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Research Note

Technical Efficiency in Maize Production in Madhya Pradesh: Estimation and Implications

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Abstract

The state of Madhya Pradesh is one of the traditional maize growing states, accounting for 13 per cent of the total maize area and contributing equally to the total maize production in the country. However, its productivity when compared to other maize growing states is very low. The study has found that even though a majority of the farmers cultivate improved maize cultivars, the overall technology adoption by them is poor. This may be due to the inability of a majority of farmers to follow the recommended package of practices for the improved cultivars because of the high costs involved in their adoption and lack of infrastructural facilities. Therefore, steps need to be initiated to solve this problem.

A comparison of costs on cultivation of traditional, composite and hybrid cultivars has revealed that the cost increases significantly on using the improved cultivars due to higher requirements of fertilizers, irrigation, and plant protection chemicals as compared to those in the traditional varieties. However, with the significant increase in yield, the unit cost of production has been much lower in the case of improved cultivars. The economics of cultivation of maize when compared with its competing crops like paddy and soybean have revealed that the paddy is superior to all the maize cultivars in output/input ratio. The hybrid maize has been found superior to soybean as well as paddy in terms of net returns and hence the farmers could cultivate maize rather than paddy since the latter has higher water requirement. The estimation of technical efficiency of the farmers has revealed that on an average the sample farms operate 23 per cent below the frontier output levels. Hence, it has been observed that the maize output can be increased through adoption of proper technology by the farmers. It requires support from both the state government (in terms of

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providing infrastructural/ institutional support like drying and storage facilities, arrangement for assured procurement, etc.) as well as the private companies (in terms of supply of quality seeds and chemical pesticides at reasonable prices).

Introduction

Maize is one of the most potential cereals grown globally, and is the third after wheat and rice in total foodgrain production. Due to its high adaptability and productivity, the cultivation of maize spread rapidly around the globe and currently it is being produced in most countries of the world. In India too, maize is emerging as the third most important crop, after rice and wheat. Maize was traditionally grown as staple food, primarily for household consumption, but its demand for feed and industrial uses has increased rapidly in the recent past. In our country, more than 50 per cent of maize produce is being used as animal feed (Singh *et al*., 2003). Further, Asian maize import has consistently exceeded 30 million tonnes annually, as a result of imports flowing into Japan and South Korea. Maize utilization and imports by Southeast Asia also increased sharply in the past decade. It all depicts the growing importance of maize in India for domestic as well as export to the neighbouring countries. An apprehension has, therefore, emerged that the present pace of growth in maize production is unlikely to meet its growing demand in future.

The state of Madhya Pradesh is one of the traditional and potential maize growing states, accounting for 13 per cent of the total maize area and contributing equally to the total maize production in the country (2001-03). However, the productivity of maize in Madhya Pradesh is very low if compared to that of other maize-growing states. The identification of the factors responsible for enhancing maize productivity, therefore, demands considerable attention. It also calls for a detailed examination of the farm efficiency in terms of technical, allocative and economic efficiencies for increasing productivity in a resource-poor state like Madhya Pradesh. The technical efficiency is the ability of the farm to achieve the maximum possible output with available resources, while the allocative efficiency refers to the ability to obtain optimal allocation of given resources. Economic efficiency is the combination of both the technical and allocative efficiencies. The measurement of economic efficiency is thus not complete without a study of technical efficiency and it is the frontier production function that enables the measurement of technical efficiency of farmers (Elsamma and George, 2002). The present study has examined various aspects of technical efficiency in maize production in Madhya Pradesh so that suitable policy options for enhancing maize production and productivity in the state could be implicated.

The Data

The primary data on various aspects of maize production from 300 households of Madhya Pradesh collected under the NATP project of the Division of Agricultural Economics (IARI) was used for the study. Based on the importance of maize production, three major maize-growing districts, viz. Chindwara, Shahdol and Mandsaur, were selected. From each of the selected districts, two blocks were randomly chosen. At the penultimate stage, a cluster of 1-3 villages from each selected block was selected. Finally, 50 maize-growing farmers were randomly selected from each cluster of villages.

Methodology

Technological Adoption Index

The technological adoption index is a catch-all measure of technology adoption of the farmers. The technology adoption practices include area under high-yielding varieties (HYVs), appropriateness of irrigation level and dosages of fertilizers. The technology adoption index was computed using the formula, given by Equation (1):

$$TAI_i = \frac{1}{5}\left[\frac{AH_i}{CA_i} + \frac{NA_i}{NR_i} + \frac{PA_i}{PR_i} + \frac{KA_i}{KR_i} + \frac{IA_i}{IR_i}\right]\times 100 \qquad \dots (1)$$

where,

i = Number of farmers, say 1, 2, 3, ..., n

TAI_i = Technology adoption index of the ith farmer

AH_i = Area under modern maize varieties (ha)

CA_i = Total area of maize (ha)

NA_i = Quantity of nitrogen applied for maize (kg/ha)

NR_i = Recommended dose of nitrogen for maize crop (kg/ha)

PA_i = Quantity of phosphorus applied for maize (kg/ha)

PR_i = Recommended dose of phosphorus for maize crop (kg/ha)

KA_i = Actual amount of potash applied for maize (kg/ha)

KR_i = Recommended amount of potash applied for maize (kg/ha)

IA_i = Actual number of irrigation applied

IR_i = Recommended number of irrigation for maize crop.

The index was calculated for all the 300 maize-growers, which ranged between 0 and 100. Thereafter, they were classified into three categories, viz. low adopters (< 33% TAI), medium adopters (34-66% TAI), and high adopters (> 66% TAI).

Estimation of Technical Efficiency

The stochastic frontier production function is widely used to estimate technical efficiency (Russel and Young, 1983). The stochastic frontier production function is presented as Equation (2):

$$Y_i = f(x_i\,;\,b_i)\,\exp(v_i - u_i) \qquad \ldots(2)$$

where, Y_i is the possible production level of the ith farm, $f(x_i\,;\,b_i)$ is the suitable functional form (e.g. Cobb-Douglas, CES or Translog) of the vector of inputs (X_i) and vector of unknown parameters $b_{i.}$ The v_i is distributed randomly and a symmetrical two-sided error-term as $v \sim N(0, s_v^2)$, which captures the effects of random shocks outside the farmers control, i.e. observation and measurement error, and other statistical noise. Thus, v allows the frontier to vary across farms, or over time for the same farm, and therefore the frontier is stochastic. The u_i is distributed half-normal one-sided error-term as $u \sim N(0, s_u^2)$ that captures deviations from the frontier due to inequality. Both u_i and v_i are independent of each other. The technical efficiency of an individual farm is defined as the ratio of the observed output to the corresponding frontier output, conditional on the levels of inputs used on farm.

Specification of the Model

The stochastic frontier production function is specified as per Equation (3):

$$\ln y_i = \beta_i 1 + \beta_i 2 \ln L + \beta_i 3 \ln F + \beta_i 4\, K + v_i - u_i \qquad \ldots(3)$$

$$i = 1, 2, \ldots, n$$

where,

y_i = Yield of maize in the ith farm (q/ha)

L = Human labour use in maize crop (mandays/ ha)

F = Quantity of fertilizer (N + P + K) used (kg/ha) in maize crop

K = Capital which includes overhead expenditure on animal and machine labour, seeds and pesticides (Rs/ha)

$v_i - u_i$ = Random error-term

n = Number of maize-growing farms

Results and Discussion

Profile of Sample Households

The profile of the sample households is given in Table 1. The average size of holdings ranged from 1.36 ha for small to 6.73 ha for large farms with the overall average of 3.11 ha. The irrigated area accounted for more than 50 per cent of the cultivated land for most of the farmers. Due to leasing-in by the small, and up to some extent by medium farmers, cropping intensity was 183 per cent for small farmers and less than 150 per cent for large farmers. Across all the size groups, maize was the dominant crop being cultivated on around one-fifth of the cropped area. However, during *rabi* season, wheat was the most preferred crop.

The average family size of the selected farmers was 6.67 members, and it was found to increase with farm size. Across all the categories, around 40 per cent of the family members were helping in agricultural operations.

Area under Different Maize Cultivars

The area under different maize cultivars is given in Table 2. In the selected state, small, medium and large farmers were allocating 0.58 ha, 1.06 ha and 1.54 ha, respectively to maize crop. Hybrid cultivars dominated across the farm-size group as they occupied 59 to 68 per cent of the total maize acreage. Overall, around 12.75 per cent was occupied by the traditional cultivars and around 19.15 per cent by composite, among the sample farms.

Table 1. Profile of sample households, Madhya Pradesh: 2000-01

Particulars	Farm-size groups			All farms
	Small	Medium	Large	
Average size of holdings (ha)	1.36	2.96	6.73	3.11
Irrigated area (%)	66.2	67.6	42.8	54.7
Cropped area (ha)	2.48	5.13	8.94	4.79
Cropping intensity (%)	183	173	133	154
Maize (% of CA)	23.44	20.60	17.20	19.77
Rice (% of CA)	5.28	3.65	6.30	5.27
Other *kharif* crops (% of CA)	21.69	25.9	29.08	26.32
Wheat (% of CA)	18.60	19.22	15.45	17.35
Other *rabi* crops (% of CA)	31.00	30.60	31.96	31.31
Average family size (No.)	6.17	6.71	7.51	6.67
Total workers	2.50	2.66	3.01	2.67
	(40.52)	(39.66)	(40.10)	(40.03)

Figures within the parentheses denote share of workers in family size

Table 2. Area under different maize cultivars on sample farms

(% of total maize area)

Crop	Farm-size groups			
	Small	Medium	Large	All farms
Traditional	14.80	8.82	15.48	12.75
Composite	17.38	13.46	25.44	19.15
Hybrid	67.82	77.22	59.08	68.10
Total	100	100	100	100
	(0.58)	(1.06)	(1.54)	(0.95)

Figures within the parentheses denote area under maize crop in ha

This revealed that a majority of the farmers in the state are cultivating hybrids or improved cultivars of maize.

Adoption of New Maize Technology

Different levels of adoption of maize technology on sample farms is given in Table 3. The adoption of new maize technology means using the entire package of practices for cultivation along with improved varieties/ cultivars. To capture this, the technology adoption index was calculated for individual farmer which included adoption of improved cultivar, recommended doses of chemical fertilizers, recommended number of irrigations, etc., as discussed in methodology.

It was observed that 97 per cent of the farmers fell under the category of low adoption and only 3 per cent belonged to the medium adoption category. No farmer was found having adoption more than 66 per cent. The trend of adoption was almost similar across different farm-size categories. The prevalence of small and marginal farmers with poor resource-base may be mainly attributed for such a low level of adoption, whereby the farmers were unable to purchase the required quantity of fertilizers.

Table 3. Levels of adoption of new maize technology on sample farms

(% of farmers)

Adoption level	Farm-size groups			
	Small	Medium	Large	All farms
Low adotpion (0-33%)	97.22	97.60	95.90	97.00
	(140)	(81)	(70)	(291)
Medium adoption (34-66%)	2.70	2.40	4.10	3.00
	(4)	(2)	(3)	(9)

Figures within the parentheses are number of farmers in respective categories

Table 4. Economics of maize and its competing crops on sample farms

(Rs/ha)

Particulars	*Kharif*-maize		*Kharif*-competing crops		
	Traditional	Composite	Hybrid	Soybean	Paddy
Input cost	5625	8604	10546	10087	7601
Output value	6889	12076	16917	15944	12578
Net return	1264	3472	6371	5857	4977
Output/input ratio	1.22	1.40	1.60	1.58	1.65

Moreover, non-availability of irrigation source when needed was also a constraint; it prevented them from providing the recommended number of irrigations to the crop. In the case of medium and large farmers, low selling price of maize and uncertainty of the output market led to such poor adoptions.

Economics of Cultivation of Maize and Its Competing Crops

The maize cultivation is generally considered less rewarding and therefore the profitability in maize cultivation has been compared with that of its competing crops, i.e. paddy and soybean, to find the true picture. The economics of cultivation of maize and its competing crops have been given in Table 4. The net return was found more (Rs 6371/ha) in the case of hybrid maize and lowest (Rs 1264/ha) in the traditional maize cultivars. It is clearly evident from Table 4 that net return from the hybrid maize cultivar was more even than that of soybean (Rs 5857/ha) and paddy (Rs 4977/ha). However, the traditional and composite cultivars of maize had less net return than their competing crops. The output/input ratio was more in the case of paddy than hybrid maize, which may be due to the high cost of new seed for hybrid maize. In the case of traditional and composite cultivars, the output / input ratio was much lower as compared to that of the competing crops. However, hybrid maize may be preferred to paddy due to not only better returns but also less requirement of water as compared to its competitive crops.

Impact of Improved Maize Technology

The production technology is said to be improved if it either increases the per unit quantity of production with the given inputs or enables reduction in the cost of production (per unit of output). The impact of improved maize cultivars on the yield as well as cost of production is presented in Table 5. The maize yield increased from 1.54 t/ha to 2.72 t/ha with composite cultivar and to 3.81 t/ha with hybrid cultivar. In other words, the maize yield increased

Table 5. Impact of improved maize technology over traditional technology on sample farms

Cultivars	Yield (t/ha)	Increase in yield (%)	Cost of production (Rs/q)	Reduction in cost (%)
Traditional	1.54	-	364	-
Composite	2.72	77	317	13
Hybrid	3.81	147	277	24

by 77 per cent with composite cultivars and 147 per cent with hybrid cultivars over the traditional variety. The cost of production of composite had reduced to Rs 317/q from Rs 364/q for the traditional; and for hybrids, it had reduced to Rs 277/q. In other words, the cost of production had reduced by 13 per cent and 24 per cent for composite and hybrid cultivars, respectively when compared to the traditional maize cultivars. In nutshell, the improved cultivars were able to increase the crop yield and reduce the cost of production significantly.

Estimates of OLS and Frontier Production Function

Out of the 300 sample farms, 48 farmers did not apply chemical fertilizers to maize crop and grew only traditional cultivars of maize. These farmers cultivated maize crop mainly for domestic consumption and their marketed surplus was very low. Therefore, only 252 farms were considered to estimate the technical efficiency. The dependent variable included in the model was the output of maize crop. The inputs included human labour, fertilizer and capital, which consisted of overhead expenditure on seeds, plant protection chemicals, animal and machine labour. The estimates of Cobb Douglas production function and frontier production function for the maize crop are given in Table 6.

The coefficient of multiple determination (R^2) indicates that 46 per cent of the variation in the yield could be explained by the variables considered in the model for the maize crop. All the three variables, viz. labour, fertilizer and capital, had positive and significant coefficients, indicating their importance in maize production in the state.

The OLS function could narrate the response of the average farms while the frontier function reflects the response of the best and efficiently managed farms. The symbol 'λ' (Table 6) denotes the ratio of the variance of the farm-specific production behaviour (σ_u) to the variance of the statistical noise (σ_v) and its value (4.5) indicates that the one-sided error component dominated more than symmetric error component. The vale of 'γ', which is

Table 6. Estimates of Cobb Douglas and Frontier production functions

Variable	Cobb-Douglas production function estimates (OLS)	Frontier production function estimates (MLE)
Constant	-0.9291	0.3115
Labour	0.2224**(5.4)	0.0755**(2.1)
Fertilizer	0.2315**(7.8)	0.2110**(9.3)
Capital	0.2520**(4.7)	0.1954**(4.2)
	$R^2 = 0.46$	$\sigma^2_v = 0.004$
		$\sigma^2_u = 0.087$
		$\sigma^2 = 0.0920$
		$\lambda = 4.5063$

Notes: Figures within the parentheses are *t*-ratios
** and * indicate significance at 1 and 5 per cent probability levels, respectively

Table 7. Distribution of maize growers under different levels of technical efficiency

Efficiency levels (%)	Number of farms	Per cent of total
40-50	3	1.1
50-60	31	12.3
60-70	44	17.5
70-80	44	17.5
80-90	66	26.2
> 90	64	25.4
Total	252	100

the ratio of the variance of the farm-specific performance of technical efficiency (σ^2_u) to the total variance of output (σ^2) was found as 0.95. This means that 95 per cent of the variation in output among the farms was due to the difference in efficiencies.

The value of constant term was observed higher in the stochastic frontier function than the OLS method. This means that compared to the OLS method, the frontier production could shift vertically. As expected, the co-efficients of two variables (fertilizer and capital) were almost similar in both the estimates. In the case of labour, a significant decrease was observed in its value. Since the frontier parameters indicate the maximum possible contribution of each input to output, when the inputs are utilized efficiently following the best farming techniques, it may be inferred from the results that though labour is an important variable in production process, its contribution in frontier output is overestimated.

Technical Efficiency of Sample Farms

The distribution of farms under the efficiency categories is given in Table 7. The minimum technical efficiency was found 42 per cent and the mean technical efficiency was 77 per cent. The maximum number of farms came under the category of 80-90 per cent technical efficiency. The study implied that the maize output of the "average farmer" could be increased by 23 per cent by adopting the technology followed by the "best practice" farmers.

Conclusions and Policy Implications

The yield of maize in Madhya Pradesh being much lower than the national average, the study has assumed importance in its attempt to decipher the various determinants of efficiency and its implications on maize production in the state. The study has found that even though a majority of the farmers cultivate improved maize cultivars, the overall technology adoption by them has been poor. This may be due to the inability of a majority of farmers to follow the recommended package of practices for the improved cultivars because of the high costs involved in their adoption and lack of infrastructural facilities. Therefore, steps need to be initiated to solve this problem.

A comparison of costs on cultivation of traditional, composite and hybrid cultivars has revealed that the cost increased significantly on using the improved cultivars due to higher requirements of fertilizers, irrigation, and plant protection chemicals, as compared to those in the traditional varieties. However, with the significant increase in yield, the unit cost of production has been much lower in the case of improved cultivars. The economics of cultivation of maize when compared with that of its competing crops like paddy and soybean, have revealed that the paddy is superior to all the maize cultivars in output/input ratio. The hybrid maize has been found superior to soybean as well as paddy in terms of net returns and hence the farmers could cultivate maize rather than paddy since the latter has higher water requirement. The estimation of technical efficiency of the farmers has revealed that on an average the sample farms operate 23 per cent below the frontier output levels. Hence, the maize output can be increased by 23 per cent by adopting proper technology by farmers.

The economic efficiency of the maize growers in the state of Madhya Pradesh can be improved by increasing the adoption level of the improved package of practices. This can be made possible by providing good quality seeds of improved maize cultivars and easy and cheap credit for the purchase of critical inputs like fertilizers, plant protection chemicals, etc. Additionally, an assured market for their output through forward linkage with agroprocessing industries will indirectly reduce the price volatility in maize produce and increase the socio-economic status of these farmers.

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