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Comparative Study on Technical Efficiency of Paddy Production Under Major and Minor Irrigation Schemes in Anuradhapura District

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ABSTRACT. This paper investigates the resource use characteristics and technical efficiency of paddy production in the Rajangana major irrigation scheme and the Elayapattuwa minor irrigation areas in the Anuradhapura district. Data used in this study were obtained from a survey of stratified randomly selected 97 farmers during December 2001. The analytical framework used in this study was the maximum likelihood estimates of the Stochastic Frontier Model estimated with the "Frontier 4.1" computer software package. Results of the study indicated substantial differences in productivity, resource use and technical efficiency in two types of irrigation schemes. Paddy productivity in Rajangana scheme (4204 kg ha^{-1}) was 14% higher than in the minor irrigation schemes (3599 kg ha^{-1}). The average technical efficiencies of paddy production was found to be 78% and 57% in the major and minor irrigation schemes, respectively. The low asset level of the farmers and poor participation in farmer organization activities had a significant influence on the technical efficiency among the farmers in Elayapattuwa. Further, it was also evident that part time farming was associated with a higher level of inefficiency in both study areas. These results suggest that increasing technical efficiency is the most appropriate means of enhancing paddy production in the irrigation schemes. Given the importance of the minor tanks in paddy production in Sri Lanka, major attention should be paid to raising their level of technical efficiency.

INTRODUCTION

The agriculture sector has continued to play a leading role in the economy of Sri Lanka. It contributed 19.4% of the total Gross Domestic Product (GDP) while paddy production independently contributed 3.5% of the total GDP (Central Bank of Sri Lanka, 2001). Recently, the drop in domestic production and import restrictions through licensing requirements raised rice prices sharply in the domestic market. In the wake of these increasing prices, the cooperative wholesale establishment and the private sector were allowed to import rice on a duty free basis towards the latter part of the year (Central Bank of Sri Lanka, 2001). In view of the growing competition due to an open market and high production costs, production efficiency becomes an important determinant of future of paddy production in this country. The efficiency of rice production can be measured by the competitiveness coefficient (CC). This coefficient is indicative of varying levels of production efficiency and estimates of average CC for rice was 0.46-0.65 during 1990-1998. These values state that at a country average level, one rupee worth of resources

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produce less than 0.65 cents worth of paddy (Department of Agriculture, 2000). This is a clear comparative disadvantage. The low comparative coefficients show that Sri Lanka's rice sector is still characterised by high cost of production and low yields.

In Sri Lanka, paddy is grown under the three modes of water supply, namely major irrigation (471,000 ha), minor irrigation (191,000 ha) and rainfed area (230,000 ha.) (Department of Census and Statistics, 2002). Average yield for major and minor irrigation schemes are 4286 kg ha^{-1} and 3562 kg ha^{-1}, respectively (Central Bank of Sri Lanka, 2001). The constraints associated with paddy production can be categorized as socio- economic constraints like high cost of inputs and land fragmentation and technical constraints such as low fertility of lands and water scarcity. The high cost of production especially due to increase in labour wages, machinery and agro-chemical costs directly impact on the profitability of paddy production. In addition, farmers do not identify the production possibilities open to them. There is a wide belief that it is very difficult to increase productivity without increasing the inputs.

Given the high cost of production and stagnation in productivity in paddy cultivation, improving efficiency is important to increase paddy production in Sri Lanka. Analysis of efficiency is vital in development policy formulation to increase paddy production. However, only very few studies have been carried out with regard to level of efficiency that may exist under major and minor irrigation schemes in Sri Lanka. Bogahawatte (1982) investigated the efficiency of farm holding size and tenancy status in Giritale, in the Polonnaruwa district. Ekanayake and Jayasooriya (1987) and Karunaratne and Herath (1989) studied the technical efficiency at the head end and the tail end of the irrigation scheme of Mahaweli H system. Technical efficiency of tomato production under protective culture and potato production have studied by Gunaratne and Weerakkody (2000) and Amarasinghe and Weerahewa (2000), respectively. They found significant output increases could be secured without adding any inputs. Further they found training to be the key to improve the technical efficiency in production.

Thus, the objective of this study was to investigate the resource use characteristics, productivity and technical efficiency under the Rajangana major tank and the minor tanks in Elayapattuwa agrarian services area in the Anuradhapura district. The study also aims to suggest policy recommendations for improving the efficiency of resource use and productivity in paddy production in the irrigation schemes.

METHODOLOGY

The theoretical model

Although productivity and efficiency are often used interchangeably; they are not precisely the same. Productivity measurement assumes that each firm exhibits optimising behaviour, and the observed output, inputs, and price data are assumed to be the result of such behaviour. Productivity growth may be achieved through either technological progress or efficiency improvement. However, technical efficiency measurements deal with the same production frontier to reflect the ability of a firm to obtain maximum possible output from a given set of input levels. Technical efficiency examines the production side, in particular input use and is independent from the costs associated with production. It bears more implications on sustainability as it deals with better use of resources without moving towards advanced technology. The conventional production function approach of productivity measurements has the weakness of not taking into account inefficiency effects. Despite this weakness they provide valuable information on technology and scale of operation. It is also important to distinguish technical efficiency from technological change. Technical efficiency denotes the firm's ability to produce maximum output given a set of inputs and technology. On the other hand, technological change denotes an upward shift of the production function or a downward shift of the unit isoquant. This study focuses on the technical efficiency of paddy farming in major and minor irrigation schemes.

Technical efficiency of a farm is defined in terms of the ratio of the observed output (Y_i) or input (X) to the corresponding frontier output (Y*) or input (X*). Farrel (1957) defined technical efficiency, as the ratio of inputs required (X*) to produce Y* to the inputs actually used (X) to produce Y*. In other words, any production process is technically efficient if output Y = Y* and technically inefficient if Y < Y* or X > X*. Thus technical efficiency is, TE = Y/Y* or TE = X/X*

Earlier production function analyses that followed Farrel (1957) were deterministic, in that they assumed a parametric form of the production function along a strict one-sided error term (Schmidt, 1976). Such forms take no account of the possible influence of measurement errors and other causes of distortions from the estimated frontier are assumed to be the result of technical efficiency. These problems were subsequently addressed to open the way to the numerous adaptations that represent the stochastic frontier function of the present day (Aigner *et al.*, 1977; Coelli, 1995).

Currently, the stochastic frontier production function is basically specified as a composed error model of the general form:

$$Ln(Y_i) = F(X_i, \beta) + \varepsilon_i \quad i=1,2....N \quad \varepsilon_i = v_i - u_i \tag{1}$$

where Y_i denotes production level, X_i is input level and (is a vector of unknown parameters to be estimated. F(.) represents an appropriate function (*e.g.*, Cobb-Douglas, transcendental, logarithmic *etc.*) and ε_i is the composed error term that equals v_i - u_i. The term v_i is a symmetric error, which accounts for random variations in output due to factors beyond the control of the farmer, *e.g.*, weather and disease outbreak, and it is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$. The term u_i is a non-negative variable representing inefficiency in production relative to the stochastic frontier. The distribution of u_i is also assumed to be independent and identical as $N(0, \sigma_u^2)$ which could be half normal at zero mean, truncated half-normal (at mean μ), and based on conditional expectation of the exponential ($-u_i$). The technical efficiency relative to the stochastic frontier e^{-U} is captured by the one-sided error component $U_i \geq 0$. When $U_i = 0$, production lies on the stochastic frontier and is technically efficient and when $U_i > 0$, production lies below the frontier and is technically inefficient.

According to Battese and Coelli (1995), technical inefficiency effects are defined by;

$$U_i = Z_i \delta_i + W_i \qquad i=1.....N \tag{2}$$

where Z represents factors contributing to inefficiency. In this study, farming experience in years, education, part time farming, asset level and membership in farmer organizations were considered as possible factors contributing to inefficiency. δ_i is a vector of known parameter to be estimated, W_i is unobservable random variables, which are assumed to be identically distributed, obtained by truncation of the normal distribution with mean zero and unknown σ^2, such that U_i is non negative.

A stochastic frontier production function can be estimated using either the maximum likelihood method or using a variant of the COLS (Corrected Ordinary Least Squares) method suggested by Richmond (1974). The original specification has been used in a vast number of empirical applications over the past two decades. The efficiency indices obtained for individual farms were subsequently regressed in a second stage against some socio-economic variables. Critics on this use of the two steps procedure noted a significant problem with this two-stage approach, *i.e.*, the assumption of independent and identical distribution of the inefficiency effects is violated in the second stage when they are made to be a number of farm specific factors with no identical distribution. In this study all parameters were estimated in a single stage Maximum Likelihood Estimate (MLE) procedure as in the computer software-FRONTIER version 4.1 (Coelli, 1994).

According to Battese and Corra (1977), the variance ratio parameter (which relates the variability (σ^2) can be calculated in the following manner;

$$\gamma = \sigma_u^2 / \sigma^2 \tag{3}$$

and

$$\sigma^2 = \sigma_u^2 / \sigma_v^2 \qquad \delta = \sigma_u / \sigma_v \tag{4}$$

where σ_u and σ_v are standard deviations of U_i and V_i, respectively and the γ parameter has value between zero and one. If γ is close to zero, the difference between a farmer's yield and the efficient yield is mainly due to statistical error. On the other hand if γ is close to one, the difference is attributed to the farmer's less than efficient use of the technology *i.e.*, technical inefficiency (Coelli, 1995). The estimates of σ^2, δ and parameter vector β are obtained by the MLE method.

Technical efficiency is measured as the deviation (e^{Ui}) of the individual farmer from the best practice frontier, which is assumed to be stochastic corresponding to additive two-sided error term V_i exogenous shock and one sided error term U_i represents technical efficiency or deviation in technical efficiency. It may be noted that the production function of the form $f(X_i\beta)\, e^{Vi-Ui}$ does not depict a purely technical relationship between inputs and outputs for the mere reason that input prices and expected product prices varied across the study area and influenced farmers' input use and production decisions. With the underlying influence of prices, efficient combinations of inputs are no longer a purely technical decision but also rely on economic judgment. Therefore, the results of technical efficiency ultimately have to be referred to in terms of economic efficiency. The combination of technical efficiency and allocative efficiency is defined as economic efficiency, where allocative efficiency deals with the optimum use of input combinations in production.

The final model was derived by, first, fitting Ordinary Least Squares (OLS) models experimentally before estimating by the maximum likelihood methods. This procedure also helped to check on econometric problems, *e.g.*, endogeneity and multicollinearity existing in the data. The multicollinearity problem was overcome by having a small number of explanatory variables and by increasing the number of the sample size. The estimated production function was of the form:

$$Ln(Y_i) = \Sigma \beta_i \quad (X_{ij}) + v_i - u_i + \Sigma \delta_j Z_j \tag{5}$$

where Y_i is (the logarithm of) kilograms of production produced by the i-th farmer, F is the Cobb-Douglas functional form; X_{ij} are the vector of (the logarithm of) inputs used by the i-th farmer, such as land area under paddy, in acres, labour in man days, cost of seed, cost of agrochemicals and cost of machinery; Z_j are variables which may influence the efficiency of the farm, such as farming experience, part time farming, asset level and membership in farmer organizations. The following hypothesis were developed and tested to investigate the problem:

1. There are no differences in resource use, productivity and technical efficiency of paddy production between cultivators in major and minor irrigation schemes.

2. Factors that contribute to such efficiency are the same for cultivators in both major and minor irrigation schemes.

Study area, sampling and data collection

The data for this study were obtained form a survey carried out during December 2001 in the Rajanganaya scheme and Elayapattuwa Agrarian Services Division in the Anuradhapura district (Fig. 1). A stratified random sampling procedure was undertaken to collect the data, where at the first stage farmers cultivating paddy in the head end and tail end were stratified. From the 18 tracts in the Rajangana scheme, 48 farmers were randomly selected from tract numbers 1, 2 ,3 and 4 of the right bank main channel. In the Elayapattuwa division, from three minor tanks, namely Wihara Kalanchiya, Wihara Bulankulama and Maha Elayapattuwa, 49 farmers were randomly selected.

RESULTS AND DISCUSSION

Paddy productivity and resource use

Data on input usage, output, and farmers' characteristics for major and minor irrigation areas are presented in Table 1. The average cultivated area were 0.99 and 0.54 ha in Rajangana and Elayapattuwa, respectively indicating greater fragmentation of land under the minor irrigation schemes. Paddy productivity in Rajangana was higher (4,204 kg ha^{-1}) than in the minor irrigation scheme (3,599 kg ha^{-1}). In Rajangana scheme, higher input usages were observed for land, material and power than in the minor tank areas. The minor

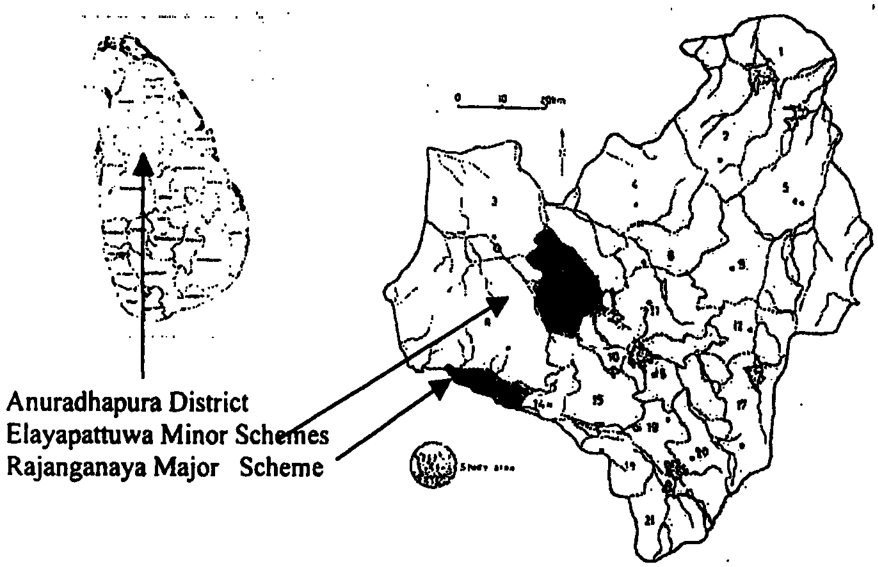

Fig. 1. Map of study area showing Rajangana, Elayapattuwa and Anuradhapura.

irrigation scheme farms were found to use 20% more labour intensively than in Rajangana. This indicates that when farmers are poor, wherever possible manual family labour is substituted ($P<0.05$). In the major irrigation scheme, a majority of the cultivators were younger and full-time farmers. Further, in the minor tank area, the cultivators were less concerned with the long-term productivity of the land. This could be the reason for low productivity in the minor tank areas.

Cost and net incomes including family labour were higher in the case of Rajangana than in the minor tank area. This was due to more long-term investment in soil and water conservation. Further, it can be seen that intensity of land use in the major tank area was 1.6 while in the minor tank areas it was 0.8 (Table 1). This reflects the existing water scarcity problem in the minor tank areas. The net returns to total cost ratios show that they were twice as large among owners than minor tank cultivators. Paddy cultivation seems to be unprofitable under minor tank areas. However, a majority of the farmers in the minor tank areas were found to cultivate paddy mainly for home consumption purposes.

Results of the efficiency analysis are presented in Table 2. The LR test values for Rajangana and Elayapattuwa are 106 and 60, respectively. These values indicate that the models had a good fit. Parameter γ is close to 1.0. This implies that the technical inefficiency effects are significant in the stochastic frontier model. The estimate parameters of the production function confirms to a priori expectation. In Rajangana scheme, the model showed land and power significantly impact on paddy production. In the Elayapattuwa minor tank area land had low positive significant effect while seed had significant negative impact on paddy production. In both areas the labour was over used thus it reflected insignificant effect on production. These reveal the problems of under utilization of land, over use of labour and use of low quality seed paddy in the minor tank areas.

Table 1. Paddy productivity, input usage and selected farm characteristics of Rajangana and Elayapattuwa minor tank areas in Anuradhapura district.

Indicators	Rajangana (n=8)	Elayapattuwa (n=49)
Average extent (ha)	0.99	0.54
Cropping intensity	1.60	0.80
Average yield (kg ha^{-1})	4,204	3,599
Labour cost (Rs. ha^{-1})	21,866 (59%)	12,818 (55%)
	46 MDs*	55 MDs
Material cost (Rs. ha^{-1})	11,055.00 (30%)	8,790.00 (37%)
Power cost (Rs. ha^{-1})	3,940.00 (10%)	1,650.00 (07%)
Soil and water conservation (Rs. ha^{-1})	340.00 (01%)	198.00 (01%)
Total cost of production (Rs. ha^{-1})	37,201.00	23,456.00
Net revenue (Rs. ha^{-1})	10,710.00	6,925.00
Net income / Total cost	0.93	0.41
Age of respondent (years)	51	60
Education $\geq$ Secondary level	85%	57%
Assets (2 or 4 wheel tractors)	31%	14%
Part time farming %	35%	56%

*MD = man days including family labour
Figures in parenthesis are % to total cost of production

Technical efficiencies of paddy cultivators in major and minor tank areas

The means and ranges of the estimated technical efficiencies for Rajangana and the Elayapattuwa minor tank areas are summarised in Table 3. The estimated mean technical efficiency exhibits a higher average technical efficiency of 79% for Rajangana, which was 22% higher than the minor tank technical efficiency. Technical efficiency ranged from 41-94% among Rajangana cultivators and it ranged from 13-99% in the Elayapattuwa area. Further, the comparison shows that larger farms are much more likely to appear efficient than small ones. Based on the mean of technical efficiency, farmers were categorized into three levels: low (<60% TE), average (61% <TE> 80%) and high (>81% TE) efficient farmers (Table 3). About 15% and 53% of the farmers had low technical efficiency in Rajangana and minor tank areas, respectively.

It is important to note that 6% of the farmers in the minor tank area had very low efficiency, which was mainly due to land degradation. About 22% and 33% of the farmers had average technical efficiency in Rajangana and the minor tanks, respectively. More technically efficient farmers (65%) were found in the major scheme compared to the minor scheme (20%). It may be inferred from this result that the 53% of the farmers in the minor tank areas who were operating at low technical efficiency should improve to reach the average technical efficiency. However, due to microenvironment and soil condition differences all the farmers cannot attain higher or close to average technical efficiency and the best farmers possibility to reach 100% of the present technology also cannot be expected. The average yield of the best farmers who represent 20% and 65% of the population in the Rajangana and minor tank areas should be improved through technological change in seed, appropriate mechanization and wise use of irrigation water. A two sample t-test shows the two efficiency levels are significantly different ($P<0.05$).

Table 2. Maximum likelihood estimates for parameters of stochastic frontier production function and inefficiency function for Rajangana and Elayapattuwa area (*Maha* 2000/01).

Variables	Parameters	Rajangana Coefficient	(t-ratio)	Elayapattuwa coefficient	(t-ratio)
Stochastic frontier					
Intercept	β_0	0.460	(0.528)	0.696	(0.127)
Land (ha)	β_1	0.337**	(2.640)	0.265*	(1.968)
Labour (man day)	β_2	0.239	(1.937)	-0.119	(0.106)
Power (Rs.)	β_3	0.174***	(3.157)	0.095	(0.961)
Agro-chemicals (Rs.)	β_4	-0.145	(-0.115)	0.198	(0.150)
Seeds (Rs.)	β_5	0.7332	(0.693)	-0.265*	(-2.174)
Inefficiency effects					
Education	δ_1	0.140	(0.580)	0.931	(0.287)
Farm assets	δ_2	-0.323**	(-2.403)	-0.135	(1.452)
Experience (years)	δ_3	0.4616	(0.153)	0.1461	(0.743)
Farmer organisation	δ_4	-0.349**	(2.229)	-0.346*	(-2.013)
Part time farming	δ_5	0.005*	(2.070)	0.153*	(1.945)
Total variance	σ^2	0.276	(0.107)	0.346	(0.022)
Variance ratio	$\gamma = \sigma^2_s / \sigma^2$	0.963***	(0.242)	0.911***	(0.197)
Log likelihood (LLF)		-0.339		0.403	
LR test		106		60	
Number of iterations		20		58	

*** Significant at $P<0.01$. ** Significant at $P<0.05$. * Significant at $P<0.10$.

Table 3. Distribution of technical efficiency level among major and minor irrigation schemes in Anuradhapura district.

Technical efficiency (%)	Number of farmer (%) Rajangana (major)	Minor tanks (minor)
Low <20	00 (00)	03 (06)
21-40	01 (02)	07 (14)
41-60	06 (13)	16 (33)
Average 61-80	10 (22)	14 (29)
High >80	31 (65)	09 (20)
Maximum	0.94	0.97
Minimum	0.41	0.13
Average	0.79	0.57

Factors affecting technical efficiency

Causes of inefficiency in farms were determined with the production frontier in a single stage maximum likelihood estimate (Table 2). The inefficiency model reveals that inefficiency exists more among the minor tank area cultivators. Farmers' assets level had a significant impact on technical efficiency in Rajangana but not in Elayapattuwa.

This suggests that farmers with more asset base are efficient in the major scheme but not in the minor irrigation schemes membership in farmer organizations was found to be the key variable that improves the technical efficiency in both study areas. Reduction of inefficiency with participation in farmer organization activities was shown with higher and negative significance level in Rajangana, and in the Elayapattuwa area it showed a negative sign but low significant level ($P<0.10$). Further, the part-time farmers were associated with higher level of inefficiency in both study areas. The other variables such as education and experience in farming did not affect the variation in farm efficiency significantly.

CONCLUSION AND POLICY IMPLICATIONS

This study has examined the issues of productivity and efficiency differentials in paddy cultivation between Rajangana and the Elayapattuwa minor irrigation areas in the Anuradhapura district. The stochastic frontier production technique was used to examine the technical efficiency of 97 farmers. Results from the study indicated a substantial difference in productivity and efficiency between these two types of irrigation schemes. Further, results indicated an under utilisation of land and other resources in most areas in the minor irrigation schemes. The under utilisation arises due to water shortages and fragmentation of land. Thus, land cultivation could be further improved by improving water availability through rehabilitation and land consolidation programs.

The stochastic frontier production function results demonstrate that farmers were 22% more technically efficient in the Rajangana major irrigation scheme compared to the minor irrigation schemes. The average efficiency of paddy farmers in major and minor irrigation schemes were 79% and 57%, respectively. About 53% of the farmers in the minor irrigation scheme were operating at the average technically efficient level. Many farmers however showed potential for further increases in yield in relation to the best practice technology.

Farmers' asset level and membership in farmer organisation activities mostly in the major schemes had significant impact on productive efficiency among cultivators. Full time farmers were found to be more efficient than part time farmers. Following the hierarchy of efficiency levels revealed by the results of this study could be speculated that farmers need more training to improve their farming skills than they need new technologies. These can be achieved through becoming member in the farmer organizations. Since the study indicates that participation of farmers in farmer organization is important in increasing technical efficiency, further research is required to study factors hindering farmers in participating in farmer organization activities.

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