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Economic efficiency of farm household in semi-arid tropics (SAT) India

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Abstract
This study set out to estimate the economic efficiency and also determine socio-economic and farm specific factors that influence economic efficiency in VDSA farms of SAT India.
The study results show that mean economic efficiency scores were ranged between 4.1 and 90%. There is tremendous opportunity to improve economic efficiency among the farmers in that it is possible to increase production by 50% from the current level of technology and input use because average economic efficiency score near 50 per cent in all the states. It also explains further, that 13.95% of the farmers have efficiency scores that are less than 20% and 51.74% of the farmers have technical scores above 50% with only 9.69% having economic efficiency scores above 80%.Farmers who are older, use hybrid seed, accessed credit and have livestock ownership exhibit higher efficiency scores.

Keywords: marginalization, Economic efficiency, marginal holdings, marginalization medium and large holdings, markedly, smallholdings, optimal proportions, technical efficiency, land productivity and input intensity, factor productivity exploitation, innovated technologies, socio-economic

1. Introduction

The agrarian structure of India has been undergoing a process of reduction in size of farms and increase in marginalization of holdings for the past several decades. During the period 1960-61 to 2002-03, the proportion of marginal holdings went up (from 39.1 per cent to 69.8 percent). The proportion of medium and large holdings declined (from 38.3per cent to 13.8per cent), the percentage of operated area by marginal farmers increased markedly (from 6.9 percent to 22.0 percent) and area under smallholdings increased significantly (from 12.3per cent to 20.0 percent) at all-India level (Dev, 2012).

The small land base of the Indian farmer is one of the major factors contributing to rural poverty. The analysis of NSS data has shown that rural poverty is related to land ownership. In 2004-05, the poverty ratio for all farmers was estimated to be 15.2 per cent, with 22.0 per cent among landless farmers, 20.0 per cent among sub marginal farmers, 18.1 per cent among marginal farmers, 14.8 per cent among small farmers and 9.8 per cent among medium and large farmers (Chadha, 2008). The efficiency of a farm/production unit can be measured in terms of allocative efficiency (reflecting the ability of a farm to use inputs in optimal proportions, given their respective prices) and technical efficiency (TE). In this study, we focus on the latter (i.e., TE). Briefly, the TE is the ratio between actual and potential output of a production unit. A few empirical studies provide the estimates of TE of raising a particular crop (mostly rice) within a state/region. For instance, Kalirajan (1981) [18], Shanmugam and Palanisamy (1993), Tadesse and Krishnamoorthy (1997) and Mythili and Shanmugam (2000), estimated the TE of rice farms in Tamil Nadu. Datta and Joshi (1992) measured the TE of rice farms in Uttar Pradesh while Jayaram *et al.*, (1987) and Shanmugam (2002) measured the TE of raising rice crop in Karnataka respectively. Shanmugam (2000) estimated the efficiency of rice farms in Bihar. An exception is Shanmugam (2003), which provides TE of rice, cotton and groundnut growing farms in Tamil Nadu. The results of these studies are useful for policy makers to rationalise the development policies for a particular crop in region.

In recent years, one common debate has been on the ability of small farmers to reap the benefits of new technology (Sharma and Sharma, 2000). The argument advanced in this debate is that technology adoption among different segments of the same state/region widely varies. To work out the technical efficiency, land productivity and input intensity are the valid measures. The present study has dealt this issue in the context of Semi-Arid Tropical region (SAT India). In the context of SAT region, only scanty literature on factor productivity was available (Dhillon and Ali, 2002; Singh and Hossain, 2002), and no study seems to have been conducted using frontier production function approach for different regions.

Inefficiency in crop production is one of the major factors hindering the exploitation of full potential of the innovated technologies, particularly in the developing countries (Bravo-Vrata and Evenson, 1994; Jayaram *et al.*, 1992; Taylar and Shonkwiler, 1986; Ali and Flinn, 1989; Kalirajan and Shand, 1989; Arindam, 1994; Sharma and Datta, 1997 and Thomas and Sundaresan, 2000). Inefficiency, the inability of a farmer to realize optimum output, is influenced by various socioeconomic factors that interfere in the decision-making process of a farmer (Dawson, 1985; Kalirajan and Shand, 1989; Kalaitzandonakes *et al.*, 1992). In this study, the level of technical inefficiency in at farm level among different state has been investigated along with the influence of various farm specific socio-economic variables.

1.1 The conceptual framework

The seminal paper by Farrell (1957) [14] on the measurement of productive efficiency has inspired several studies during the last years on best practice technology and efficiency measures. In this paper, Farrell proposed a stimulating idea to define output of the most efficient firms as the production frontier for all firms as opposed to the neoclassical theory that assumed all firms to be fully efficient in their use of technology. The basic idea underlying the Farrell approach to measuring efficiency is illustrated in Figure 1.

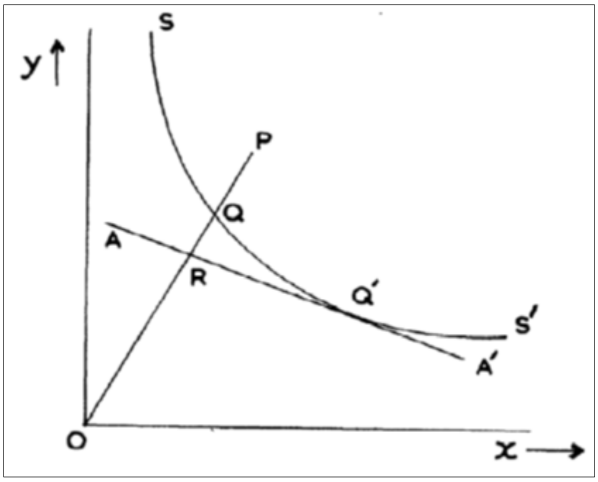

Fig 1: Farrell's measure of technical and allocative efficiency
Source: Ajibefun (2008) [6].

Farrell (1957) [14] considered a firm that employs two factors of production X and Y to produce a single product P, under conditions of constant returns to scale. These assumptions make it possible to illustrate the production function by a simple isoquant diagram, designated by SS' in Figure 1. The point P represents the units of two factors, per unit of output that the firm is observed to use. The isoquant 'SS' represents various combinations of the two factors that a perfectly efficient firm might use to produce a unit output. It is also important to note that 'SS' presents a lower bound of a scatter indicating the same level of output and as such Q and P are on the same isoquant. The point Q represents an efficient firm using the two factors in the same ratio as P. It can be seen that it produces the same output as P using only a fraction OQ/OP as much of each factor. It is producing OP/OQ times as much output from the same inputs. Therefore, OQ/OP is defined as the technical efficiency of Firm P. The technical inefficiency of that firm is presented by the distance QP which is the amount by which all inputs could be proportionally reduced without a reduction in outputs. The firm is technically efficient if the ratio is equal to 1. If the ratio is less than 1 the firm is inefficient. Price or allocative efficiency of the firm can be measured from the same diagram above. This measures the extent to which a firm uses the various factors of production in the best proportions, in view of their prices. Considering the budget line represented by AA**'**, its slope is equal to the ratio of the prices of the two factors of production. Therefore, the optimal point is obtained where the isoquant curve is tangential to the budget line and that is point Q'. At this point the firm is both technically and allocatively efficient. The allocative efficiency is the fraction OR/OQ.

1.2 The stochastic production frontier (SPF) approach

Following the pioneering work of Farrell various modifications and improvements have been made. Aigner and Chu (1968) [4] translated Farrell's frontier into a production function and later, Aigner *et al.* (1977) [5], Meeuseen and van den Broeck (1977) [23] and Battese and Corra (1977) [9] suggested the stochastic frontier approach. This approach deals with stochastic noise and permits statistical test of hypothesis pertaining to production structure and degree of inefficiency. Some authors like Kalirajan (1981) [18], estimated stochastic frontiers to predict firm level efficiencies, and then regressed these predicted efficiencies upon firm specific variables (such as managerial experience, ownership characteristic and production conditions) in an attempt to explain variations in output between firms in an industry. To overcome inconsistencies in the assumptions regarding the independence of inefficiency effects in this two-stage estimation procedure, Kumbhakar *et al.* (1991) [22] and Reifschneider and Stevenson (1991) [28] proposed a single stage stochastic frontier in which the inefficiency effects (*ui*) are express as an explicit function of the vector of firm specific variables and a random error. Battese and Coelli (1995) [8] proposed a model that imposed allocative efficiency, removes first order profit maximizing conditions and permits panel data. The Battese and Coelli (1995) [8] model specification can be expressed as:

$$Yi = \exp(Xi\beta + \varepsilon_i) = \exp(X_i\beta + V_i - U_i)\ \varepsilon_i = V_i - U_i, i = 1, \dots, N\ (1)$$

Where, *Yi* is scalar output of the 1th farm, *Xi* is a vector of input quantities and β is a vector of parameters to be estimated, *exp*is the exponential function, *Vi* is the disturbance term assumed to be independent and symmetrically distributed *N* (0,σV2) and it captures the effects of random shocks outside the farmers control (e.g. weather, disease outbreaks, measurements errors, etc.), *Ui* is a non-negative random variable associated with technical inefficiency in production and is assumed to be independently distributed as truncations of the *N* (Ziδ,σU2) distribution. Following Battese and Coelli (1995) [8], *Ui* can be represented as:

$$U_i = Z_i\delta + W\ (2)$$

Where *Zi* is a p x 1 vector of variables which may influence the efficiency of the 1th firm, δ is a 1 x p vector of parameters to be estimated and *WI* is the random variable defined by the truncation of the normal distribution with mean 0 and variance σU^2.

Technical efficiency is defined as the ratio of the observed output (Y) to the corresponding frontier output (Y*) conditional on the levels of inputs used by the firm. In the context of the stochastic frontier production function Equation (1), technical efficiency is given by:

$$TE = \frac{Y_i}{Y_i^*} = \frac{\exp(X_i\beta + V_i - U_i)}{\exp(X_i\beta + V_i)} = \exp(-U_i) \quad (3)$$

Aigner *et al.* (1977) [5] suggest using a likelihood function to allow for two variance parameters, $\sigma^2 = \sigma U\ 2 + \sigma V\ 2$ and $\lambda = \sigma U/\sigma V$ in the stochastic frontier production function. Values of γ must lie between zero and one with values of 0 indicating the deviations from the frontier are entirely due to noise, and values of 1 indicating that all deviations are due to technical inefficiencies.

2. Methodology

2.1 The Data and Sample

For the study, the longitudinal household survey data collected under the Village Dynamics Studies in South Asia (VDSA) project by the ICRISAT, Hyderabad, has been used. The data were collected for the period 2009 to 2014 in 12 villages across 6 states (Andhra Pradesh, Telangana, Karnataka, Maharashtra, Madhya Pradesh and Gujarat) in Semi-Arid Tropics (SAT)region of India. The household data pertain to 30 households in each village comprising 10 large farmers, 10 medium farmers and 10 small farmers. The high frequency information has been collected by the resident field investigators from these households continuously for the study period under the project.

Data was collected using structured questionnaire, on farmers output of all the crops, input used in the production process (land, labour, capital, fertiliser and seed) on each plot and the socio economic and plot specific characteristics. These included farmers age, level education household size, head of the family wither male or female and farm and non-farm income. These characteristics have been included in many studies of the production. The reference period of the study between 2009 to 2014. The variable used in the analysis are defined in table1.

The majority of the farmers are meals, with an average age of 49 years. The age of the household's head is important as it determine whether the household benefited from the experience of older farmers or risk taking attitude of younger farmers. The average number of years in formal education is 5 years, which is primary education. 83 per cent households acquired credit.

In this five years, farmers average gross return from all the crops operation is Rs. 153540 per farms with maximum income Rs. 3971700. The average farm size was 2.75 hectares and Rs. 9640 of money spent on the purchase of the seed. The expenditure on the labour was Rs. 14766 per farms against mean land area of 2.75 hectares. The expenditure incurred in the purchase of fertilizer was Rs 7896 per farms.

Stochastic Frontier Analysis of the Technical Efficiency of VDSA Households in SAT India

Table 1: Variable definitions and measurement units for the empirical model

Variable	Description	Units	Observations	Mean	Std. Dev.	Min	Max
Y	Gross Returns	Indian Rupees	3096	153540	262708	0	3971700
Y	Net Returns	Indian Rupees	3096	100617	194888	-234636	3524833
X1	Fertilizer used Value	Indian Rupees	3096	7896	12334	0	130131
X2	Seed used Value	Indian Rupees	3096	9640	16674	0	379726
X3	Operational Holding	Hectares	3096	2.75	3.31	0.07	35.63
X4	Hired Labour Value	Indian Rupees	3096	14766	31246	0	951665
Z1	Received Credit	1=Yes, 0=No	3096	0.83	0.38	0.00	1.00
Z2	Use of Hybrid Seed	1=Yes, 0=No	3096	0.92	0.27	0.00	1.00
Z3	Owns Livestock	1=Yes, 0=No	3096	0.82	0.38	0.00	1.00
Z4	Household Head Years of Education	Years	3096	5.17	4.71	0.00	18.00
Z5	Household Head Age	Years	3096	49.70	12.13	20.00	90.00
Z6	Household Head Gender	1=Male	3096	0.97	0.18	0.00	1.00
Z7	Total Household Income	Indian Rupees	3096	221165	269329	-141996	4043175
Z8	Non-Farm Income	Indian Rupees	3096	72175	136616	0	3601000

Source: Village Dynamics in South Asia (VDSA data)

2.2 Empirical Model

This study uses the stochastic frontier production function model which has the advantage that it allows for simultaneous estimation of individual technical efficiency of the respondent farmers as well as determinants of technical efficiency (Battese & Coelli, 1995) [8]. Following technical efficiencies and their determinants were estimated using a one-step maximum likelihood estimates (MLE) procedure. This is done by incorporating the model for technical efficiency effects into the production function. This study specifies the stochastic frontier production function using the flexible translog specification and later carries out a log likelihood ratio test to determine if the translog reduces to Cobb-Douglas production function. The translog model is specified as follows:

$$LnY = b_0 + b_1 lnX_1 + b_2 lnX_2 + b_3 lnX_3 + b_4 lnX_4 + b_{12} lnX_1 lnX_2 + b_{13} lnX_1 lnX_3 + b_{14} lnX_1 lnX_4 + b_{23} lnX_2 lnX_3 + b_{24} lnX_2 lnX_4 + b_{34} lnX_3 lnX_4 + V - U \quad (4)$$

Where, Ln is the natural logarithm, Y is net income of if ith farmer, X's are inputs variables presented in Table 1 and β's are parameters to be estimated. Maximum likelihood estimation of Equation (4), provides the estimators for β'sand variance parameters σ [2] and γ. The inefficiency model is estimated from the Equation given below.

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 \quad (5)$$

Where, Z's are various operational and farm specific variables described in Table 1 and δi's are unknown parameters to be estimated.

2.3 Output Elasticities and Return to Scale
The first-order coefficients of the Translog production function Equation (4) are not considered as they are not very informative, instead the determination of elasticities becomes necessary for the estimation of responsiveness of yield to inputs. Output elasticities for each of the inputs calculated at the variable means are of great importance in this case. (Awudu & Eberlin, 2001) [1]. The elasticity of output with respect to the 1th input, ei, evaluated at the mean values of the relevant data points can be derived as:

$$e_i = \frac{\partial \ln Y}{\partial ln x_i} + \beta_i + 2\beta_{ij} ln\, \bar{X}_i + \Sigma_{j \neq i} B_{ij} ln \bar{X}_j \qquad (6)$$

Using Equation (4), output elasticity with respect to input, X1 evaluated at the sample mean can thus be computed from the following Equation:

$$e_{X_1} = \frac{\partial \ln Y}{\partial ln x_i} + \beta_1 + 2\beta_{11} ln\, \bar{X}_1 + 2\beta_{12} ln\, \bar{X}_2 + 2\beta_{13} ln\, \bar{X}_3 + 2\beta_{14} ln\, \bar{X}_4 \qquad (7)$$

The elasticity of output with respect to the ith input measures the responsiveness of output to a 1% change in the ith input. The measure of returns to scale, RTS representing the percentage change in output due to a proportional change in use of all inputs, is estimated as the sum of output elasticities for all inputs. If this estimate is greater than, equal to, or less than one, we have increasing, constant, or decreasing returns to scale respectively.

3. Result and Discussion
The maximum likelihood estimates (MLE) of the parameters of stochastic frontier production function and the inefficiency model were simultaneously obtained using frontier in State. All summary statistics and regression reports in this paper were generated using the same software. Table 2 shows the MLE of parameters of the stochastic production frontier model and those of the economic inefficiency model.

Table 2: Parameter estimates of stochastic production frontier and economic inefficiency models

Variables	Parameter	Coefficient	Standard error
Stochastic production Frontier			
Constant	β0	7.500734***	0.8626
Ln fert	β1	-0.0936	0.1609
Ln seed	β2	0.3926115***	0.1335
Ln farm	β3	0.2034	0.1891
Ln labour	β4	0.1352	0.1328
Ln fert ln seed	β12	0.0011	0.0166
Ln fert ln farm	β13	-0.0540049*	0.0302
Ln fert ln labour	β14	0.0411145***	0.0146
Ln seed ln farm	β23	-0.045371*	0.0236
Ln seed ln labour	β24	-0.0400347**	0.0170
Ln farm ln labour	β34	0.1138961***	0.0232
Technical Inefficiency Model			
Constant	δ0	10.08078***	0.1505875
Received Credit (1=Yes)	δ1	0.1174097***	0.045872
Use of Hybrid Seed (1=Yes)	δ2	0.3807204***	0.061332
Owns Livestock (1=Yes)	δ3	0.1782925***	0.055951
Household Head Years of Education	δ4	0.025007***	0.006035
Household Head Age	δ5	0.0070986***	0.002130
Total Household Income	δ6	0.00000318***	0.0000001
Non-Farm Income	δ7	-0.00000297***	0.0000002
Variance parameters			
Sigma squared	σ^2	1.05661	0.16925
Gamma	γ	0.54745	0.07182
Ln (likelihood)		-3046.32	
Mean Technical Efficiency		0.5027	0.0040

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Given the lack of direct interpretation of parameters in the translog production frontier, the parameter estimates of the stochastic production frontier Equation (4) will be summarized and explained later in terms of output elasticities with respect to various inputs. The γ parameter associated with variances in the stochastic production frontier is estimated to be close to 0.5(Table 2). Although the γ- parameter cannot be interpreted as the proportion of the total variance explained by economic inefficiency effects, the results indicate that economical inefficiency effects do make a significant contribution to the level and variation of net returns of the VDSA farms in SAT India.

Output Elasticities and Returns to Scale

Table 3: Output elasticities

Input Variable	Elasticity
Fertilizer	0.2930498***
Seed	0.0517332***
Farm size	0.3418911***
Labour	0.171246***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The estimates of output elasticities evaluated at means of relevant data points and defined by Equation (7) are

represented in Table 3. As expected, the estimated values of output elasticities for all inputs are positive. Furthermore, all elasticities are significantly different from zero at the 0.1 levels of significance. Fertilizer is found to have the highest elasticity (0.29), followed by labour (0.17) and seed (0.05).
The returns to scale computed as the sum of output elasticities for all inputs is estimated as 0.856, indicating that on average the average net farm income has decreasing returns to scale. Put another way, if the farmers increased all factors by 1%, net farm income would increase by 0.856%, and farmers would not in a profit.

4. Economic Efficiency

The mean economic efficiency scores were ranged between 4.1 and 90% (Table 4). There is tremendous opportunity to improve technical efficiency among the farmers in that it is possible to increase production by 50% from the current level of technology and input use because average economic efficiency score near 50 per cent in all the states of the SAT India.
Despite the five states being far from each other and have different natural and market condition, there is slight variation in the economic efficiencies. Maharashtra is observed to have higher economic efficiency as compared to Andhra Pradesh and Karnataka. The differences can be attributed to farm and farmer's characteristics which are expected to vary from household to household and hence from state to state

Table 4: Economic efficiency by states

Statistic	Andhra Pradesh	Gujarat	Karnataka	Madhya Pradesh	Maharashtra	Telangana	Overall
Observation	204	702	618	276	1032	264	3096
Mean	0.478	0.519	0.437	0.521	0.532	0.500	0.503
Std. Dev.	0.233	0.228	0.230	0.223	0.220	0.184	0.225
Min	0.088	0.072	0.041	0.087	0.068	0.091	0.041
Max	0.836	0.903	0.880	0.875	0.866	0.873	0.903

Table 5: Distribution of farmers' specific Economic efficiencies

Efficiency	Number of Households	Percentage	Cumulative Percentage
<10	84	2.71	2.71
10-19.99	264	8.53	11.24
20-29.99	360	11.63	22.87
30-39.99	420	13.57	36.43
40-49.99	366	11.82	48.26
50-59.99	384	12.40	60.66
60-69.99	444	14.34	75.00
70-79.99	474	15.31	90.31
80-89.99	294	9.50	99.81
90-100	6	0.19	100.00
Total	3096	100.00	

The distribution of technical efficiency across the 3096VDSA farmers is fairly normal. Table 5 shows that 13.95% of the farmers have efficiency scores that are less than 20% and 51.74% of the farmers have technical scores above 50% with only 9.69% having economic efficiency scores above 80%.

Factor effecting economic efficiency

The inefficiency model in Table 2 gives some insights on factors affecting economic efficiency. A negative sign on a parameter means that the variable reduces economic efficiency while a positive sign increases economic efficiency. The survey revealed that six main determinants were associated with economic efficiency in the sampled farmers. These include, age of farmer, use of hybrid seed, access to credit, ownership of livestock, years of formal education and off-farm income.
Access to credit addresses the problem of liquidity and enhances use of agricultural inputs in production, as it is often claimed in development theory. In this study, access to credit, was observed to significantly influence economic efficiency in the positive sense. Farmers with access to credit are better able to access expensive efficiency enhancing technologies like hybrid seed and fertilizer. Similar results were observed by Desai and Mellor (1993) [11] and Nwagbo (1989) [25] who argued that farm level credit when properly extended encourages diversified agriculture which stabilizes and perhaps increases resource productivity, agricultural production, value added, net farm incomes and therefore facilitates adoption of innovations in farming, encouraging capital formation and marketing efficiency.
Farmers have various options before them on what type of seed to use, subject to the constraints they face. In this case, farmers used mainly either hybrid seed or local and recycled hybrid seed. A comparison between those using hybrid and local or recycled hybrid seed suggests that farmers using certified hybrid seed are observed to have higher economic efficiency compared to those using recycled and local seed.
The age of a household head is observed to have a positive coefficient indicating that older farmers are more economic efficient than other ones. Wozniak (1987) [30] observed similar results and argued that the older the farmer, the more experienced he/she will be. Besides, given the importance and significance of land, labor, capital and other resources in farm production, it could be argued that young households are deficient in resources and might not be able to apply inputs or implement certain agronomic practices sufficiently quickly. As timely application of inputs and implementation of management is expected to enhance efficiency, young farmers may find this challenging.
Finally, in this study off-farm income is observed to diminish economic efficiency. It can be hypothesized that managerial input may be withdrawn from farming activities with increased participation of the educated in non-farm activities, which leads to lower efficiency. Similarly, Abdulai and Eberlin

(2001) [7] found higher inefficiency of production with involvement of households in non-farm activities. This could be because farmers who have various sources of income beside crop production are more likely to be preoccupied with other income generating activities and hence pay less attention to important agronomical practices. In such instances, labor contributions to on-farm operations is negatively affected and this affects efficiency negatively. On the contrary, total household income affects technical efficiency positively. The difference between off-farm income and total household income is the value of crop sales. This implies that farmers with higher proportions of total household income from crop sales have higher economic efficiency. Such farmers are likely to concentrate more on crop production and invest in efficiency enhancing technologies. For both off-farm and total incomes, the effects are highly significant but the magnitude of the effect is very minimal if not negligible.

5. Conclusion and Recommendation

This study set out to estimate the economic efficiency and also determine socio-economic and farm specific factors that influence economic efficiency in VDSA farms of SAT India.

The study results show that mean economic efficiency scores were ranged between 4.1 and 90%. There is tremendous opportunity to improve economic efficiency among the farmers in that it is possible to increase production by 50% from the current level of technology and input use because average economic efficiency score near 50 per cent in all the states. It also explains further, that 13.95% of the farmers have efficiency scores that are less than 20% and 51.74% of the farmers have technical scores above 50% with only 9.69% having economic efficiency scores above 80%.Farmers who are older, use hybrid seed, accessed credit and have livestock ownership exhibit higher efficiency scores.

Despite continued government investment in the agriculture sector through agricultural input subsides, extension services and promotion of new technology, small scale farmers has remained economic inefficient. Three policy issues emerge from the results of this analysis. Firstly, given the positive effect of certified hybrid seed on efficiency, it is important to continue promoting use of hybrid seed among farmers. Secondly, given the positive effect of access to finance on economic efficiency, it is therefore of great importance that the agricultural development strategy focuses on creating an environment that facilitates farmers to access to rural finance. There is available evidence that suggests that investment in public goods such as agricultural research, extension and roads constitutes one of the most effective tools available for stimulating economic growth and poverty reduction.

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