates goodness of fit. The variables such as machinery (x_2), seed (Lnx_6) and plant protection chemicals (Lnx_5) were significant and positively related (Table 2).

Semi-Plain Area: The estimated Transcendental production function model for rainfed wheat of Semi-Plain area showed that the Coefficient of multiple determination (R^2) was 0.754 indicating that the variables included in the model were able to explain 75.4% of variation in the average production of rainfed wheat per hectare. The F-value was 73.914 and significant at 1% level, which indicates goodness of fit of the model. The variables such as machinery (x_2), negatively and seed (LnX_6 and X_6), positively were significant and related (Table 3).

Mountain Area: The estimated Transcendental production function model for rainfed wheat of Mountain area showed that the Coefficient of multiple determination (R^2) was 0.552 indicating that the variables included in the model were able to explain 55.2% of variation in the average production of rainfed wheat per hectare. The F-value was 20.95 and significant at 1% level, which indicates goodness of fit. The variables such as nitrogen fertilizer(x_3) and seed (LnX_6), were significant and positively related (Table 4).

Whole Study Area: The estimated transcendental production function model for rainfed wheat of study area showed that the Coefficient of multiple determinations (R^2) was 0.661 indicating that the variables included in the model ere able to explain 66.1% of variation in the average production of rainfed wheat per hectare. The F-value was 73.914 and significant at 1% level, which indicates goodness of fit. The variables such as seed (X6), positively, area situation (X9), negatively, nitrogen

Table 9: Frequency distribution of technical efficiency ratings for Rainfed Wheat(Number)

Efficiency rating (Class interval %)	Classification	Plain area N	Plain area %	Semi-Plain area N	Semi-Plain area %	Mountain area N	Mountain area %	Overall N	Overall %
0-60	Poor	14	21.2	23	33.9	18	29	54	27.6
61-70	Low	18	27.3	23	33.9	19	30.6	59	30.1
71-80	Medium	33	50.0	20	29.4	21	33.9	75	38.3
81-90	High	1	1.5	2	2.9	3	4.8	7	3.6
More than 90	Very High	-	-	-	-	1	1.6	1	0.5
	Total	66	100	68.0	100	62	100	196	100
	Mean Efficiency	0.668		0.646		0.651		0.655	

Table 10: Frequency distribution of technical efficiency ratings for irrigated wheat (Number)

Efficiency rating (Class interval %)	Classification	Plain area N	Plain area %	Semi-Plain area N	Semi-Plain area %	Mountain area N	Mountain area %	Overall N	Overall %
0-60	Poor	3	8.6	3	11.1	12	29.3	18	17.5
61-70	Low	11	31.4	15	55.6	17	41.5	43	41.7
71-80	Medium	20	57.1	6	22.2	10	24.4	36	35.0
81-90	High	1	2.9	3	11.1	2	4.9	6	5.8
More than 90	Very High	-	-	-	-	-	-	-	-
	Total	35	100	27	100	41	100	103	100
	Mean Efficiency	0.704		0.68		0.646		0.676	

fertilizer (X3), negatively and plant protection chemicals(X5), positively, were significant at level of one or 5% (Table 5).

Irrigated Wheat: The Transcendental production function run for irrigated wheat were estimated in the Plain, Mountain and study areas only, due to their sample number which were more than or equal to 30.

Plain Area: The estimated transcendental production function model for irrigated wheat of Plain area showed that the Coefficient of multiple determination (R^2) was 0.755 indicating that the variables included in the model were able to explain 75.5% of variation in the average production of irrigated wheat per hectare. The F-value was 30.797 and significant at 1% level, which indicates goodness of fit. The variables such as nitrogen fertilizer (X_3), seed (LnX_6) and human labor (X_1) were significant at level of 1 or 5%, positively (Table 6).

Mountain Area: The estimated Transcendental production function model for irrigated wheat of Mountain area showed that the Coefficient of multiple determination (R^2) was 0.552 indicating that the variables included in the model were able to explain 55.2% of variation in the average production of irrigated wheat per hectare. The F-value was 16.003 and significant at 1% level of significance, which indicates goodness of fit. The variables such as seed (LnX_6) and human Labor (LnX_1) were significant at level of 1% and positively related (Table 7).

Study Area: The estimated Transcendental production function model for irrigated wheat of study area showed that the Coefficient of multiple determination (R^2) was 0.618 indicating that the variables included in the model were able to explain 61.8% of variation in the average production of irrigated wheat per hectare. The F-value was 16.003 and significant at 1% level of significance, which indicates goodness of fit. The variables such as seed (LnX_6) and human Labor (LnX_1) were significant at level of 1% and positively related (Table 8).

Technical Efficiency on Sample Farmers: To assess the level of technical efficiency obtained by individual farmers for major crops, the outputs obtained and inputs used were compared with the corresponding values derived from the frontier production function. The crop and area-wise frequency distribution of technical efficiency ratings for all three areas as well as study area are presented in the following sections.

Rainfed Wheat: The technical efficiency for rainfed wheat farms in the study area is presented in Table 9. The results showed that in Plain area most of the farmers were in medium efficiency category (50%) followed by low, poor and high efficiency categories (27.3, 21.2 and 1.5%). There was no farmer in very high efficiency group. In Semi-Plain area most of the farmers belonged to low and poor (33.9% for each category) efficiency categories followed by medium and high efficiency categories (20 and 2%). In Mountain area most of farmers belonged to medium efficiency category (33.9%) followed by low, poor, high and very high efficiency categories (30.6, 29, 4.8 and 1.6%, respectively). At the aggregate, most of the farmers belonged to medium efficiency category (38.3%) followed by low, poor, high and very high efficiency categories (30.1, 27.6, 3.6 and 0.5%, respectively).

The average of technical efficiency in all the three areas was 0.668, 0.646 and 0.651 in that order. The same for the entire area was 0.655. This showed that rainfed wheat farmers were technically less efficient.

Irrigated Wheat: The technical efficiency for irrigated wheat farms the study area is presented in Table 10. The results showed that in the Plain area most of the farmers were in medium efficiency category (57.1%) followed by low, poor and high efficiency categories (31.4, 8.6 and 2.9%, respectively). There was no farmer in very high category group. In Semi-Plain area most of the farmers belonged to low (55.6%) category followed by medium, high and poor categories (22.2, 11.1 and 11.1%) and also there was no farmer in very high category in Semi-Plain area. In mountain area most of farmers were belonged to low category (41.5%) followed by poor, medium and high efficiency categories (29.3, 24.4 and 4.9%, respectively). At the aggregate, most of the farmers belonged to low category (41.7%) followed by medium, poor and high efficiency categories (35, 17.5 and 5.8%, respectively).

The average of technical efficiency in all the three areas was 0.704, 0.684 and 0.646. The same for the entire area was 0.676. This showed that irrigated wheat farmers in the Plain area were technically medium efficient and others areas' farmers were technically less efficient.

CONCLUSION

As the result shows that there are different variables which effect wheat production both irrigated and rainfed and type of variables differ from on area to another. Again result show that, most of the farmers in all area as well as for both irrigated and rained farms are technically less efficient.

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