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Abstract

The study aims to estimate the technical efficiency of agricultural production in India using production frontier model for both cross section and panel data for the years 1999 and 2007. Given the persistent problem of under utilization of capacity in Indian farm sector still there is a serious need to identify the determining factors for technical efficiency for agricultural production in order to accelerate sustainable productivity and technological improvement. Farmers' age and education level, household size, household's management in production, proportion of irrigated area covered by canals, availability of wells, yielding variety of lands, services provided by the government, agricultural expenditure by local government are the factors which significantly contribute to efficiency in resource utilisation. Traditional method of farming or learning by doing is preferred to adoption of new technologies which creates technological lock-in.

Keywords: *Production function, agricultural farmers, technical efficiency, India*

JEL Codes: *C33, D20*

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INTRODUCTION

India is an agriculture-dominant country where the developmental policy that aims growing agricultural productivity is the governments' usual response for poverty eradication and increasing food security in rural areas. Although around 500-550 Mt of crop residues are produced per year in India annually it is estimated that Indian Agricultural production can be able to produce two times more with dwindling cultivable land and resources to increase farmers' income and environmental sustainability[1]. India has now been considered as the fastest growing major economy of the world since last few years. However, the accelerating economy-wide growth has not been resulted through an acceleration of agricultural output growth[2] which is expected. The real per capita gross domestic product (GDP) (1999-2000 prices) averaged less than 5 per cent per year during the 1980s and 1990s and it has increased to more than 7 per cent per year during the period 2003-07'(*Planning Commission 2008*). Whereas, in terms of the share in GDP, the agricultural output growth fell from 37.9 per cent during the early 1980s to 17 per cent during 2008-09. Also, the share of agriculture in total employment has been declined. The agriculture sector employs 73.9 per cent of the economically active population in 1973-74 down to 56.5 per cent in 2004-05. This sector has a huge potential to engage millions of the country's poor to improvement of their standard of living. Total factor productivity (TFP) growth has experienced large variation over time and it was negative for some period after mid-1980s. In the initial periods of economic reforms, TFP growth has accelerated and then it has shown a downward trend after mid-1990s. TFP in Indian agriculture has been rising at a faster rate after the mid-2000s. The rising trend in TFP growth after 2004-05 suggested that

[1] Annual Report, 2015-16, –Indian Agricultural Research Institute.

[2] In view of the structural change in the economy, there has been a continuous decline in the share of agriculture and allied sector in the GVA from 18.5 percent in 2011- 12 to 17.4 percent in 2014-15 at current prices. A fall in the share of the agriculture and allied sector in GVA is an expected outcome in a fast growing and structurally changing economy. Annual Report (2015-16), Department of Agriculture, Cooperation and Farmers' Welfare, GOI.

the recent growth in agriculture is accompanied with improved technology and efficiency and is thus sustainable (DARE/ICAR Annual report, 2014-15). Since 2008-09, the world economy has been witnessing the slow growth rate which has resulted in sluggish growth in all the sectors in India, 11th five year plan (2007-08 to 2011-12) made a target to reverse the deceleration in agriculture growth and productivity and that continued to be main focus in 12th five year plan. Although the farm productivity is low as compared to other developed countries, some improvements have been found due to certain developmental activities. These include, technological advancement, usage of improved quality of fertilizers, insecticides, pesticides, adoption of HYVs (High yielding Varieties) of seeds, new cropping pattern, new irrigation facilities, farm research and management practices. Therefore the main question pursued in this paper is why the farm economy has not responded to the demand side forces that have been unleashed on it from the rapid economy-wide growth. One more issue is that before making more and more policies to enhance productivity we need to know whether the farmers grow crops efficiently with available technologies or they use resources with excess capacity. This paper finds some of important factors that may influence the technical efficiency of the farmers so that development of agricultural policies follows the right track.

This paper examines the technical efficiency of Indian agricultural farmers in both cross section and panel year of 1999 and 2007 using production frontier model. Further, it determines the factors which may affect the production efficiencies. The study has taken the factors such as household age, education level of the households, household size, proportion of family supervision cost to total labour cost, proportion of high yielding area, distance to pucca road, proportion of irrigated area covered by canals, tanks as well as wells, the government agriculture extension services, agricultural expenditure by local government and women reservations. These factors may influence the production process and technical efficiency of the farmers.

METHODOLOGY AND DATA

The technical efficiency (TE) is defined as the ratio between actual and potential output of a production unit. Efficiency measurement is useful in determining the magnitude of the gains that could be achieved by adopting improved practices in agriculture production with a given technology (Zhu, 2000, Tauer, 2001, Rehman, 2003, Armagan, 2008). There are number of studies that have estimated technical efficiency in different sectors. Thiam, Bravo-Ureta and Rivas (2001) have used a meta-analysis to review empirical estimates of technical efficiency (TE) in developing country agriculture. A data set of 51 observations of TE from 32 studies has been used to examine whether specific characteristics of the data and econometric specifications account for systematic differences in the efficiency estimates. Shanmugam and Venkataramani (2006) have shown that health, education, and infrastructure can be powerful drivers of efficiency. Rao, and Donnell (2004) and Donnell, Rao, and Battese (2008) developed same meta-frontier (MF) model, which enables the estimation of technology gaps for producers under different technologies relative to the potential technology available to the industry as a whole. The model facilitated the interpretation of grand technical efficiency scores by decomposing them into group specific efficiency and technology differences as well. Rao, Brümmer and Qaim (2012) have taken a meta-frontier approach and combined this with propensity score matching to estimate treatment effects among vegetable farmers in Kenya.

Technical efficiency is considered as the ability to produce a given level of output with a minimum quantity inputs under certain technology. Early studies focused primarily on technical efficiency using a deterministic production function with parameters computed using mathematical programming techniques. However, with inadequate characteristics of the assumed error term, this approach has an inherent limitation on the statistical inference on the parameters and resulting efficiency. Aigner (1992) and Meeusan, and Van den Broeck (1997) independently developed the stochastic frontier production function to overcome this deficiency. The stochastic frontier production function for the panel data for estimating household level technical efficiency is specified as:

$Y_{it} = f(X_{it}; \beta) + \varepsilon_{it}$ i=1,2,…n and t=1,2,..T (1)

Where i is the nth observations and t id Tth time periods. Y_{it} is output, X_{it} denotes the actual input vector, β is vector of production function and ε is the error term that is composed of two elements, that is

$\varepsilon = V_{it} - U_{it}$ (2)

Where V_{it} is the symmetric disturbances assumed to be identically, independently and normally distributed as N $(0, \sigma_{vt}^2)$ given the stochastic structure of the frontier. The second component U_{it} is a one sided error term that is independent of V_{it} and is normally distributed as $(0, \sigma_{ut}^2)$, allowing the actual production to short fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

The household-specific technical efficiency is defined in terms of observed output (Y_{it}) to the corresponding frontier output ($\overset{*}{Y}_{it}$) using the available technology derived which is defined as follows:

$$TE_{it} = \frac{Y_{it}}{\overset{*}{Y}_{it}} = \frac{E(Y_{it} \mid u_{it}, X_{it})}{E(Y_{it} \mid u_{it} = 0, X_{it})} = E[\exp(-U_{it}) / \varepsilon_{it}] \quad (3)$$

TE takes values within the interval (0,1), where 1 indicates a fully efficient firm.

The Cobb-Douglas production function is used in this paper. Here, the model is estimated using STATA 11.2.

The paper used the two-stage estimation procedure in which first the stochastic production function is estimated, from which efficiency scores are derived, then in the second stage the derived efficiency scores are regressed on explanatory variables using ordinary least square methods. The technical efficiency effects are defined as

$$TE_{it} = Z_{it}\delta \qquad (4)$$

Where z is a vector of observable explanatory variables and δ is a vector of unknown parameters.

The paper used the last two rounds (1999 and 2006)[3] of the National Council of Applied Economic Research (NCAER) Rural Economic and Demographic (REDS) surveys that form a village and household data base providing consistent information on 242 villages spread across 16 states in India. The first round of the survey for which complete village and household information is available is the 1971 round of the Additional Rural Incomes Survey (ARIS), which includes 4527 households in 259 villages which was meant to be representative of the entire rural population of India residing in 17 major states. The original sampling frame was a stratified design that included the following:

[3] The data collection for the last round of the REDS survey started in 2006, which is why it is normally referred to as the 2006 round. However, for most states the household schedule that contains the agricultural data was collected in 2007, with the exception of Kerala, where it was collected in 2008.

(i) One district in each state that was part of the Intensive Agricultural District Programme (IADP), an extension and input provision programme placed in areas thought to have high potential for crop productivity growth.

(ii) One district from each state that was covered by the Intensive Agricultural Area Programme (IAAP).

(iii) A random sample of other districts. There are 100 districts represented in the 1971 ARIS.

In 1982, 250 of the original 259 villages were revisited (the state of Assam was excluded due to local political disturbances rendering survey activity impossible) and 4979 household surveyed, approximately two-thirds of which were the same as in 1971. In 1999, all of the 1971 villages were surveyed, but excluding the 8 sample villages from Jammu and Kashmir (again owing to problems of local insurgency). In this survey round, all of the surviving households in the 1982 survey were surveyed again, including in this round all split-off households residing in the same village, plus a small random sample of new households. Because of household division and the new sample design incorporating all village-resident male 1982 household surveyed household members, the number of households in the 1999 round increased to 7474. The current round of 2006 has a sample size of 8659 households from 242 villages and it includes all of the households surveyed in 1999 and the split-off households residing within these villages. Each village has approximately 8 new randomly selected households. The panel date set encompassing 1999 and 2007 rounds of the survey includes 5885 households.

Each round of the survey has three components. A listing of the village households is first done and it broadly locates, identifies and collects information on household head, split offs, out migration etc. Households in the listing sheets of each successive round can be traced across rounds. In the current round, the listing and the village questionnaires were administered in 2006 while the household questionnaires were canvassed in over three agricultural years (most of the households surveyed in the agricultural year 2007-2008).

RESULTS AND DISCUSSIONS

The data for the 1999 and 2006 rounds are summarized in Table 1. The paper used the state level consumer price indices for rural agricultural labour. Since the survey was rolled out over more than two years, the survey period is matched in each state with the average of the respective months of the CPI for rural agricultural workers. The paper used the consumer price index to convert all values and prices in real term. The agricultural households are 4487 in 1999 round of survey and they are 4869 in 2006 round of survey. The total panel agricultural households are 2273. The 2007 values are deflated using 1999 as a base period. The crop value has increased by 12 per cent in 2007 which can be attributed to the high base effect of 1999. The data shows that the agricultural production has increased over the periods. The proportion of irrigated land has increased by 5 percentages from 1999 to 2007. Further, the value of seed per acre has increased sharply from 1999 to 2007 and the rise was about 22.5 per cent. Value of fertilizer and manure per acre while has jumped from Rs. 1013 to Rs. 1244 from 1999 to 2007. The proportion of manure to total value of fertiliser has declined. This perhaps reflects less demand for manures. Value of pesticides per acre has increased modestly from Rs. 151 in 1999 to Rs. 191 in 2007. Labour cost in 1999 was Rs. 1044 which has climbed to Rs. 1821 in 2007. Hired labour per acre was Rs. 363 in 1982 which rose to Rs. 480 in 1999 and again declining to Rs. 322. Hired labour ratio to total labour has been increased from 1999 to 2007. Fixed cost per acre was Rs. 3084 in 1999. It has increased to Rs. 6528 in 2007 reflecting the increased fixed cost component in farming. This seems that Indian agriculture is shifting to machinery though Indian agriculture is more labour intensive. Value of bullock cost has declined. Still, most of poor farmers are adopting the traditional methods.

Table 1: Descriptive Statistics

Variables	1999 Round	2006 Round
Value of crop	7940.52	9020.04
Cropped area	6.79	6.55
Proportion of irrigated area	0.57	0.60
Value of seeds per acre	440.52	568.32
Value of fertilizer and manure per acre	1012.58	1243.82
Prop. Of manure to total value of fertilizer and manure	0.24	0.15
Value of pesticides per acre	150.82	191.33
Value of total labor cost per acre	1044.31	1821.82
Prop. Of hired labor	0.21	0.22
Value of fixed cost per acre	3083.99	6528.18
Value of bullock cost per acre	73.28	59.61
HH head age	50.19	51.63
Household size	6.55	5.68
Mean education of the HH	3.93	4.74
Family supervision/labor cost	0.10	0.04
Distance to Pucca road	2.41	1.67
No. of times AES activities	2.51	3.97
Proportion of gvt. canal irrigated	0.25	0.65
Proportion of tank irrigated	0.05	0.07
Proportion of well irrigated	0.08	0.08
Prop. HYV area	0.61	0.69
Proportion of agricultural expenditure	0.05	0.03
Women reservation	0.25	0.32
No. of households	**4487**	**4869**
No. of villages	**242**	**242**

Source: Authors' calculation from REDS data set.

Average age of household head has remain stable for all the periods while mean year of education has risen from 3.93 in 1999 to 4.74 in 2007. The proportion of family supervision to total labour cost has been declined from 1999 to 2007. Mean distance to pucca road has increased. The number of times agricultural extension services (AES) activities by the government has increased from 2.5 times in 1999 to 4 times in 2007. Proportion of government canals irrigated has increased in 2007 to 61 per cent. A proportion of tanks irrigated have also increased in 2007. It is interesting see that the proportions of wells irrigated area have constant between periods. Proportions of high yielding varieties (HYV) area have increased to 12 per cent. This data shows that the irrigated area from different sources and high yielding verities (HYV) area has increased over the periods which is very good sign for Indian agriculture. Proportion of agriculture expenditure has declined in 2007 when compared to 1999. In 1999 women reservation was at 25 percent which rose to 32 percent in 2007.

In Table 2, Cobb Douglas production function is estimated for entire sample, pooled and panel agricultural farmer's households. The different models are estimated to see the consistent of the results and it will help to give the general conclusions. The results have shown that there is an inverse relationship between cropped area and output is perhaps due to the diseconomies of scale. The proportion of irrigated area have positively related with crop output. This attributes that to higher yields on larger irrigated cropped area of the households. The seed is important factor in a production process and it has positive impact on the output. The fertilizers compare to manures have more significant contributor to output. The increased proportion of manure has declined the output. The uses of pesticide increase the production of the output. The results show that the hired labour is the important factor in a production. Because the coefficients of the hired labour are a larger compared to other inputs. The fixed cost such as value of mechanical assets, non-mechanical assets and other assets have positive impact on the output. The bullock cost per acre has declined the output in 2007 and it has positively influenced the output in 1999, pooled and panel periods. Overall the results have shown that the coefficients of the labour inputs are larger impact than other inputs and here the results conclude that mostly Indian agriculture depend upon the labour supply.

Table 2: Production Function

Variables	1999 Round	2006 Round	1999-2006 (Pooled)	1999-2006 (Panel)
	Ln(Value of Crop per acre)			
Ln(Cropped area)	-0.0813***	-0.0401***	-0.0916***	-0.0454***
	(0.00808)	(0.00899)	(0.00651)	(0.00893)
Proportion of irrigated area	0.242***	0.223***	0.120***	0.297***
	(0.0171)	(0.0191)	(0.0158)	(0.0193)
Ln(Value of seeds per acre)	0.297***	0.0137***	0.0290***	0.0413***
	(0.00841)	(0.00296)	(0.00243)	(0.00393)
Ln(Value of fertilizer and manure per acre)	0.0327***	0.0316***	0.0380***	0.0331***
	(0.00340)	(0.00335)	(0.00231)	(0.00333)
Prop. Of manure to total value of fertilizer and manure	-0.0640**	-0.188***	-0.194***	-0.139***
	(0.0323)	(0.0313)	(0.0232)	(0.0325)
Ln(Value of pesticides per acre)	0.0106***	0.0128***	0.0107***	0.0106***
	(0.000841)	(0.000901)	(0.000655)	(0.000890)
Ln(Value of total labor cost per acre)	0.0665***	0.125***	0.0770***	0.111***
	(0.00869)	(0.00896)	(0.00723)	(0.00898)
Prop. Of hired labor	0.437***	0.268***	0.281***	0.377***
	(0.0345)	(0.0443)	(0.0281)	(0.0395)
Ln(Value of fixed cost per acre)	0.0135***	0.0194***	0.00788***	0.0161***
	(0.00211)	(0.00187)	(0.00139)	(0.00204)
Ln(Value of bullock cost per acre)	0.00416***	-0.00265***	0.00114**	0.00115
	(0.000758)	(0.000800)	(0.000567)	(0.000810)
Constant	6.636***	7.861***	8.239***	7.613***
	(0.0768)	(0.0804)	(0.170)	(0.0729)
Number of households	4,487	4,869	9,356	4,531
Panel households	-	-	-	2273
Wald chi2	4159.46	1533.36	9993.25	1618.08
Technical efficiency	**0.751**	**0.755**	**0.798**	**0.855**

Source: Authors' calculation from REDS data set.

The results from cross sectional data show that the technical efficiency of the agricultural farming households is 75.1 per cent in 1999 and it has marginally increased to 75.5 per cent in 2007. The technical efficiency of pooled sample is 79.8 per cent and it is 85.5 per cent for panel households. This results show that on an average the panel households are more technical efficient than whole sample households and the technical efficiency has been increased over periods.

In the Table 3, the results of determinants of technical efficiency are presented. Initially technical efficiency is estimated using production function and then technical efficiency is used as dependent variable in the second stage regression model to estimate its determinants.

The household characteristic of the agricultural household is one of the important factors to influence the technical efficiency. The results show that the aged head of household is more efficient to produce the output efficiently and it is significant for the panel households. This ensures that aged households have more experience and using their past learning in the production process to produce more output with given level of inputs efficiently. The larger household size has positive impact on technical efficiency. The average education of household is positive and significant with technical efficiency in most of the regression models. The coefficient of proportion of family supervision to total labour cost is positively significant. This ensures that the family supervision is technically efficient and the family supervisions have greater role on production process.

Table 3: Determinants of Technical Efficiency

Variables	1999 Round	2006 Round	1999-2006 (Pooled)	1999-2006 (Panel)
HH head age	-0.00285	0.00313	0.00168	0.0116***
	(0.00432)	(0.00398)	(0.00213)	(0.00133)
Household size	0.00423*	0.0107***	0.00785***	0.00768***
	(0.00245)	(0.00228)	(0.00121)	(0.000688)
Mean education of the HH	0.00183***	0.000415*	0.0001	0.000385***
	(0.000700)	(0.000237)	(0.000168)	(0.0001)
Family supervision/labor cost	0.0163**	0.0282**	0.00282	0.0184***
	(0.00668)	(0.0117)	(0.00397)	(0.00168)
Distance to Pucca road	-0.000658***	-0.00159***	-0.000102	-0.000456***
	(0.000149)	(0.000127)	(0.0001)	(0.00004)
No. of times AES activities	0.00130***	0.000261**	0.000376***	0.0001***
	(0.000131)	(0.000132)	(0.0001)	(0.00003)
Proportion of gvt. canal irrigated	0.000352	0.000864***	0.000614***	0.00003
	(0.00276)	(0.000193)	(0.000149)	(0.000139)
Proportion of tank irrigated	0.0119	0.00120	-0.00280	0.0108***
	(0.00880)	(0.00504)	(0.00323)	(0.00277)
Proportion of well irrigated	0.000609	0.0163***	0.00263	0.0114***
	(0.00623)	(0.00480)	(0.00278)	(0.00321)
Prop. HYV area	0.0274***	0.00542	0.00360*	0.0326***
	(0.00432)	(0.00387)	(0.00205)	(0.00171)
Proportion of agricultural expenditure	0.00907	0.0445***	-0.00296	0.0119***
	(0.0122)	(0.0110)	(0.00591)	(0.00351)
Women reservation	0.000865	0.0215***	0.00289**	0.00277***
	(0.00283)	(0.00225)	(0.00128)	(0.000524)
Constant	0.740***	0.684***	0.776***	0.797***
	(0.0164)	(0.0161)	(0.00835)	(0.00522)
No. of households	4,487	4,868	9,355	4,531
No. of panel households	-	-	-	2273
Hausman Fixed effect	-	-	-	Yes
F-stat	20.07***	27.35***	9.42***	13.92***

Source: Authors' calculation from REDS data set.

The results find that the distance to pucca road negatively influences the technical efficiency. This seems location matters. That means if household situated in remote area then the technical efficiency will be declined. The agriculture extension workers activities (AES) such as demonstration, film, exhibition and lecture about the agriculture production have significantly increased the household efficiencies. This reveals the local government should undertake more AES activities in villages.

The most important determinant of technical efficiency is the different irrigation sources. The models have taken the proportion of area irrigated by government canal, tank waters and open well waters as determinates of technical efficiency. The results find that all the sources have made significant contribution to agricultural production and the technical efficiency have increased. The results have shown that if the proportion of high yielding verities area of a village increases then it tends to increase the technical efficiency of farmers. The expenditure on agricultural programs by government shows that technical efficiency has increased due to more agricultural expenditures by the government. These results suggest that the government should increase the agricultural expenditures to push up the farmers to increase their efficiencies. The results find that the women headed panchayats are doing better and the technical efficiency of these villages has increased over the periods.

CONCLUSION

The empirical results established few interesting facts such as if cropped area increases it declines the output growth but the proportion of irrigated area increases the crop output. Input utilization in the production process has positive impact on output growth irrespective of nature of inputs. However, the degree of impact varies. The results have shown that the coefficients of the labour inputs are larger than other inputs and this reveals that mostly Indian agriculture is still labour intensive.

It has been observed that on an average the panel households are more technically efficient than whole sample households and therefore there is a sharp upward tendency in technical efficiency over time for panel households. The results clearly suggest that mostly the panel households are agricultural households they have the maximum more potential with given and obtainable technology and also they use the inputs optimally.

The results also claims that aged households have more experience and they use their past knowledge in the production process to produce more output using optimal inputs efficiently. Learning by doing is more preferred way rather than adoption of new technologies. Education of the household is an important factor in the production process that’s why technical efficiency has been increased for educated farmers. More informed farmers are less locked in older process. Therefore it suggests that education enhances skills and innovations which are useful in terms of the allocation of inputs in a rapidly changing technological environment and then it increases the farm efficiency.

The larger family size are doing significantly better off and they are more technically efficient. The remoteness of villages from pucca road is inversely related with the technical efficiency. The irrigation facilities are important factors in the production which increase the technical efficiencies of the agricultural farmers. The more number of activities through agricultural extension service programs have significant positive impact on the technical efficiency of the farmers. The local government expenditures on agricultural programs have positive impact on the productivity of the farmers. Last but not the least, results found that the women reserved panchayats have positive impact on technical efficiency of the farmers in that areas. It might give an indication that women reserved panchayats act even-handed in allocation of resources.

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