Technical Efficiency Changes at the Farm Level: A panel Data Analysis of Wheat Farms in Northern Highland Region, Republic of Yemen

Ali Abdul Majeed Alsururi
Branch of Agricultural Research and Extension, Regional Research Station Northern Highland Lands, Sanaa, PO Box 2366,
Republic of Yemen

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The Correspondent Researcher:
Ali Abdul Majeed Alsururi
E-mail: alsururi61@yahoo.com

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ABSTRACT

This study is additional knowledge for the production of wheat, as more a food crop consumption and less productive in Yemen and with the aim of increasing production of it to access or approach the self-sufficiency, Where the study aimed to test the efficiency of technological changes on the level of wheat farms in the region of North Highlands in the Republic of Yemen over a period of fifteen years (1996 to 2010) using North Highlands region panel data. Results from the stochastic production frontier analysis indicate that all inputs included in the model were positively significant; the average annual rate of technological change for wheat was 5% at decreasing rate, while average technical efficiency of wheat has slightly increased from 73.7% to 74.1% over this period due to improved performance of farms as well as socio-economic factors as farm size, family size, Age, education, fragmentation and time. Age, fragmentation and time are factors negatively influencing technical efficiency while the relationship with farm size, family size and education are positive. Under the current production techniques and the use of agricultural inputs, there is a possibility to increase wheat production by 26%. Policy recommendations include consolidation of land and strengthening of agricultural research, extension services, improved seeds and supporting institutions for agricultural production.

تغيرات الكفاءة ألتكنولوجيه على مستوى المزرعة: تحليل بيانات جدوليه من مزارع القمح في المرتفعات الشمالية، الجمهورية اليمنية

علي عبد المجيد السوروري
فرع الهيئة العامة للبحوث والإرشاد الزراعي، المحطة الإقليمية لبحوث المرتفعات الشمالية
صنعاء ص ب 2366، جمهورية اليمن

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الباحث المُرَاسِل: علي عبد المجيد السوروري
بريد الكتروني:
alsururi61@yahoo.com

الكلمات الدالة

كفاءة تكنولوجيا، محصول القمح، اليمن

المُستلخص

تعتبر هذه الدراسة إضافة معرفية عن إنتاج القمح باعتباره أكثر المحاصيل الغذائية استهلاكا واقل إنتاجا في اليمن وذلك بهدف زيادة الإنتاج منه للوصول أو الاقتراب من الاكتفاء الذاتي، حيث تهدف الدراسة لاختبار التغير في الكفاءة التكنولوجية على مستوي مزارع القمح في إقليم المرتفعات الشمالية في الجمهورية اليمنية عبر خمسة عشره سنه (1996 إلى 2010) باستخدام بيانات جدوليه لمنطقة المرتفعات الشمالية لتقدير مؤشرات مدخلات الإنتاج وقياس التغير في الكفاءة التكنولوجية عبر الزمن لمحصول القمح ، حيث بينت نتائج تحليل الدالة ألمجاليه العشوائية أن جميع مدخلات الإنتاج ألداخله في النموذج كان لها تأثير معنوي وايجابي في زيادة إنتاج القمح وان معدل النمو السنوي للقمح زاد بمعدل متناقص بمقداره 5 %، بينما متوسط الكفاءة الفنية من القمح قد زادت قليلا من 73.7 % إلى 74.1 % نتيجة تحسين أداء المزرعة وتأثير العوامل الاقتصادية والاجتماعية مثل المستوى التعليمي وحجم مساحة المزرعة وحجم الأسرة التي كان لها تأثير ايجابي على الكفاءة التكنولوجية ، بينما تجزئة الحيازة وعمر المزارع كان لها تأثير سلبي على الكفاءة، و في إطار تقنيات الإنتاج الحالية واستخدام المدخلات الإنتاجية الزراعية، هناك إمكانية لزيادة إنتاج القمح بنسبة 26 %. وقد تضمنت التوصيات السياسية للدراسة بضرورة دعم الأبحاث وخدمات الإرشاد الزراعي والمؤسسات الداعمة للإنتاج الزراعي.

Introduction

Wheat is one of the important food crops in Yemen, where it occupies about 15.5 % of the total area of grain, amounting to 121.3 thousand hectares and contributes about 25% of the total production of grains estimated at about 189.8 thousand tons on average for the period 2005-2010. Based on agricultural census of 2002, the irrigated area of wheat was estimated to be about 53.6% of total wheat area. However, wheat consumption is about 2204.7 thousand tons for the same period. This is due to the steady increase in population and pattern change in consumption. Efforts to increase domestic production must be increased in order to raise self-sufficiency, which does not exceed 9.2% on the one hand and to reduce the volume of imports, which is estimated at 2.044 million tones worth about 582.37 million dollars a year for the same period on the other hand. Further increase in production is possible only through improvement in productivity of the crop. In this context technical efficiency in the production of crop is of paramount importance. The policy makers can either attempt to enhance the adoption of improved relevant technologies particularly to small-scale agricultural production by improving research and development processes, or they can take steps which enable the farmers to improve technical efficiency in production. The first option probably requires long time, considerable funds and efforts but is likely to yield long term benefits. Else, raising technical efficiency offers realize more immediate goals at modest costs, if it can be shown that substantial inefficiencies are present in agricultural production. Such research efforts are, therefore, based on analysis of technical inefficiencies in production of wheat crop by farmers. in light of this background, this study reportes technical efficiency of wheat crop under irrigated conditions in the districts of Northern highland region in Republic of Yemen Republic. The specific objectives of the study were:

(a) To estimate the cost and returns for local and improve variety of wheat under irrigation contestation.

(b) To identify the changes in farm-level technical efficiency over time for wheat farms under irrigation in Yemen, this is the key factor in sustaining agricultural growth and food security.

(c) To identify the factors influencing technical efficiency in wheat production under irrigated conditions.

Materials and Methods

Multi-stage random sampling procedure was followed in the selection of governorates, district, ozlahs (sub-districts), villages and the farmers in Northern highland region. In the first stage, three governorates (Sanaa, Amran, and Almhweet) were selected randomly on the basis of common area. In the second stage, two districts were selected randomly from each governorate; in each district, two ozlahs (sub-districts) with highest command area were selected randomly from each district; three villages were randomly chosen from each ozlah (sub-districts) according to the size of the village within the common area, which gives a total of 36 villages. In the fourth stage, samples of 308 farmers growing wheat were selected for the study. The data were collected through personal interview using pre-tested schedules.

(1) Panel Data

The data for this analysis were collected as bounds of economic section programs for the research station of the Northern highland region for the same governorates, districts, ozlahs (sub-districts) and villages of three surveys of wheat production. in the 1996 survey the sample size was 150 farmers; second survey conducted in 2001 represented 88 farmers of wheat; the last survey was conducted in 2010 and the sample size was 70 farmers. Samples were collected seasonally from June to August for three seasons1996, 2001 and 2010. For the purpose of characterization of production systems and profitability, data were collected on holding size, fragmentation land, family size, education levels, family labor, input use like seeds, fertilizers, organic manor, irrigation, machinery, animal power, human labor etc. and all management operations like ploughing, seeding, fertilizing, irrigating, weeding, harvesting, threshing ...*etc*, and methods of cultivation of wheat. Main yield and by-products of respective crops were also collected. Existing market prices of all inputs and outputs were collected for profitability analysis. During data collection an interview schedule was employed keeping the objectives of the study in mind. The sample of these three surveys is nationally representative as documented by the researcher himself. However, because of the objectives of our paper, we used farm level panel data. Therefore, we consolidated the data for all three surveys such that the total observation stands at 308 farmers.

(2) Analytical Techniques

The stochastic frontier approach (SFA) was first introduced by Farrell, (1957) and independently proposed by Aigner *et al.,* (1977) and Meeusen and Van den Broeck, (1977). SFA has contributed significantly to the literature by using econometric modeling of production and technical efficiency of farms both in a static or a dynamic framework. SFA involves two random components (two error terms), one to account for the existence of technical inefficiency of production and the other to account for factors such as measurement error in the output variable, weather, etc., and the combined effects of unknown inputs on production. The advantage of the SFA is its capability to measure the efficiency in the presence of statistical noise. Applications of frontier functions have involved both cross-sectional and panel data. In our study we used a panel data set as it is more informative and is able to capture dynamic behavior (Goyal, 2006, Baltagi and Song, 2006). Specifically there are some advantages in using panel data instead of a cross section or time-series data (Hsiao, (2003) Baltagi, (2005) and Mohammad Jahangir *et. al*., (2011). These advantages are:

(1) Panel data have more variability and less co linearity among variables.

(2) Panel data controls individual heterogeneity and, therefore, able to get unbiased estimates.

(3) Can identify and estimate effects which are not detectable in a cross-section or time-series data.

The SFA approach can effectively handle statistical noise in panel data but is adversely affected by measurement error when applied to cross-sectional data. Furthermore, Sickles, (2005) showed that the panel data version of the stochastic frontier model works well. This is because the panel data model incorporates additional information from the times-series nature of the data as well as the distributional assumptions, which allow estimation via the method of maximum likelihood (ML). Therefore, we chose to apply the stochastic frontier production function with a simple half normal specification of time varying farm effects defined in following Equation (1):

$Y_{it} = f(X_{it} : \beta)\, Exp(V_{it} - U_{i})$ … (1)

Where Y_{it} is the output of the i^{-th} farm in the t^{-th} time period; x_{it} is a vector ($1 \times K$) of inputs and other explanatory variables for the i-th farm in the t-th time period; β is a vector (Kx1) of the unknown parameters to be estimated; V_{it} is the random error, which is supposed to have a normal distribution with mean zero and constant variance (σ^2), that is $V_i \sim iid\ N(0, \sigma^2)$; and U_{it} is the non-observable and non-negative random error, which ranged between zero and one, where one indicates full technical efficiency and zero indicates full technical inefficiency that captures technical inefficiency for the i-th farm. Following Battese and Coelli, (1992), U_{it} can be defined as:

$U_{it} = \eta_{it} Ui = \{exp[-\eta(t - T)]\}\ Ui$ ... (2)

$i = 1,2,.........,N$

Where η is an unknown scalar to be estimated, t is the time period analyzed and T is the total number of periods. *TE* increases, remains constant or decreases with time when $\eta > 0$, $\eta = 0$ or $\eta < 0$, respectively. The U_{it} term can have different specifications and the most popular are the non-negative distribution of a truncated normal with an average μ and a constant variance $(Ui \sim iid/N\ (\mu, \sigma^2_U))$ and the half-normal distribution $(Ui \sim iid/N\ (0, \sigma^2_U))$.

Coelli *et al.* (1998) suggests that the choice of a more general distribution, such as the truncated normal, is generally preferable. However, this is an empirical question and consequently, in this paper, the truncated normal distribution was tested against the half-normal. Given the compound error term (*V-U*), (Jondrow *et al.,* (1982) an, Battese and Coelli, (1988). The technical efficiency of an individual farmer is defined as the ratio of the observed output to the corresponding frontier output given the available technology, which lies between zero and one and is estimated by:

$TE = exp(-Ui) = Yi/Yi$ ….(3)

Where Y_i is the observed farm output, Y_i is maximum possible output using the given level of inputs and *U* is specified in equations (1) and (2) The *TE* for each farm is calculated by using the conditional expectation of $(-U_i\ (exp(-Ui\ ))$, all these calculations were done using (STATA 11.2 Software) which provides maximum likelihood estimates for the parameters of the stochastic frontier model.

Considering the specifications indicated above, the null hypothesis that technical inefficiency is not present in the model was tested. This is equivalent to saying that $\gamma = 0$, taking into account that this parameter corresponds to the ratio between the variance of the one-sided error ($\sigma^2 u$) and the total variance ($\sigma^2 v + \sigma^2 u$), that is $\gamma = \sigma^2 u / (\sigma^2 v + \sigma^2 u)$. The value of γ is in the range of zero (means no technical inefficiency) to one (means no random noise). (Battese and Corra, 1977). The null hypotheses is that technical inefficiency is time invariant ($H0: \eta = 0$) and that it follows a half-normal distribution ($H0: \mu = 0$) was also tested.

(3) Model Specification

For empirical analysis, a Cop Deglas stochastic frontier production function is Specified as given below:

$$ln\ (Y_i) = ln\ \beta_0 + \beta_1 lnX_{1i} + \beta_2 ln\ X_{2i} + \beta_3 ln\ X_{3i} + \beta_4 ln\ X_{4i} + \beta_5 ln\ X_{5i} + \beta_6 ln\ X_{6i} + \beta_7 ln\ X_{7i} + \beta_8 ln\ X_{8i} + \beta_9 ln\ D_i + (v_i - u_i)\ ....\ (4)$$

Where Y =Wheat yield (kg/ha), $\beta 0$ = Constant or intercept, *X1* = Area under wheat (ha), *X2* = Quantity of seed used (kg/ha), *X3* = Quantity of fertilizers used (kg/ha), *X4*= Organic manure (bag/ha), *X5*= Irrigation (m^3/ha), *X6*= Machine power (hours/ha), *X7*= Animal power (day/ha), *X8*= Human labour (days/ha), *Di* = dummy variable improve variety =*1*, others wise =*0, T* = Time variable (technology change), T^2 = square of time, βi = Unknown parameters to be estimated, $\boldsymbol{v_i}$ = An independently and identically distributed random error, and u_i = A non-negative random variable associated with technical inefficiency in production which is under the control of the farmers $i = 1, 2, 3,\ldots\ldots,n$.

(4) Determinants of Technical Efficiency

Bravo-Ureta and Pinheiro, (1993) draw attention to those applications which attempt to investigate the relationships between technical efficiency and various socioeconomic variables such as farm size, family size, age, level of education of the farmers, fragmentation index and time. The linear regression model used for estimating the factors affecting technical efficiency of wheat growers under irrigated farming was:

$$ln\ [\ TE/\ (1\text{-}\ TE)] = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_7 + u_i\ \ldots\ (5)$$

Where, *Z1* = Farm size (ha), *Z2* = Family size, *Z3* = Female workers (human days/ha), Z4 = Age of the farmers by year, *Z5* = Education level of the selected farmers (up to post-graduation level), *Z6* = Fragmentation index, *Z7* = Time, $\delta 0$ = Constant, and δi = Unknown parameters to be estimated, and $i = 1, 2, 3,\ldots.., n$.

Results And Discussion

(1) Sample Characteristics

A basic summary of the values of the key variables, defined in the model is presented in Table I. The figures are for a per hectare basis. The average wheat production was 3080 (kg/ha) which ranged from 1400 kg to 5926kg. The average yield of local variety of wheat was 2183 (kg/ha) which ranged from 1400 kg to 2853kg, while the average improved wheat variety yield was 3456 (kg/ha) with range from 2143 kg to 5926kg. The area under wheat on the sample farms varied from a very small farm of 0.022 hectare to large farm of 1.68 hectares with average of 0.46 hectare. The average seed rate for wheat was 134 (kg/ha) which ranged from 110 (kg/ha) to 167 (kg/ha). The average Chemical fertilizer (urea) used was 197 (kg/ha) which ranged from zero to 535 (kg/ha). The average Organic manures used was 270 (bags/ha) which ranged from zero to 727 (bag/ha). The average Irrigated water was 6388(m3/ha) which ranged from 2862 (m3/ha) to 10438 (m3/ha). The average tractor power was 16 (hour/ha) which ranged from zero to 28 (hour/ha). The average power was 44 (day/ha) which ranged from zero to 100 (days/ha). The mean human labor was 85 (man/ day/ha) which ranged from 37 to 174 (man/ day/ha). In describing how the inefficiency effects in stochastic frontier production function may vary across different farmers, five socio- economic variables, viz., farm size, family size, age of head of family, education level and Fragmentation index were studied. The average farm size was 0.46 ha which was ranging from 0.022 ha to 1.68 ha. The farmers had a wide range of family size ranging from 4 to 45 members with an average of 15.7 members per family. The average age of the head of family ranges from 14 to 79 years, average being 48.8 years. The average education level of the farmers was 2.12 years of formal education. However, about 39.9% of the sample farmers had no formal education, about 51.1% can read and write only, and about 7.1% had primary education and about 1.6% had at least 10 years of formal education.

Table 1: Means and Standard Deviations of key Variables

Variables	Mean	Standard deviation	Min	Max.
Output (kg/ha)	3080	829	1400	5926
Output local variety (kg/ha)	2183	300	1400	2853
Output improved variety (kg/ha)	3456	664	2143	5926
Inputs:				
Seed (kg/ha)	134	10	110	167
Chemical fertilizer (urea) (kg/ha)	197	97	0	535
Organic manures (bag/ha)	270	121	0	717
Irrigated water (m^3/ha)	6388	1666	2862	10438
Tractors (hour/ha)	16	4	0	28
Animal power (day/ha)	44	16	0	100
Human Labor (man/ day/ha)	85	21	37	174
		Farm-specific		
Farm size (ha)	0.460	0.343	0.0216	1.68
Family size (No)	15.7	7.427	4	45
Age The Farmer (years)	48.8	11.153	14	79
Education of famers (years)	2.12	2.05	0.00	12.00
Fragmentation index	4.47	4.31	0.09	29.63

(2) Cost and Returns of Irrigated Wheat Crop

The data on cost and returns of irrigated local and improved wheat varieties for the three years 1996, 2002 and 2010 , presented in Table 2, revealed that operational cost, fixed cost and total cost were all lower under irrigated local wheat variety than for irrigated improved wheat variety for the three years. It is also observed that though the cost involved in irrigating local wheat variety was 43.6%, 42.2% and 40.5% of the total cost in these two varieties for the three years 1996, 2002 and 2010 respectively, its yield was much less (2.06, 2.11 and 2.43 ton /ha respectively) than in irrigation of improved wheat variety (3.08, 3.67 and 4.09 ton/ha for the same years, respectively). Their BCR worked out to be 1.16, 1.17 and 1.38 for local wheat variety and 1.35, 1.49 and 1.53 for improved wheat variety for the three years respectively.

Table 2: Cost and Returns of Local and Improve Irrigated Varieties of Wheat in Northern Highland Region during 1996 - 2010.

	Local wheat variety			Improve wheat variety		
Particulars	1966	2002	2010	1966	2002	2010
Operational cost (YR/ha)	73588	133662	257851	94455	180578	391956
Total cost (YR/ha)	77508	140861	273929	100326	193090	419094
Yield (tan/ha)	2.06	2.11	2.42	3.08	3.67	4.09
Gross income (YR/ha)	90151	165442	376767	134998	287554	635919
Benefit-cost ratio (BCR)	1.16	1.17	1.38	1.35	1.49	1.52

(3) Estimates of the Frontier Production Function

The Maximum-Likelihood Estimates (MLE) of the stochastic production frontier are presented in Table 3. The estimates of the stochastic frontier showed that a coefficient for the variables: area, chemical fertilizer, organic manures, irrigation, tractors power, animal power and human labor were positively significant at 1% level of significance.

Table 3: Maximum Likelihood (ML) Parameter Estimates of Cobb-Douglas Production Function of Irrigated Wheat Crop in Northern Highland Region.

Variables	Coefficients	Standard Error	t
Intercept	5.068**	0.524	9.67
Area (ha)	0.489**	0.090	5.41
Seed rate (kg/ha)	0.055	0.085	0.65
Chemical fertilizer (kg/ha)	0.034**	0.005	6.95
Organic manures (bag/ha)	0.046**	0.007	6.6
Irrigation (m3/ha)	0.115**	0.046	2.47
Tractors (hour/ha)	0.070**	0.015	4.66
Animal power (day/ha)	0.047**	0.012	3.82
Human Labor (man/ day/ha)	0.142**	0.032	4.46
Dummy wheat variety	0.304**	0.027	11.39
T (time)	0.049**	0.007	6.98
T^2	-0.002**	0.000	-4.67
Returns of scale (RTS)	0.999	0.293	
	Variance parameters		
σ_v	0.078**	0.013	6.032
σ_u	0.128**	0.025	5.107
sigma ($\sigma^2 = \sigma^2_u + \sigma^2_v$)	0.023**	0.005	4.790
Lambda ($\lambda = \sigma_u / \sigma_v$)	1.646**	0.037	44.194
$\gamma = \sigma^2_u / \sigma^2$	0.731		
Log likelihood function	246.127		
Likelihood-ratio test of sigma_u	3.86**		

(**Coefficient is significantly different from zero at 0.05 probability level*; ***Coefficient is significantly different from zero at 0.01 probability level*).

The values revealed the possibility of 0.489%, 0.034%, 0.046%, 0.115%, 0.07%, 0.047% and 0.142% increase? in wheat crop production under irrigated conditions with 1% increase in variables of area, chemical fertilizer, organic manures, irrigated, tractors power, animal power and human labour respectively. This result is in consistence with the findings of (Sarfraz and Bashir, 2005), (Tuna *et al.,* 2006), (Mohiuddin *et al.,* 2007), (Hasan, 2008), and (Jyoti Kachroo *et al.,* 2010). The coefficient for the seed rate is 0.055, positive but non-significant. The coefficient for dummy variable of the improved varieties of wheat is 0.304. This indicates that a high-yielding variety if introduced and adopted by farmers will increase or shift upward wheat production by 0.304%. The coefficient for time is 0.049 and positively significant at 1% level of significance, showed output increase, due to new varieties of wheat, chemicals or other scale neutral technological innovations, indicating an average technical progress of at an annual rate of approximately 5.02% for the period 1996–2010. The coefficient of time squared is negatively significant at 1% level of significance, indicating that the rate of technical progress increase at decreasing rate through time. This result is in line with those of (Covaci and Sojková, 2006). The sum of input coefficients was 0.999 indicating that the sample farms are operating at constant returns to scale. The significant values of (σ_u) and (σ_v) are 0.128 and 0.078 respectively, indicating that the difference between the observed wheat output and frontier output was not due to the statistical variability alone but also due to technical inefficiency. The significant value of the ratio of the standard error of u (σ_u) to the standard error of v (σ_v), known as Lambda (λ) is 1.646. Based on (λ), we can derive gamma (γ) which measures the effect of technical inefficiency in the variation of observed output ($\gamma = \sigma^2_u / \sigma^2$). The estimated value of 'γ' was 0.731, which means that 73.1% of the difference between the observed and frontier output was primarily due to factors which were under the control of farmers. These findings conform to the results of the study by (Gunaratne and Leung, 2001).

(4) Technical Efficiency in Sample Farms

A perusal of Table 4 reveals that technical efficiency of each farm was predicted for all years observed. The mean efficiencies of observations involved, the individual technical efficiency values were not presented. However, for better indication of distribution of individual efficiencies, a frequency distribution of predicated technical efficiencies within ranges of 10% for each year and mean efficiency of each farmer are presented in Table 4.

Table 4: Distribution of Wheat Growers under Different Levels of Technical Efficiency of Irrigated Wheat in Northern Highland Region.

Technical Efficiency Level (%)	1996		2001		2010	
	No. of farms	(%) of total	No. of farms	(%) of total	No. of farms	(%) of total
50 - 60	5	3.4	4	4.55	1	1.56
60 - 70	39	26.3	17	19.7	18	25
70 - 80	63	41.9	41	46.97	34	48.44
80 - 90	37	24.6	24	27.27	16	23.44
90 -100	6	3.9	1	1.52	1	1.56
Total farmers	150	100	88	100	70	100
Mean TE	73.7		73.8		74.1	
Minimum	55.3		56.3		58.1	
Maximum	96.1		91.5		88.5	

The examination of technical efficiencies for the individual farmers revealed that there were wide variations in technical efficiencies. The predicted technical efficiencies for wheat farmers ranged from 55.7 % to 97.8% in 1996; from 57.1% to 93% in 2001 and from 59.4% to 96.1 % in 2010. The coefficient for years of observation in the model for technical efficiency effects was positive and statistically significant. It implied that the efficiencies are time varying and tend to increase over the years. The annual mean efficiency which was 73.7% in year 1996 increased slightly to 73.8% in 2001 and 73.1% in the 2010. Further it was observed that about 3.4% of the farmers have technical efficiency lower than 60 % in 1996 and increased to 4.55% in 2001 and decreased to 2.53% in 2010. The %age of farmers who had technical efficiency level (60-80 %) was about 68.2% in the first year 1996, and decreased to 66.67% and increased 83.54% in the 2001 and to 73.44 % in 2010. The % age of farmers who had technical efficiency above 80% was about 28.5% in the first year 1996; slightly increased to 28.8% in 2001 and decreased to 25 % in 2010. This indicates that most farmers during the years 1996, 2001 and 2010, had technical efficiency within the level 60%-80%. The Majority of the farmers (68.93 %) had technical efficiency from 60 % to 80%. Therefore, there was a potential for increasing wheat production in these farms using the same level of inputs and technology. The operation level of this group is very important because any attempt to bring the farmers to the frontier production will increase wheat production at the household's level and will add to the aggregate region production as well.

(5) Estimated Potential Yield in Irrigated Wheat Crop

In a different year, Table 5 revealed that the estimated average potential yield (calculated for each year as potential yield = 100/ TE* actual yield) of wheat was 3374 kg/ha and the average actual yield was 2509 kg/ha in 1996; the potential yield of wheat in 2001 was 3917 kg/ha and average actual yield was 2958 kg/ha, while the average potential yield of wheat was 4350 kg/ha and average actual yield was 3270 kg/ha in 2010.

Table 5. Estimated Potential Yield of Irrigated Wheat in Northern Highland Region.

Years	% age of total farmers	Technical efficiency	Yield (Kg/ha)	Potential yield (Kg/ha)
1996	58.1	73.7	2706	3672
2002	21.1	74.0	3253	4477
2010	20.8	74.1	3319	4478
Total	100	73.8	3146	4263

Thus, the difference between the potential and actual yields was 866 kg/ha, 960 kg/ha, 1080 kg/ha and 1047 kg/ha, for the years 1996, 2001, 2010 and the mean for all sample respectively for the above mentioned efficiency levels. These results are in conformity with those of (Kibaara, 2005), and (Ingosi, 2005), and (Jyoti Kachroo, 2010).

(6) Factors Affecting Technical Efficiency

A perusal of Table 6 indicates that the coefficient of farm size was positively significant at 1% level of significant, implying that the large farms are relatively more technically efficient than the small farms. This is in conformity with the work of (Ahmad *et al.,* 2002), (Manjeet Kaur *et al,* 2010), and (Jyoti Kachroo *et al,* 2010).

Table 6. Indicators of Technical Efficiency in Wheat Farms in Northern Highland Region.

Variables	Param-eters	Co-effi-cient	Standard error	*t Stat*
Intercept	δ0	1.1417**	0.1309	8.719
Farm size (Z_1)	δ1	0.0437**	0.0135	3.234
Family size (Z_2)	δ2	0.0127**	0.0036	3.516
Age The Farmer (Z_3)	δ 3	-0.0067**	0.0024	-2.823
Education (Z_4)	δ 4	0.0283*	0.0149	1.898
Fragmen-tation Index(Z_5)	δ 5	-0.0103*	0.0051	-2.014
Time	δ 6	-0.004 n.s	0.0045	-0.911

(**Coefficient is significantly different from zero at 0.05 probability level*; ***Coefficient is significantly different from zero at 0.01 probability level*)

The coefficient of family size was positive and significant at 1% level, indicating that technical efficiency has increased. It is maybe due to the fact that farms with large family size may be using more family labor compared to those having small family size which may be using more hired labor. Family labor in the efficiency effects is positive as expected. The age of the farmer's coefficient has a negative effect on the efficiency reported by (Wadud and White, 2000), (Sarfraz *et al.,* 2005), (Balcombe *et al.,* 2008), and (Mohammad Jahangir *et al.,* 2011). It implies that the older farmers are more technically inefficient than younger farmers. It is because of the fact that older farmers tend to be more conservative and thus less willing to adopt new farming practices, thereby perhaps having greater inefficiencies in wheat production. This is in conformity with the work of (Goyal *et al,* 2006) for wheat farmers in the region. The coefficient of education has a positive and significant influence on technical efficiency, suggesting that improvements in human capital increase technical efficiency. The role of human capital in improving the efficiency in agriculture is well documented by (Mittal and Kumar, 2000), and (Dey *et al.,* 2004). Education not only helps in better farm management decisions, but also places the farmer in an advantageous position to acquire information and other extension services in a cost-effective manner. The coefficient of fragmentation index was negatively significant at five % level of significant, indicating that efficiency decreased significantly with increased fragmentation level of the farms. This may be due to the fact that highly fragmented land inhibits the use of improved technologies, making farms more inefficient. This is in conformity with the work of (Reddy, 2004).

Conclusions

The study used the Stochastic Frontier Production Function with time varying farm effects model to examine the changes in technical efficiency at the farm-level for wheat farms in northern highland region using a weak balanced panel data for a cohort of 308 farms for three years (1996, 2001 and 2010). Results indicated that the technological progress increased at decreasing rate through time and have contributed to output significantly but technical efficiency has increased over the study period. It was 74.3% in 1996 whereas it was 75.5 and 75.2% in 2001 and 2010 respectively. Technical efficiency showed wide variations across sample farms ranging from 59.4 to 96.1 in the last year of the study period. These numbers indicate that wheat farmers were not fully efficient in Yemen and that the level of technical efficiency was slightly increasing over time at the farm-level. Thus, the study indicated that there was scope to improve the productivity of the crop with the given level of inputs and technology used. The farm-specific variables were used to explain technical inefficiencies and indicate that farmers who are young and have larger farms and less fragmentation tend to be more efficient. The family size has positively significant influence in increasing efficiency in wheat farming showing the large family size may be using more family labor compared to those having small family size who may be using more hired labor. The education level has significant effects in increasing technical efficiency in wheat farming suggesting that improvements in human capital increase technical efficiency. The technical efficiency has declined over time, but the decrease was not significant. It is of utmost importance to design appropriate policies to improve efficiency at the farm level. From policy point of view, consolidation of land ownership can improve the technical efficiency level of wheat farms. However, consolidation is a long term process. Short time inefficiency in wheat farming can be reduced significantly by strengthening agricultural research, extension services and support, improved seeds supply and improved farm. We therefore, recommend paying more attention on this aspect in attempt to increase efficiency and to contribute to increased sector productivity and output growth.

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