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Technical efficiency of rain-fed maize farms in tribal area of Central Gujarat

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Abstract
The present investigation was undertaken with view to study farm specific technical efficiency and factors determining technical efficiency of rain-fed maize farmers of tribal area of Central Gujarat. A stochastic frontier production function has been estimated to determine technical efficiency of individual farms and variance as well as regression analyses have been carried out to find the influence of socioeconomic factors. The average level of technical efficiency was estimated at 70.18 percent for farms as a whole, implying that on an average the sample farmers tend to realize around 70 percent of their technical abilities. Therefore, it was possible to improve the yield by 30 percent by following the efficient crop management practices. Among the determinants of technical efficiency, operational area, experience in maize cultivation, education level of the farmer, contact with extension agency and proximity to the market yard were found positive and significant. The variable, number of working family members had shown negative relationship with the technical efficiency. By adopting good management practices and proper allocation of the existing resources and technology, along with sound extension programmes, the potential that exists for improving the productivity of maize in the state, could be exploited.

Keywords: Technical efficiency, coefficient, determinants

Introduction
Globally, maize is known as “queen of cereals” because it has the highest genetic yield potential among the cereals. Maize accounts for nearly 24 percent share of total global cereal production as compared to 27 percent for wheat and 25 percent for rice (http://cornindia.com). Globally maize accounts for 15 percent of the world's proteins and 19 percent of the calories derived from food crops (www.ikisan). Growing demand for food grains resulting from swelling population and increasing per capita income can only be met by increasing the food grain production through productivity enhancement. One of the ways to achieve these objectives is to increase the efficiency of farm production. The empirical evidences concluded from the previous studies show that the Indian farms are technically inefficient and the productivity is much lower than the developed nations. Hence, it is essential to assess how the existing inputs are being used at farm level, its problems and possibilities available for improving efficiency of agricultural production system in India. Technical efficiency becomes central to the achievement of high levels of economic performance at the farm level. It was shown that technical efficiency determines the allocative efficiency (Kalirajan and Shand, 1994) [11]. The average productivity of Gujarat was 1727 Kg/ha which was lesser than the average country’s productivity of 2552 Kg/ha. Therefore, improvement in technical efficiency is the key for meeting the growing food grain demand in the years to come. Therefore, this study is to be undertaken to analyze the technical efficiency of the farms in the Central Gujarat.

Methodology
Data collection and Sampling Method
Maize is grown intensively in the Central Gujarat region which accounts for 78.83 percent of total area, contributing 80.90 percent of total maize production in the state. In Central Gujarat, Panchmahal, Dahod and eastern part of Vadodara district (newly Chhotaudepur district) is a tribal belt. In this tribal belt, maize is the major crop, which is grown in kharif season as a rain-fed crop. Maize is the main staple food and source of livelihoods for the tribal community of this region. Considering this, tribal area of Central Gujarat region was selected purposively for the present study.

For the sample selection, multistage stratified sampling method was adopted. At the first stage, all three tribal districts Viz., Panchmahal, Dahod and Chhotaudepur were selected. Talukas formed the second stage of sampling units, where two talukas from each district were selected on the basis of concentration of area under maize cultivation. Two villages from each taluka were selected randomly. Thus a total of twelve villages were chosen from the six selected talukas. Finally, from each selected villages, 20 maize growers were selected at random. From each selected village, the list of maize growers was prepared and the maize growers were stratified in to four size groups, *viz.*, marginal (up to 1 ha), small (1.01 to 2 ha), medium (2.01 to 4 ha) and large (above 4 ha). Further, from the each village list of maize growers 20 farmers were randomly selected ensuring proportionate representation of the four strata. In this way, 240 farmers were selected from the study scattered over the three districts.

The primary data for the study were collected through personal interview method with help of pre-tested comprehensive interview schedule.

Method of Analysis

The measurement of technical efficiency in maize production of the sample farm of Gujarat has been done using frontier production approach (Aigner *et al.* 1977; Kalirajan and Shand, 1989; Anuradha and Zala, 2010) [1, 10, 2].

However, the stochastic frontier production model has the advantage over others, as the model considers the introduction of a disturbance term representing noise, measurement error and exogenous shocks beyond the control of the production unit in addition to the efficiency component. This avoids the overestimation of inefficiency. Thus, for the present study stochastic frontier production function model was employed to find out the technical efficiency.

Specification of the model

For estimating the technical efficiency, Stochastic Production Function approach has been used. The parameters of frontier production function were estimated using the Maximum Likelihood Estimation (MLE).

The stochastic frontier production function has been specified as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (V_i - U_i)$$

Where the subscript i, denotes the i^{th} farmer in the sample

In = represents the natural logarithm (i.e. to base e)

Y_i = represents the output of maize (q/ha)

$\beta_{0....} B_6$ = parameters to be estimated

X_1 = represents Quantity of seed (kg/ha)

X_2 = represents Human labour (Man days/ha)

X_3 = represents Tractor charges (Hrs/ha)

X_4 = represents Quantity of fertilizers (NPK) (kg/ha)

X_5 = represents Quantity of manure in (t/ha)

X_6 = represents Plant protection chemicals (kg/ha)

$V_i - U_i$ = random error term

n = number of farms growing maize

The model is estimated by using stochastic production function and the Maximum Likelihood Estimates (MLE). The model was estimated using the computer programme FRONTIER 4.1 (Coelli, 1996) [6] to estimate simultaneously the parameters of the stochastic production frontier and the technical inefficiency effects.

Determinants of technical efficiency

The observed differences in technical efficiency may be due to numerous factors including the time period and the degree of sample homogeneity, output aggregation, the method employed and differences in farm specific characteristics. The present study analyses the variation in technical efficiency in maize production due to farm specific characteristics such as land area under maize cultivation, age of the maize growing farmer, experience of farmer in maize farming, education level of the farmer, number of working family members, contact with the extension agency(s) and the proximity to the market yard from the farm. In order to find out the contribution made by each factor, the level of technical efficiency of the farmers under consideration was regressed on these factors. A simple linear multiple regression equation of the form given below was estimated using Ordinary Least Square (OLS) technique.

$$TE_i = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + e_i$$

Where,

TE_i = technical efficiency of the i^{th} farm

X_1 = area under maize crop (in ha)

X_2 = experience in maize cultivation (in years)

X_3 = education level of the farmer

X_4 = number of working members in the family

X_5 = contact with extension agency(s)

X_6 = proximity to the market yard (Km)

b_0 = Intercept term

$b_1 \ldots b_6$ = coefficients of respective factors influencing the technical efficiency

e_i = random error term.

Results and Discussion

Estimation of Frontier Production Function:

For estimating the technical efficiency, Stochastic Production Function approach has been used. The parameters of frontier production function were estimated using the Maximum Likelihood Estimation (MLE) and the results are presented in the Table 1. The frontier function reflects the response of the best and efficiently managed farm. The estimate, γ is an important parameter in determining the existence of a stochastic frontier (Battese and Corra (1977) [4]. The observed variance parameters i.e σ^2 was significantly different from zero except in small farms and γ significantly different from zero in large farms. This provides statistical confirmation that there were differences in the technical efficiency among the farmers. The variance ratio γ showed that the farm specific variability contributed more to the variation in yield, which means that variation in output from frontier is attributed to technical inefficiency. The estimated value of γ is 0.999 in large farms suggest that about 99.9 percent of the variation in output among the farmers is due to the differences in technical efficiency and that only 0.01 percent of the variation in maize output among the farmers is caused by random shocks outside the farmers control. In case of all farms, estimated value of γ is one, indicates almost hundred percent variation in maize output among the farmers is due to farmer's inefficiency in decision making. These findings corroborate the observations made by John and Emmanuel (2013) [8]. In other word, it is said that almost hundred percent of differences between the observed and maximum production frontier output were due to the factors which were under farmer's control. Thus, the one sided error u_i dominated the symmetric error v_i and the short fall of realized productivity from the frontier was largely due to technical inefficiency and was mainly within the control of individual farmers.

Table 1: MLE Estimates of Stochastic Frontier Production Function for Sample Maize Farms

Variables	Marginal		Small		Medium		Large		All	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	2.312**	0.419	1.231**	0.142	1.430**	0.199	3.353**	0.658	1.755**	0.119
Seed	0.378*	0.190	0.267**	0.053	-0.055	0.128	0.528	0.428	0.670**	0.054
Human Labour	0.235	0.198	0.359**	0.047	0.548**	0.110	-0.224	0.351	0.108*	0.046
Tractor charges	-0.027	0.036	0.171**	0.027	0.277	0.011	-0.166	0.338	-0.549**	0.018
Fertilizers	0.177*	0.124	0.177**	0.044	0.087*	0.034	-0.083	0.060	0.252**	0.043
Manures	-0.013	0.012	0.004	0.003	-0.003	0.005	0.204	0.526	0.001	0.005
Pesticides	0.031	0.017	0.010*	0.004	0.006	0.009	0.377**	0.086	0.027**	0.007
Sigma Square (σ^2)	0.031**	0.004	0.019	0.000	0.002**	0.000	0.002*	0.001	0.014**	0.001
Gamma (γ)	1.000	0.002	1.000	0.014	1.000	0.039	0.999**	0.000	1.000	0.003
Log likelihood	32.763		147.176		57.372		31.135		168.703	

Note: ** Significant at 1 percent level * Significant at 5 percent level SE= Standard error

Further, the estimates of the stochastic frontier shows that in case of all farms, the estimated value of the all independent variables considered had positive coefficient except tractor charges. All independent variables were statistically significant except manures. The estimated value of the coefficient of seed, fertilizers, human labour and pesticides were positive and highly significant, indicating that seed, fertilizers, human labour and pesticides were productive inputs for successive production of maize crop. Seed was the most significant factor of production with an elasticity of 0.670, which implies that an increase in the seed would significantly lead to increased maize output or 1 percent increase in seeds will lead to increase in maize output by 0.67 percent. Fertilizer was the second most important factor of maize production. The estimated value of tractor charges was negative and significant indicating over use of the factor in producing the crop. Manures has positive impact on output; however the estimated coefficients were not statistically significant. Statistically significant and positive values of estimated coefficients indicated that farmers could increase per hectare yield by implying more units of these inputs. In case of marginal farmers, the estimated value of the coefficient of seed and fertilizers were positive and significant. Thus, the marginal farmers can increase per hectare yield by applying more units of seed and fertilizers. Human labour and pesticides were positive but statically insignificant. The estimated value of tractor charges and manure were negative and found non-significant. In case of small farms, all the independent variables considered had positive and significant except manures. Seed, human labour, tractor charges and fertilizers were highly significant where as pesticides was significant at 5 percent level of significance indicating the scope for increasing the productivity by increasing application of these inputs. In case of medium farms, the estimated value of coefficient of human labour and fertilizers had positive and significant. It implies that the productivity of maize can be increased by increasing the use of human labour and fertilizers. The estimated coefficient of tractor charges and pesticide was positive but insignificant while seed and manures had negative value of coefficient. Among the large farms, the estimated value of coefficient for pesticide was positive and highly significant indicating the scope for increasing the productivity as well as efficiency by increasing use of pesticide. Seed and fertilizers were positive but statistically insignificant. All other variables were negative indicating over use of these factors in producing maize crops.

Technical Efficiency of Sample Farms

Details regarding farm specific technical efficiencies are important as they provide detailed information to the policy makers on nature of production technology used in farms. Table 2 shows the frequency distribution of sample farms by level of technical efficiency in raising the maize crop. It was observed that there were wide variations in the level of technical efficiency among the sample farms in raising the maize crops. The average level of technical efficiency is estimated at 70.18 percent for farms as a whole, implying that on an average the sample farmers tend to realise around 70 percent of their technical abilities. Hence, on an average, approximately 30 percent of the technical potentials are not realised. Therefore it was possible to improve the yield by 30 percent by following the efficient crop management practices without having to increase the level of application of inputs.

Table 2: Distribution of Sample Maize Farmers under Different Levels of Technical Efficiency

Efficiency (%)	Number of Farms	% to total
Less than 60	14	5.83
60-70	69	28.75
70-80	69	28.75
80-90	72	30.00
More than 90	16	6.67
Total farms	240	100.00
Mean Efficiency (%)	70.18	

It was also observed that majority of the farmers (30 percent) operated at technical efficiency levels between 80-90 percent. About only 6 percent of the maize farms lied below 60 percent of the technical efficiency. Further, the analysis revealed that equal percent (28.75 percent) of sample farmers were operating at 60-70 percent and 70-80 percent technical efficiency level. About 7 percent of the farmers were operating closer to the frontier with the technical efficiency of more than 90 percent. In essence, around 59 percent of farmers were operating in the zone of 70 to 90 percent technical efficiency level.

Technical Efficiency by Farm Size Groups

The frequency distribution of estimated technical efficiency for the sample households by the farm size groups is given in Table 3. It is evident from the table that the mean technical efficiency ranged from 66.64 percent on marginal farms to 89.69 percent on medium farms. On the other hand, around 13 percent marginal size farms were found to be at less than 60 percent efficiency level. Around 65 percent of marginal farmers operated at the efficiency levels between 60-70 percent. About 98 percent of small farmers operated at the efficiency levels between 70-90 percent. The result also revealed that around 71 percent of large farmers operated at the efficiency levels between 80-90 percent and about 7 percent farmers operated closer to the frontier level with the technical efficiency of more than 90 percent. Medium farm size groups were found to be most efficient in maize farming as they were operating closer to the frontier with the mean technical efficiency of 89.82 percent. This implies that on an average, medium size farms are more efficient than large, small and marginal ones. Similar trend was found by Bhende and Kalirajan (2007) [5] and Anuradha and Zala (2010) [2] for rice farm.

Table 3: Frequency Distribution of Farm-Specific Technical Efficiency

Efficiency (%)	Frequency of sample maize farms							
	Marginal	% to total	Small	% to total	Medium	% to total	Large	% to total
Less than 60	14	13.08	0	0.00	0	0.00	0	0.00
60-70	69	64.49	0	0.00	0	0.00	0	0.00
70-80	19	17.76	47	54.65	0	0.00	3	21.43
80-90	5	4.67	37	43.02	20	60.61	10	71.43
More than 90	0	0.00	2	2.33	13	39.39	1	7.14
Total farms	107	100	86	100	33	100	14	100
Mean Efficiency (%)	66.64		80.05		89.69		83.47	

Determinants of technical efficiency

In the previous section, the analysis of efficiency estimates revealed that there were significant technical efficiency differences among the maize farmers. Given a particular technology to transform physical inputs into outputs, some farmers were able to achieve maximum technical efficiency while others were found relatively inefficient. This divergence could be due to many factors. A number of studies (Kalirajan and Shand, 1989; Shamugam and Venkataramany, 2006; Rahman and Umar 2009; Anuradha and Zala 2010; Michael 2013 and Jimjel *et al.* 2015) [10, 2, 15, 14, 12, 7] have suggested that efficiency of farmers is determined by various socio-economic and demographic factors. Therefore the results of regression analysis carried out in this regard are presented in the Table 4.

Table 4: Factors Affecting Technical Efficiency

Variables	Coefficients	Standard Error
Constant term	0.5291**	0.0071
Operational Area (in ha)	0.0022*	0.0023
Experience in maize cultivation (in years)	0.0027**	0.0004
Education level of the farmer	0.0210**	0.0042
Number of working family members	-0.0006	0.0012
Contact with extension agency(s)	0.0190**	0.0028
Proximity to the market yard (Km)	0.0011**	0.0003
R^2	0.9556	

Note: ** Significant at 1 percent level
* Significant at 5 percent level

The value of the estimated coefficient of the operational area is positive and significant, which indicated that farmers with large operational area were more efficient in producing maize. The value of coefficient (0.0027) of experience in the maize cultivation is not only positive but also highly significant at 1 percent level. This means that as the experience increases, the technical efficiency also increases. This is possibly due to the fact that the farmers learn from their previous mistakes during the cultivation of maize and rectify them in the ensuing seasons. The findings of Kalirajan and Shand (1986) [9] and Anuradha and Zala (2010) [2] support the present result. The value of the estimated coefficient of education (0.021) was positive and highly significant which indicated that higher the education more would be the technical efficiency. The educated farmers might have followed and implemented the technology in a better way and achieved higher technical efficiency. The present result is in corroboration with the earlier findings of Anuradha and Zala (2010) [2], Asmerom, and Ngesh Timgum (2015) [3]. Number of working family members had shown insignificant and negative relationship with the technical efficiency. The coefficient (0.019) of extension contact was positive and highly significant in the present study. In general, it is expected that the farmers who have contacts with extension agencies will get the timely suggestions making themselves more efficient in the operation and management of their maize farm. This corroborates with the findings of Nelson *et al.* (2015) [13]. The value of the coefficient (0.001) was found positive and highly significant indicating direct relationship of technical efficiency with the proximity of market yard from the place of harvest. This could be due to strong preference of technically efficient farmers to sell their produce in well organised market at a higher price than the one offered at local/ nearby markets.

Conclusions and Policy Implication

The variation in output among agricultural farms in the region is due to differences in technical efficiency. Variations in amounts of production inputs have a significant influence on the level of production and efficiency across farm households. The level of technical efficiency among agricultural households differs significantly across size groups. Medium size farms achieve the highest technical efficiency. Seed, fertilizers, human labour and pesticides were found to be major determinants of maize productivity in Central Gujarat. The shortfall of realized maize productivity from the frontier was largely due to technical inefficiency and was mainly within the control of individual farmers. The mean technical efficiency has been found 70 percent among the sample farms, which indicates that on an average, the realized output can be raised by 30 percent without any additional resources in tribal area of Central Gujarat. By proper management and proper allocation of the existing resources and technology, a potential exists for improving the productivity of maize.

This study shows that given the present state of agricultural technology, farms have a potential to enhance productivity by increased use of inputs. Seed is identified as the main factor for determining yields and were underutilized due to non availability of seed of popular varieties. So it is necessary to produce seed of popular varieties by government sectors like Gujarat Seed Corporation, State Agricultural Universities etc., and distribute at proper time. Fertilizers are also identified as the main factor for determining yields and were underutilized due to high cost, hence government support is needed in provision of adequate and timely supply of fertilizers and provision of credit should be made in this regard. Operational area, experience, education and contact with extension agency are recognized as the most influential determinants of technical efficiency. These are also the shifting factors of the production frontier. Government policies should target increased operational farm size by changing the land tenancy laws which can help in creating liberalized land lease market in the state. The findings reveal that contact with extension agency is positive impact on technical efficiency. Therefore concerted more efforts are essential to bridge the gap between awareness and adoption of technologies by strengthening the agricultural extension system with sound extension programmes. The study reveals that number of working family members had a negative impact on technical efficiency, hence government should take up some policies or design some programmes in providing alternate employment opportunities in the region, like MNREGA.

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