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Technical Efficiency of Major Food and Cash Crops in Karnataka (India)

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I

INTRODUCTION

Among the important issues debated in the current phase pertaining to the agricultural sector include the expectations about the next technological phase and the efficiency parameters during the current phase. Growing population as well as income enhances the demand for agricultural products and there is no scope for expanding land frontiers and further there is increasing trend of diversion of cultivable land for non-agricultural purposes (Deshpande and Bhende, 2003). The only option remained to increase agricultural production is through adoption of improved technology and efficient use of available resources. The experience shows that input use as well as output levels varies across regions (macro level) and also within the regions among different farm size classes (micro level). The inter-regional studies ignore the intra-farm variations in resource endowment of the regions as well as the farmers. Agricultural output is conditioned by agro-climatic factors as well as technology at regional level, whereas, varying levels of input use impinge upon the productivity at the farm level. Yield gap may arise due to the comparison between the yields obtained on research farms/demonstration farms under ideal or controlled conditions and the actual yield realised by the farmers at the farm level. The yield gap mainly arises due to sub-optimal or inefficient use of resources. However, the analysis of variations between the potential and the actual yields on the farm, given the technology and resource endowment of farmers, provided better understanding of the productivity gap. Now, with the changes in the macro economic policies and introduction of economic liberalisation in India, emphasis is on efficient use of scarce resources, which have alternative uses. The present investigation was taken up against this background to understand the resource use efficiency across the farm size groups for major food and cash crops in Karnataka.

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One of the important measures of overall resource use efficiency is technical efficiency. The ratio between the actual and the potential outputs is defined as a measure of technical efficiency of an economic decision-making unit in the literature and the production environment in which a farm/firm operates (socio-economic characteristics) determines the variations in the efficiency levels of the farm household (Kalirajan and Shand, 1994). In this study, an attempt is made to estimate farm-specific technical efficiency of major food and cash crops grown in Karnataka. We have selected rice, and sorghum as major food crops (as they account for more than one-third of the gross cropped area in the state) and groundnut and cotton are the major cash crops. Though rice is grown during *kharif* as well as summer season, we considered only high-yielding variety (HYV) rice grown during *kharif* season, as it constitutes more than 70 per cent of the area under rice. Similarly, local sorghum is grown extensively during *rabi* (post-monsoon) season in vast tracts of northern Karnataka and it is a major staple food in the state.

Technical efficiency is estimated using the stochastic frontier production function approach. Further we attempted to identify the factors conditioning the technical efficiency of farmers in producing these crops. Improving technical efficiency is important to reap the potential benefits of the existing technology, rather than searching for new technology (Kalirajan *et al.,* 1996). Studies by Umesh and Bisaliah (1991), Shanmugam (2001, 2002) have indicated that it is possible to raise the productivity of crops without raising the input application. The study would help in identifying the levels of inefficiency and also in formulating the policy to improve the efficiency of the farm households.

A brief introduction is followed by discussion on the methodology used in the study to estimate farm-specific technical efficiency. Data, specification of the model, and variables used are discussed in Section III. The estimates of technical efficiency (TE) and determinants of TE are presented in Section IV. Finally, Section V summarises the findings of the study and its implications for agricultural policy.

II

METHODOLOGY

Efficiency of a firm/farm refers to its performance in the utilisation of resources at its disposal. The performance of a firm/farm is either compared with the normative desired level or with that of any other firm or farm. A firm is defined as being technically efficient for a given technology, if it fully realises its own technical efficiency potential by following the best practice techniques of the chosen technology and produces on its production frontier consistent with its socio-economic physical environment. Technical efficiency (TE), is defined and measured as the ratio of the firm's/farm's actual output to its own maximum possible frontier output for a given level of inputs and the chosen technology (Kalirajan and Shand, 1994).

Farrell (1957) introduced the concept of technical efficiency and argued that the frontier production function of a firm showing the maximum possible output can be best compared within the peer group and not with some arbitrary standard norms. Farrell (1957) constructed a free disposal convex hull of observed input-output ratios by using the linear programming technique. This approach is non-parametric in nature. It has been extended and applied by Farrell and Fieldhouse (1962), Seitz (1970) and Afrait (1972). Aigner and Chu (1968) estimated a deterministic parametric frontier by specifying a homogenous Cobb-Douglas production function.

The deterministic models described above provide a common production frontier for all the firms under study and the firm's efficiency is derived by comparing the firm's performance with that of the common production frontier. This approach ignores the fact that a firm's performance is affected by some exogenous factors, such as weather, which are beyond the control of the firm. Thus, the deterministic approach needs to be corrected for this aspect of production environment faced by firms. It is in this context, the stochastic frontier model proposed independently by Aigner *et. al.*, (1977) and Meeusen and van den Broeck (1977) takes into consideration the influence of uncontrollable exogenous factors in the estimation process. The stochastic frontier has been modelled with a composite error term, comprising two components. A symmetric component permits random variation of the frontier across firms and captures the effects of measurement error, other statistical noise and random shocks outside the firm's control. A one-sided component captures firm-specific effects such as slackness in production due to labour shirking, which are under the control of the firms and influence their level of achievement of technical efficiency.

Cornwell *et al.* (1990) estimated technical efficiency by using panel data. This methodology was applied among others, by Kumbhakar (1990), Kalirajan and Shand (1989), and Jha and Singh (1994). Battese and Coelli (1992) proposed a stochastic frontier production model, which has firm effects that are assumed to be distributed as truncated normal random variables and can vary systematically with time. A number of comprehensive reviews of literature on the frontier production such as Forsund *et al.* (1980), Battese (1992), Schmidt (1986), Bauer (1990), Greene (1993), and Kalirajan and Shand (1999) are available in the literature.

For the purpose of the present analysis, the production frontier of the i-th firm, producing a single output with multiple inputs following the best practice techniques can be defined as,

$$Y_i^* = f(x_{i1}, x_{i2}, \ldots, x_{im}) | T \qquad \ldots (1)$$

where Y^* and x_is are the frontier output and inputs of the i-th firm, and T is the given technology that is common to all firms in the sample. If the i-th firm uses the best practice technique, but there are either statistical errors such as measurement errors or influence of external factors such as weather, then the firm's frontier function is calculated as

$$Y_i^* = f(x_{i1}, x_{i2}, \ldots x_{im}) \exp(v_i)$$

The presence of v_i here also means that the frontier is stochastic with a random disturbance v, implying that the frontier function may vary randomly across firms or over time for the same firm. Consider a situation in which the i-th firm is not producing its maximum possible output owing to some slackness in production induced by various non-price and socio-economic-organisational factors such as labour shirking. The production function of the i-th firm can be written in a modified neo-classical framework as follows:

$$Y_i = f(x_{i1}, x_{i2}, \ldots x_{im}) \exp(v_i - u_i) \quad \ldots (2)$$

where, u_i represents the combined effects of various non-price and organisational factors which constrain the firm from obtaining its maximum possible output Y_i^*. In other words, $\exp(-u_i)$ which is firm-specific, reflects the i-th firm's ability to produce at its present level, which is otherwise called the i-th firm's technical efficiency. The values taken by u depend on the real situation that the firm faces. Nevertheless, an upper limit can be set for the values of u. When there are no socio-economic and organisational constraints affecting the firm, u takes the value 0. When the firm faces constraints, u takes a value greater than zero. The actual value of u depends on the extent to which the firm is affected by the constraints.

One advantage of the above model is that it is possible to find out whether the deviation of a firm's actual output from its potential output is mainly because it did not use the best practice technique or is due to external random factors. Thus, one can say whether the difference between the actual output obtained and the potential frontier output, if any, occurred accidentally or not. If both the error terms are not distinguished in the estimation process, then OLS estimation can be carried out and it will give some sort of an average production function.

A measure of technical efficiency of the i-th firm can be defined as:

$$\exp(-u_i) = \frac{Y_i}{Y_i^*} = \frac{\text{Actual output}}{\text{Maximum possible output}} \quad \ldots (3)$$

The above equation (3) is the basic model generally used for measuring technical efficiency and it is called "the conventional frontier production function approach" in this paper. In this model, the measurement of technical efficiency is based on the residual as in Solow's approach of measuring total factor productivity growth. A major difference is that unlike in the Solow's approach statistical errors are removed from the residual to some extent in the present approach. Following Kalirajan and Flinn (1983), with the assumption of a half normal distribution for u and a normal distribution for v, the individual-specific technical efficiency exp(-u_i) can be estimated from the conditional expectation of exp(- u) given with the composite error term, ε_i as:

$$E[\exp(-u_i/\varepsilon_i)] = -\frac{\sigma_u \sigma_v}{\sigma}\left[\frac{f(.)}{1-F(.)} - \frac{v-u}{\sigma}\sqrt{\frac{\gamma}{1-\gamma}}\right] \qquad \ldots(4)$$

where f(.) and F(.) are standard normal density and distribution function respectively; and $\gamma = \frac{\sigma_u^2}{\sigma^2}$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$ where σ_u^2 and σ_v^2 are variances of u and v respectively. The model specified for the present study is described in detail in the following pages.

III

DATA, MODEL AND VARIABLES USED IN THE STUDY

The study uses the farm level cross section data compiled by the University of Agricultural Sciences, Bangalore, during 1993-94 under the scheme "Cost of Cultivation of Principal Crops", sponsored by the Directorate of Economics and Statistics (DES), Ministry of Agriculture, Government of India. The DES has identified important crops for each State and sample selection is based on stratified multistage random sampling procedure. Karnataka State is delineated into ten agro-climatic zones. At the first stage, talukas have been selected from each zone depending on the importance of the principal crops in the zone. In the second stage, one or two villages have been selected from each taluk and 10 farm households are finally selected from each taluk. Thus, in Karnataka, data have been collected from 450 sample households drawn from 45 taluks spread over 10 agro-climatic zones. However, zone 10 has been combined with zone 9 for data collection purpose. The important features of agro-climatic regions of Karnataka and districts/talukas covered are presented in Annexure 1. In the present study, farm households have been classified into five farm size groups based on the operational holdings.[1]

Cobb-Douglas production function has advantages over other functional forms and it is widely used in the Frontier Production Function studies (Kalirajan and Flinn, 1983; Dawson and Lingard, 1989; Bravo-Ureta and Evenson, 1994; Shanmugam, 2003). Nevertheless, a preliminary testing for the functional form of Cobb Douglas against the more general translog form supported the selection of the Cobb Douglas functional form for the present data set. Therefore, the following stochastic frontier production function of the Cobb-Douglas type was specified to estimate the technical efficiencies for the individual farms and crops.

$$\ln Y_i = \alpha + \beta_1 \ln x_1 + \beta_2 \ln x_2 + \beta_3 \ln x_3 + \beta_4 \ln x_4 + v_i - u_i$$

Where, Y_i = Actual output of the i-th farm in quintals,

α = constant term

x_1 = Area under the crop measured in hectare,

x_2 = human labour input used in man-hours,[2]

x_3 = bullock labour input in pair-hours,

x_4 = Chemical fertiliser (NPK) quantity used in kilograms,

β_i = unknown parameters to be estimated,

v_i = symmetric component of the error term and

u_i = non-negative random variable which is under the control of the farm.

'u' takes the value of zero when the farmer is efficient and assumes the value greater than zero when the farmer is inefficient. Negative value of u varies depending on the level of inefficiency. The Maximum Likelihood Estimation (MLE) method enables us to obtain the maximum possible output function. It is assumed that u and v are independent and u follows a half normal distribution with variance σ_u^2 and v follows a normal distribution N ~ $(0, \sigma_v^2)$. The computer program TEALEC developed at the Australian National University was used to estimate the frontier and firm-specific technical efficiencies.

Determinants of Technical Efficiency

An attempt was made to identify the socio-economic factors influencing the technical efficiency at the farm level. MLE estimates of technical efficiency were regressed on rental value of per gross cropped area (proxy for land quality), proportion of females in total agricultural workers in the family, proportion of children in the family, education dummy for the household having family adult member with education above primary level and farm size. As the technical efficiency variable varies between 0 and 1, the variable was transformed into ln[TE/1-TE], so that the latter transformed variable now varies between $-\infty$ and $+\infty$, which facilitates estimation of the parameters by using the OLS technique.

The following linear regression model was used to identify the socio-economic factors that condition technical efficiencies of sample farms.

$$Ln[TE_{ij}/1-TE_{ij}] = \alpha + \beta_1 X_{1ij} + \beta_2 X_{2ij} + \beta_3 X_{3ij} + \beta_4 X_{4ij} + \beta_5 X_{5ij} + \mu_i$$

Where,

TE_{ij} = Technical efficiency for i-th crop on j-th farm,

α = Intercept/constant,

β_i = regression coefficients,

X_1 = rental value per hectare of cropped area,

X_2 = proportion of female workers in total agricultural workers in the family,

X_3 = proportion of children in the family,

X_4 = dummy for adult member/s having education above primary level,
X_5 = farm size and
μ = error term.

IV

RESULTS AND DISCUSSION

IV.1. Input and Output Levels

Before getting into the estimates of technical efficiency, we present the input and output details for selected crops by farm size groups in Table 1. It can be seen from Table 1 that area under the reference crops was positively associated with the size of land holding. Human labour use per hectare for rice and sorghum was higher on small and marginal farms when compared to their medium and large farmer counterparts. On the contrary, human labour use per unit area of groundnut and cotton was the highest on medium farms. The quantity of plant nutrients used per unit area increased with the size of land holding in all the crops except cotton wherein marginal farmers have used almost double the quantity used by medium and large farmers. Per unit output of rice and sorghum was the highest on medium farms whereas semi-medium and marginal farmers obtain the highest groundnut and cotton output per unit area, respectively.

TABLE 1. AVERAGE LEVEL OF INPUT USE AND OUTPUT PER HECTARE BY FARM SIZE GROUPS

		Land holding size in hectares*					
Crop	Particulars	< 1	1-2	2-4	4-10	> 10	All
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rice	Area	0.58	0.84	1.15	1.96	3.1	1.57
	Human labour	1410	1552	1297	1190	1035	1206
	Bullock labour	236	176	192	139	125	152
	NPK	172	276	175	230	264	233
	Production	35.05	40.65	40.28	41.38	37.68	39.67
Sorghum	Area	0.71	1.14	1.82	2.52	2.72	1.95
	Human labour	553	520	438	377	319	391
	Bullock labour	74	79	66	60	67	66
	NPK	18	13	16	18	20	18
	Production	8.29	9.5	8.63	9.82	9.05	9.23
Groundnut	Area	0.59	1.03	1.44	2.09	2.39	1.56
	Human labour	355	437	481	612	475	484
	Bullock labour	66	64	90	97	88	83
	NPK	23.42	32.34	48.18	60.15	59.32	48.18
	Production	6.51	7.44	8.21	7.36	7.87	7.61
Cotton	Area	0.59	0.56	1.05	1.25	1.40	1.09
	Human labour	739	688	734	1181	786	896
	Bullock labour	157	116	125	135	110	124
	NPK	217.98	72.96	135.91	97.54	99.28	108.73
	Production	10.00	5.53	7.31	5.91	7.05	6.72

Note: * Land holding class are defined as: <1 ha as marginal, 1-2 small, 2-4 semi-medium, 4-10 medium and > 10 ha as large farmers.

IV. 2. Empirical Results

IV.2.1. Average Production Function

As stated earlier, we have estimated the average contribution of different input factors to output through the Cobb-Douglas production function using Ordinary Least Squares (OLS) technique. The OLS can be interpreted as a measure of average performance of the sample observations evaluated at the mean input levels. The output elasticities with respect to OLS estimation results are presented in Table 2. Area under the concerned crop as well as quantity of plant nutrients (NPK) used tend to be significant determinant of output. Human labour contributed significantly to groundnut and cotton output but not so much to rice and sorghum. The elasticity coefficient of bullock labour is not statistically significant either for food crops or cash crops.

TABLE 2. OLS ESTIMATES OF THE PRODUCTION FUNCTION

Variable (1)	Rice (2)	Sorghum (3)	Groundnut (4)	Cotton (4)
Constant	1.294	0.426	0.515	0.175
	(1.852)*	(1.621)	(1.233)	(0.521)
Area	0.501	0.621	0.671	0.621
	(5.905)	(6.226)	(7.880)	(4.538)
Human labour hours	0.182	0.127	0.173	0.168
	(0.655)	(1.231)	(2.341)	(1.855)
Bullock pair hours	0.044	0.097	0.098	0.044
	(0.918)	(0.788)	(1.191)	(0.298)
NPK quantity	0.308	0.021	0.020	0.045
	(5.855)	(2.040)	(2.871)	(3.546)
R^2 (F)	0.827	0.744	0.851	0.791
	(242.108)	(49.793)	(92.667)	(42.586)
N	77	68	65	45

Note: Figures in parentheses are t values.

IV.2.2. Technical Efficiency

Technical efficiency was estimated by fitting a Frontier Production function. We used land input (area under the crop), man-hours, bullock pair-hours and quantity of plant nutrients (NPK) as input variables in the estimation of parameters. The empirical results obtained for rice, sorghum, groundnut and cotton are given in Table 3. The Maximum Likelihood Estimates (MLE) are comparable to that of OLS results. However, there are a few minor changes in the magnitude of coefficients, except the constant terms as expected.

TABLE 3. PARAMETER ESTIMATES OF STOCHASTIC FRONTIER FUNCTION

Variable (1)	Rice (2)	Sorghum (3)	Groundnut (4)	Cotton (5)
Constant	1.835	0.718	0.899	0.314
	(2.73)	(3.04)	(3.07)	(0.68)
Area	0.551	0.941	0.682	0.577
	(7.04)	(7.19)	(8.20)	(3.06)
Human labour hours	0.150	0.098	0.157	0.071
	(0.43)	(0.91)	(2.06)	(0.72)
Bullock pair-hours	0.058	0.078	0.098	0.194
	(1.06)	(0.60)	(0.88)	(0.95)
NPK quantity	0.278	0.013	0.026	0.048
	(5.51)	(1.28)	(2.42)	(5.17)
σ_u/σ_v (=λ)	1.516	3.718	2.056	4.600
	(1.80)	(1.96)	(1.80)	(0.75)
$\sqrt{\sigma_u^2} + \sqrt{\sigma_v^2}$ (σ)	0.346	0.267	0.399	0.220
	(6.21)	(7.49)	(5.91)	(5.04)
σ_u^2	0.084	0.067	0.128	0.046
σ_v^2	0.036	0.005	0.030	0.002
σ_u^2/σ^2 (= γ)	0.697	0.933	0.809	0.955
Log-likelihood	4.403	27.711	-7.756	28.644
N	77	68	65	45

Note: Figures in parentheses are t values.

Rice (HYV Kharif)

Two of the four variables used in the model have *a priori* signs and are statistically significant at one per cent level. Use of human and bullock pair hours have positive impact on output, however, the estimated coefficients were not statistically different from zero. The area under HYV paddy and quantity of plant nutrients used in the production process are important factors influencing the output. The output elasticity with respect to area for rice was 0.55 whereas, it was 0.28 for chemical fertilisers. The higher value of intercept in MLE when compared with OLS estimates and comparable values of estimated parameters provide enough credence to Hick's neutral change.

The estimated value of σ_u^2 and σ_v^2 were 0.084 and 0.036 respectively. A high value of for γ (0.697) indicates the presence of significant inefficiencies in the production of the crop. In other words, about 70 per cent of the difference between the observed and the frontier output was mainly due to the inefficient use of resources, which are under the control of the sample farmers. These findings corroborate the observations made by Battese and Coelli (1995), Datta and Joshi (1992), Jayaram *et al.* (1992) and Rama Rao *et al.* (2003). Further, the significance of γ indicates that the assumption of the half normal distribution for u is valid for the present data set (Kalirajan and Shand, 1994). Table 4 shows the frequency distribution of estimated technical efficiency for the sample households by farm size class as well as for the sample as a whole. The average level of technical efficiency is estimated at 84 per cent indicating that the output can be raised by 16 per cent by following efficient crop management practices without having to increase the level of application of inputs.

TABLE 4. TECHNICAL EFFICIENCY (TE) BY FARM SIZE GROUPS – HYV RICE KHARIF

(households in per cent)

Levels of T.E.	Farm size groups					
(per cent)	Marginal	Small	Semi-medium	Medium	Large	All
(1)	(2)	(3)	(4)	(5)	(6)	(7)
<70	18	14	13	8	17	13
70 to 80	18	21	6	17	8	14
80.1 to 90	45	57	25	33	42	39
> 90	18	7	56	42	33	34
Mean TE	0.79	0.81	0.86	0.86	0.83	0.84
N	11	14	16	24	12	77

It was observed that about 13 per cent of the farms were harvesting less than 70 per cent of the frontier output, whereas little more than one-third (34 per cent) were realising more than 90 per cent of the frontier output. It was also observed that most of the farmers (53 per cent) operated at the efficiency levels between 70 and 90 per cent. Mean TE ranged from 0.79 on marginal farms to 0.86 on semi-medium/medium farms.

Local Sorghum - Rabi

All the variables used in the model have *a priori* signs. The intercept value of the stochastic frontier estimated through maximum likelihood procedure is higher than the one estimated by OLS pointing towards Hick's neutral technical change (Table 3). The land elasticity value is relatively high as compared to any other input elasticity and is statistically significant at 1 per cent level. The plant nutrient (NPK quantity) variable turns out to be statistically insignificant. The sum of the regression coefficients is 1.07 indicating constant returns to scale.

The estimated value of σ_u^2 is higher than the estimated value of σ_v^2. The higher magnitude of σ_u^2 indicated that the difference between the realised output and the frontier output was more due to inefficient use of resources at the disposal of the farmers. The ratio of the variance of the farm specific TE to the total variance of output (γ) showed that more than 90 per cent of the difference between the observed and the frontier output is mainly due to factors which were under the control of the farmers. The estimated TE ranged between 0.80 on semi-medium farms and 0.85 on medium farms, with a mean TE of 0.83 for all the farms. The results indicated that the sample farms realised only 83 per cent of their potential output (Table 5). It was interesting to note that about 35 per cent of the sample farms were operating close to the frontier (TE > 0. 90). On the contrary, little more than 16 per cent of the sample farms realised less than 70 per cent of the potential output due to inefficient use of resources.

TABLE 5. TECHNICAL EFFICIENCY BY FARM SIZE GROUPS – LOCAL SORGHUM – *RABI*

(households in per cent)

Levels of T.E. (per cent) (1)	Farm size groups Marginal (2)	Small (3)	Semi-medium (4)	Medium (5)	Large (6)	All (7)
<70	0	9	23	12	29	16
70 to 80	30	36	15	6	12	18
80.1 to 90	40	18	38	53	6	31
> 90	30	36	23	29	53	35
Mean TE	0.84	0.83	0.80	0.86	0.82	0.83
N	10	11	13	17	17	68

The proportion of farmers realising more than 90 per cent of the potential sorghum output ranged from 23 per cent of the semi-medium farmers to more than 50 per cent of the large farm households.

Groundnut

We used area under groundnut, man-hours, bullock hours, quantities of NPK nutrients in kgs as input variables in the estimation of parameters. The empirical results derived through OLS and MLE techniques are presented in Tables 2 and 3, respectively. The estimated elasticity coefficients for area under groundnut and NPK use are statistically significant at 1 per cent level. The elasticity coefficient for human labour use was statistically significant at 2 per cent level.

The estimated value of σ_u^2 and σ_v^2 were 0.128 and 0.030, respectively. A high value of γ (0.809) i.e., the ratio of the variance of the farm-specific TE to the total variance of output shows that about 81 per cent of the difference between the observed and the frontier output was mainly due to inefficient use of resources which are under the control of the sample farmers. Table 6 shows the frequency distribution of estimated technical efficiency for the groundnut growers across the farm size

TABLE 6. TECHNICAL EFFICIENCY BY FARM SIZE GROUPS – GROUNDNUT

(households in per cent)

Levels of T.E. (per cent) (1)	Farm size groups Marginal (2)	Small (3)	Semi-medium (4)	Medium (5)	Large (6)	All (7)
<70	25	21	25	33	19	25
70 to 80	13	7	8	20	31	17
80.1 to 90	50	50	42	27	25	37
> 90	13	21	25	20	25	22
Mean TE	0.80	0.83	0.79	0.76	0.80	0.80
N	8	14	12	15	16	65

groups. The estimated TE ranged from 76 per cent of the potential yield on medium farms to 83 per cent on small farms with an average of 80 per cent for all the farms. It is observed that about a quarter of the farms realised less than 70 per cent of the potential production whereas, 22 per cent of the farms harvested more than 90 per cent of the potential groundnut production.

Cotton

The area under cotton crop, human labour, bullock pair-hours and NPK quantity used are used as input variable in the stochastic production function. Two of the four variables, namely, area and plant nutrients are found to influence the cotton output (Tables 2 and 3). The function indicated decreasing returns to scale (sum of coefficients is 0.889).

The ratio of the variance of the farm-specific TE (σ_u^2) to total variance (σ^2) of output shows that as much as 95 per cent of the difference between the observed and the potential (frontier) output is due to inefficient use of resources which are at the disposal of the farmers. Mean TE varied from 80 per cent for medium farmers to 94 per cent on marginal farmers (Table 7). It is interesting to note that more than 40 per cent of the farmers are operating near the frontier or harvesting 90 per cent or more of the potential cotton output as against 13 per cent of the farmers realised only 70 per cent of the potential output. Thus there is a scope to bridge the gap between the actual realised and the potential output with the given technology by using available resources more efficiently.

TABLE 7. TECHNICAL EFFICIENCY BY FARM SIZE GROUPS – COTTON

(households in per cent)

Levels of T.E. (per cent) (1)	Farm size groups: Marginal (2)	Small (3)	Semi-medium (4)	Medium (5)	Large (6)	All (7)
<70	0	14	20	23	0	13
70 to 80	0	29	10	23	8	16
80.1 to 90	33	29	20	31	33	29
> 90	67	29	50	23	58	42
Mean TE	0.94	0.83	0.86	0.79	0.89	0.85
N	3	7	10	13	12	45

IV.3. Determinants of Technical Efficiency

Crop output is conditioned by the distribution of rainfall, incidence of diseases and pests, soils and numerous socio-economic factors. A simple linear regression was used to identify the socio-economic factors that influence the technical efficiency of the farm households.

The model explained the variation in Technical Efficiency on the sample farms (in terms of R^2) ranging from 24 per cent for rice to 38 per cent in the case of groundnut. As expected, some of the variables have a priori signs for all the crops. Rental value per hectare of gross cropped area was positively related with the technical efficiency and coefficient was statistically significant for most of the crops (Table 8). It can be inferred that technical efficiency was influenced by the quality of land as rental value was assumed to reflect the land/soil quality (better land commands higher rent). Similarly, presence of educated adult in the family adds to the efficiency in crop production. Education helps not only in better crop management decisions, but also facilitates access to information from different sources (Tilak, 1993). The contribution of female work force to Technical Efficiency was positive and significant in case of paddy and groundnut. Completion of farm operations during the specific time period are very crucial, however, it becomes increasingly difficult to complete some of the critical farm operations within time as farm size increases. The delay in timely application of inputs and completion of farm operations during critical periods on large farms might influence efficiency negatively.

TABLE 8. SOCIO-ECONOMIC DETERMINANTS OF TECHNICAL EFFICIENCY

Variables	Crops			
	Rice	Sorghum	Groundnut	Cotton
(1)	(2)	(3)	(4)	(5)
Intercept	88.732	83.895	87.148	81.305
Rental value of land	0.0003	0.0050	0.0011	0.006
	(1.974)	(3.101)	(1.673)	(3.057)
Percentage of female workers in the family	1.9805	-3.0608	5.7436	1.707
	(2.4011)	(1.022)	(3.078)	(0.285)
Percentage of children in the family	0.3921	3.1263	0.3458	-15.920
	(0.401)	(1.796)	(0.141)	(2.226)
Presence of educated member in the family	1.0616	3.4914	2.8975	2.992
(above primary level)	(2.533)	(2.413)	(3.747)	(1.058)
Farm size	0.2284	-0.1261	-0.2669	-0.361
	(1.571)	(0.274)	(1.002)	(0.381)
R^2	0.241	0.268	0.382	0.364

Note: Figures in parentheses are t values.

V

SUMMARY AND CONCLUSIONS

We have estimated farm-specific technical efficiency for rice, sorghum, groundnut and cotton using Stochastic Frontier Production Function approach. Further, we attempted to identify the determinants of technical efficiency. We have used the farm level cross section data collected by the University of Agricultural Sciences, Bangalore under the scheme of Cost of Cultivation of Principal Crops.

The analysis of technical efficiency indicated that there is a considerable scope to improve the productivity levels of both food as well as cash crops with the existing level of input use and the available technology. The (in) efficiency estimated here, is in relation to the 'best peer' who also operate under similar environment and not with any standard norm. Land input (area), human labour and plant nutrients influence the output of food and cash crops under study. The average efficiency levels of growing rice (HYV *kharif*) ranged from 79 per cent on marginal farms to 86 per cent on semi-medium and medium farms. The technical efficiency for growing sorghum (local *rabi*) varied from 80 per cent on semi-medium to 86 per cent on medium farms. On an average, groundnut growers are operating at 80 per cent level of efficiency and it ranged from 76 per cent on medium farms to 83 per cent of the potential output on small farms. Wide variations are observed in the levels of efficiency in the case of cotton and it varied from 79 per cent on medium farms to 94 per cent on marginal farms. A sizeable proportion of farmers are found to operate at an efficiency level of less than 70 per cent of the potential.

Quality of land represented in terms of rental value and presence of educated adult in the family influences the level of efficiency whereas increase in the farm size tends to reduce the efficiency level. One policy implication from the present study is that the strengthening of extension and educating the farmers may improve the efficiency of the farmers, which would lead to increased productivity and augment agricultural production. The decisive factor of production in improving the welfare of poor people is not space, energy and cropland; the decisive factors are the improvement in population quality and advances in knowledge (Schultz, 1981). Thus, the need for improving basic education attainment and extension services need not be overemphasised here.

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NOTES

1. Marginal: below 1 ha; small:1-2 ha; semi-medium: 2-4 ha; medium:4-10 ha and large: more than 10 ha.
2. The child and female labour hours were converted into male equivalent labour hours using wage rates as weights.

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ANNEXURE I

IMPORTANT FEATURES OF AGRO-CLIMATIC REGIONS/ZONES OF KARNATAKA

Zones* (1)	Districts (2)	Annual Rainfall (mm) (3)	Soils (4)	Major crops (5)
1. NETZ	Total 7 taluks consisting of entire Bidar and 2 taluks of Gulbarga	830-930	Shallow to medium black, mostly clay and lateritic in some areas	Sorghum, pulses, oilseeds, pearl millet, sugarcane
2. NEDZ	Total 11 taluks consisting of 3 taluks of Raichur and entire Gulbarga district except 2 taluks	633-807	Deep black, shallow and medium black in minor pockets	Rabi sorghum, oilseeds, pulses, cotton and pearmillet
3. NDZ	Entire Bijapur, Bagalkot, Bellary, Koppal and parts of Raichur, Gadag, Dharwad, Belgaum adding up to 35 taluks	465-786	Shallow to deep black clay in most of the areas.	Rabi sorghum, maize, pearmillet, groundnut, cotton, wheat, sugarcane and tobacco
4. CDZ	A total of 17 taluks comprising entire Chitradurga district and parts of Davangere, Hassan, Chickmagalur and Tumkur districts.	454-718	Mostly red sandy loam with shallow to deep black in remaining areas	Rice, ragi, sorghum, pulses and oilseeds
5. EDZ	Has 24 taluks from Bangalore, Tumkur and Kolar districts.	679-889	Red loamy in major areas, lateritic in remaining areas	Ragi, rice, pulses, maize, mulberry and oilseeds
6. SDZ	Has 18 taluks forming parts of Mysore, Tumkur, 7 taluk of Mandya, 1 taluka from Hassan and entire Chamrajanagar	670-888	Mostly red sandy loam with black soils in some areas	Rice, ragi, pulses, other millets and sugarcane
7. STZ	Parts of Hassan, Chickmagalur, Shimoga and Mysore and small portion of Tumkur district representing 14 taluks.	612-1054	Red sandy loam is predominant with black soils in some pockets. of the region.	Rice, ragi, pulses, tobacco and sorghum
8. NTZ	Belgaum, Haveri, Gadag and Dharwad district adding up 14 taluks.	619-1303	Shallow to medium black clay and red sandy loam in equal proportions.	Rice, sorghum, groundnut, pulses, tobacco and sugarcane
9. HZ	Has 22 taluks from Belgaum, Shimoga, Haveri, Uttar Kannada, Chickmagalur, Kodagu districts and 1 taluk of Hassan district.	904-3695	Red clay loam in major areas	Rice and pulses
10. CZ	Parts of Uttar Kannada, entire Udupi and Dakshin Kannada districts with a total of 13 taluks.	3011-4694	Red lateritic and coastal alluvial	Rice, pulses and sugarcane

Note: 1. NETZ: North Eastern Transitional Zone; 2. NEDZ: North Eastern Dry Zone; 3. NDZ: North Dry Zone; 4. CDZ: Central Dry Zone; 5. EDZ: Eastern Dry Zone; 6. SDZ: Southern Dry Zone; 7. STZ: Southern Transition Zone; 8. NTZ: Northern Transition Zone; 9. HZ: Hilly zone and 10. CZ: Coastal Zone.