ROTATIONAL TENURE AND LAND PRODUCTIVITY: FARM LEVEL EVIDENCE FROM LOW COUNTRY WET ZONE PADDY LANDS IN SRI LANKA

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Abstract

Rotational tenure systems of *Thattumaru - Kattimaru* is a special system which is peculiar to certain parts of the country specially the Mid and Low country Wet zone paddy lands. Even though the original features are slowly waning, it still survives most persistently in areas where land is limited, and agriculture remains the predominant occupation. Therefore, this study was conducted to determine the paddy production performance and resource use efficiency in the rotational tenure paddy lands.

Data from comprehensive field survey conducted in Ratnapura, Kalutara and Galle districts in 2018/2019 Maha and 2019 Yala season was used for the study. Technical efficiency and determinates of the efficiency were estimated using stochastic frontier approach. Results of the efficiency analysis reveal that inefficiencies do exist in paddy production under rotational tenure and estimated production loss due to inefficiencies is 45 percent. Land, labour and seeds have significant impact on the yield. Level of productivity can be enhanced making relevant resource adjustment while combining it with social factors.

Keywords: *Rotational tenure, Thattumaru-Kattimaru, Paddy production, Technical efficiency, Stochastic frontier*

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INTRODUCTION

Apart from the different land transfer and user rights administered by the government agencies, there are varieties of informal land arrangements that have been developed over time to own, manage and access the agricultural lands to meet specific needs. *Thattumaru-Kattimaru* tenure systems is a rotational land tenure system mainly concentrated in mid and low country wet zone paddy lands and the quiddity of *Thattumaru-Kattimaru* land tenure is the annual rotation between persons of rights to cultivate a given piece of land. In 1870, the total population of the country was 2.7 million and the per capita land area was 2.7 ha (Mapa *et al*, 2002). According to the 1982 Agricultural Census and Statistics, 42 percent of the farmers owned land area less than one acre while percentage of farmers having less the two acres is 82 percent. Most importantly, 27 percent of the farmers are land-less (ebid). At present, with an estimated population of nearly 22 million (Central Bank of Sri Lanka, 2020) the per capita arable land area is about 0.15 ha. This indicates the heavy pressure on agricultural lands. Such unbearable pressure created on land due to population growth over the generations in the wet zone of Sri Lanka has led to development of traditional agricultural land tenure systems called *Thattumaru* and *Kattimaru*. Under this traditional method of land tenure, the lands are not divided but held jointly by several owners, each of whom takes over a small area in rotation depending on his share in the joint holding (Raza, 1970). This system of tenure mostly prevails in the wet zone districts like Ratnapura, Kegalle, Galle, Kalutara and Matara.

The principle behind *Thattumaru* is that rights to cultivate a piece of paddy land are shared among two or more persons in an annual rotation. Instead of physically dividing the land, the persons with cultivation rights take turns to cultivate the land each year. In the case of *Kattimaru*, tenure land is subdivided at the death or retirement of its owner among his heirs, instead of permanent ownership rights to a particular land plot, each heir has the right to cultivate in turn each of the plots into which the estate has been divided. In addition, a more complex system of rotational tenure called *Karamaru* exists where both *Thattumaru* and *Kattimaru* are jointly operated in a single case. It is difficult to understand and explain the operating system of *Karamaru* as it is a combination of *Thattumaru* and *Kattimaru*. The basic idea of *Thattumaru* and *Kattimaru* system was to avoid over-fragmentation while maintaining a high degree of equity. The original nature of the systems has changed as land productivity has drastically reduced due to changing environmental and socio-economic conditions (Moore & Wickremasinghe, 1978).

Even though the original features are slowly waning, it still survives most persistently in areas where land is limited, and agriculture remains the predominant occupation. Although the Dry Zone produces the bulk of paddy, Wet Zone production constitutes an important buffer in the context of household food security. Declining productivity and abandonment have however raised questions regarding relevance even though these arrangements were certainly appropriate to the social, economic and technical context of an earlier era. The major drawback identified in the rotational agricultural system at present is low land productivity and subsequent abandonment of paddy lands. Weerawardena & Collonnege (1971) highlighted that *Thattumaru* and *Kattimaru* system of land tenure makes implementing legislative provisions difficult by creating obstacles in security of tenancy rights and preparation, and revision of the paddy lands registry, operation of the irrigation ordinance and Crop Insurance Act. In addition, over fragmentation and co-ownership of paddy land parcels has created several other disadvantages such as low irrigation efficiency, low labour efficiency and problem of accessibility, land protection and land insecurity, limited period of operation and finally all these have led to abandonment of the land (Raza, 1970; Weerawardena & Collonnege, 1971; Moore & Wickramasinghe, 1978; Witharana, 2014).

With this background, this study assumes that land insecurity, uncertainty, low land value, low labour efficiency and limited period of operation have led to control or reduce the usage of inputs. Subsequently, this has resulted in a significantly reduced output. In such circumstances, the operation and maintenance of paddy fields and associated irrigation systems are also affected, and the sustainability of these systems is also threatened. The study is attempting to establish a relationship between land ownership and technical efficiency in rice production in Wet zone paddy production systems in Sri Lanka. It is expected to lead the policymakers to decide where the future resources should be allocated to improve rice productivity. Hence, the primary objective of this study is to estimate technical efficiency of rotational land tenure paddy farmers that could contribute in explaining the yield gap and to determine the role of ownership in improving technical efficiency and rice productivity.

THEORETICAL BACKGROUND

The efficiency of a production unit can be defined as effective use of variable resources for the purpose of profit maximization under the best production technology available. Technical efficiency refers to a farm's ability to achieve the maximum output for a given set of inputs and technology (Färe & Lovell, 1978). Literature related to production economics highlighted that, the use of prevailing technologies is more cost effective than investing in new technologies in the context of using available technologies inefficiently in the cultivation process (Belbase & Garbowski, 1985; Shapiro, 1977). From an applied perspective, measuring efficiency is important because this is one of the best options available for resource poor farmers and can be considered as the first step in a process that might lead to substantial resource savings that has implications for both policy formulations and management.

The measurement of technical efficiency is a popular concept in the theory of production economics and well-studied in the literature and provides a range of methodologies. A variety of mathematical research models have been developed and used in quantitative research in the microeconomics of farm production. But the choice of functional form in an empirical analysis is crucial because it makes a significant effect on the results. In the context of productivity, output can be varied mainly due to three reasons, including fluctuations in inputs, technical inefficiency and random shocks. The contribution of inputs can be captured through a production function specification. There are various functional forms for estimating the physical relationship between inputs and output. Cobb-Douglas production function is preferable to other forms to measure the variation in output by different producers, caused by technical inefficiencies, if there are three or more independent variables in the model (Hanley and Splash, 1993). In most microeconomic analysis, production functions are estimated under the assumption that producers are rational in maximizing their profit and operate within their production frontiers. However, Farrell (1957), Aigner et al (1977), Meeusen and Van den Broeck (1977), and Battese and Coelli (1995) support the view that producers differ in the measured output that they produce from a given bundle of measured input, or alternatively, in the input requirements to produce a given output.

DATA AND METHODOLOGY

Data

Based on the land ownership records maintained by the Department of Agrarian Development, three districts, Ratnapura, Kalutara and Galle were selected for the study considering the high prevalence of the *Thattumaru-Katimaru* tenurial system (Moore & Wickramasinghe, 1978; Witharana, 2014). Within districts, Agrarian Services Centers were chosen based on the land extent under each tenure arrangement. A final Agrarian Research and Production Assistant (ARPA) area to implement the survey was selected with the consultation of the officials of respective ASC. From each district fifty farmers who have cultivated *Thattumaru* and *Kattimaru* land plot in the nearest cultivation year (2018/2019 *maha* and 2019 *yala* seasons) were randomly selected for the survey. Pre-tested structured questionnaire was deployed to collect primary information related to demographic, production and social factors related to the objectives of the study.

Model specification

In stochastic frontier approach, one of the parametric approaches, variation in output due to technical inefficiency and random shocks can be decomposed. Since farmers always operate under uncertainty, this study employs a stochastic production frontier approach introduced by Aigner et al. (1977); and Meeusen and Broeck (1977).

Stochastic frontier function can be expressed as;

$$y_i = f(x_i, \beta) + \varepsilon_i$$

$$\varepsilon_i = v_i - u_i; \qquad i = 1,2,\dots,N \; \dots\dots\dots \; (1)$$

Where, Y_i is production of the i^{th} farm, x_i is vector of inputs of production of the i^{th} farm, β is a vector of unknown parameter to be estimated. ε_i is the composed error term consist of two independent elements u and v. v_i is the error term of i^{th} producer for all possible random variation in output due to factors outside the farmer's control such as weather and pest and diseases. It is assumed that distributer normally, identically and independently with 0 mean and σ_v^2 variance, N (0, σ_v^2). u_i is a non-negative error term denoting inefficiency of the i^{th} producer, which Aigner et al., (1977) assume having either half normal or exponential distribution. In this study, the distribution of u_i is assumed as half-normal and identical, N (0, σ_u^2).

Equation (1) specifies the stochastic frontier production function in terms of the original production values. The technical inefficiency effect, U_i, in the stochastic frontier model (1) can be specified as:

$$u_i = z_i\delta + w_i \quad \text{...} \quad (2)$$

Where δ is the inefficiencies that farmer have controlled and w_i is the random error.

Stochastic frontier functions can be estimated using the maximum likelihood method. According to Battese and Corra (1977) the variance ratio parameter (γ), which relates the variability of u_i (σ_u^2) to total variability can be calculated as follows;

$$\gamma = \frac{\sigma_u^2}{\sigma^2}$$

$$\text{Where, } \sigma^2 = \sigma_u^2 + \sigma_v^2 \quad \text{..} \quad (3)$$

So that, $0 \leq \gamma \leq 1$

In the case of σ_v^2 = 0, γ would be equal to 1 and all the differences in the producer yield and efficient yield is a result of management factors under the control of the producer. In the case of σ_u^2= 0, γ would be equal to 0, which means all the differences between farmer's yield and efficient yield is due to factors that the producer has no control over.

Hypothesis Testing

H_0; $\sigma^2 = 0$

H_1; $\sigma^2 > 0$

Where, γ statistics is used for hypothesis testing. If likelihood ratio (LR) > χ^2, null hypothesis (H_0) is rejected. It means that there are inefficiencies, and the function could be estimated using Maximum Likelihood Methods. If H_0 is not rejected, the Ordinary Least Square Method gives the best estimation of the function.

Estimation Procedure

The Stochastic frontier production function of Cobb-Douglas type is defined in logarithmic form as;

$$\ln Y = \beta_0 + \beta_1 \ lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + (v_i - u_i) \text{... (4)}$$

The Stochastic frontier production, defined in equation (4), is a linearized approximation of a Cobb-Douglas production function. In the Stochastic frontier,

Y =Paddy output (kg/ac)

X_1 = Land size (ac)

X_2 =Quantity of seed (kg/ac)

X_3 = Quantity of fertilizer (kg/ac)

X_4 =Family labour (man-days/ac)

X_5 =Hired labour (man-days/ac)

Causes of Inefficiency

The level of efficiency differs from farm to farm, and it depends on both farm and farmer characteristics. Technical inefficiency (U_i) could be estimated by subtracting technical efficiency from one. The inefficiency estimates coming from the frontier production function implies the contribution of farmer related exogenous variables on inefficient usage of inputs. Depending on the co-efficient calculated for these exogenous variables, the inferences could be drawn (equation 5). Negative co-efficient of an inefficient variable implies the reduction of inefficiency with the presence of the respective exogenous variable.

$$U_i = \delta_0 + \sum_{j=1}^{7} \delta_j Z_{ji} \text{ .... (5)}$$

Where, δ_j is the coefficient of explanatory variables and t inefficiency variables considered in this analysis are;

Z_{1i}= Age of the farmer (years)

Z_{2i}=Education level (years)

Z_{3i}=Dummy variable for type of primary employment (Agriculture =1; otherwise=0)

Z_{4i}=District 1 dummy variable (If district is Galle = 1; otherwise = 0)

Z_{5i}=District 2 dummy variable (If district is Ratnapura = 1; otherwise = 0)

Z_{6i}=Type of involvement in paddy farming (Full time =1; otherwise = 0)

Z_{7i}=*Thattumaru* - *Kattimaru* rotation in years

The study employed Frontier 4.1 software developed by Coelli (1996) which software which can estimate the coefficient of production function and inefficiency effect model simultaneously.

RESULTS AND DISCUSSION

Demographic characteristics of the rotational tenure farmers in the study area

Average family sizes of the rotational tenure farmer are 4.1, with around 47 percent of the households having more than five members. Majority of the sample rotational tenure farmers (62 percent) are above 60 years of age highlighting less involvement of youth in paddy farming under rotational tenure (Table 1). All the farmers in study locations have relatively high levels of education, non-agricultural employment, and part time paddy farming. Agriculture is the primary source of income for the majority of the farmers, but agriculture based on paddy is not the main contributor to the total agricultural income for most of them due to small land holdings, rotational nature of cultivation and lack of marketable surplus from paddy farming. Tea, Rubber and Cinnamon cultivation are the main agricultural income sources for the majority of the farmers.

Table 1: Descriptive statistics of the variables used in the model

Variable	Mean	Std. Dev.	Min	Max
Education of farmer head (in years)	9.84	2.83	1	20
Age of farmer head (in years)	63.30	10.44	38	87
Farming experience (in years)	35.98	15.76	4	65
Paddy extent under cultivation (ac)	0.90	0.66	0.125	5
Avergae yield (kg/ac)	1116.86	391.41	336	2200
seed rate(kg/ac)	41.25	7.37	17.5	66.67
Chemical fertilizer (kg/ac)	109.79	34.39	20	225
Family labour (mandays/ac)	11.25	6.68	2	44
Hired labour (mandays/ac)	10.59	9.71	0	61

Source: Authors' estimations

Input output relationship

Individual farm level efficiency was estimated for Kalutara, Galle and Ratnapura districts. Cultivation data for the nearest cultivation season at the time of data collection was considered for the analysis. The summary results of the analysis are shown in Table 2.

The results in Table 1 show that γ value for two districts are significantly different from zero, hence the null hypothesis $\gamma = 0$ was rejected at the 1 percent significance level. Thus, it can be concluded that technical inefficiencies do exist in paddy cultivation in *Thattumaru* and *Kattimaru* lands in selected districts of wet zone. According to the 1 percent significance, 99 percent of the random variation in paddy production was explained by the model. The observed variations in production efficiency among paddy farmers were mainly due to differences in farm practices of sample farmers rather than random factors that are not within the control of farmers.

One-sided LR tests of $\gamma = 0$ provide statistics of 25.726 for the models and that exceeds the chi-square critical value at five per cent. Hence, the stochastic frontier model does appear to be a significant improvement over an average production function.

Table 2: Estimated Coefficients of the Frontier Analysis

Parameter	**Coefficient**	**SE**	**t-ratio**
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.131	0.019	6.67*
$\gamma = \sigma_u^2 / \sigma^2$	0.99	0.19E-05	0.53 E+06*
Log likelihood	- 33.059		
LR test	25.726		
Variables in the production function			
Seeds	0.606	0.048	12.559*
Fertilizer	0.017	0.094	0.184
Hired labour	0.008	0.013	0.622
Family labour	-0.059	0.031	-1.910***
Land	-0.131	0.065	-2.000**
Determinants of the inefficiency			
Galle District	-0.431	0.139	-3.091*
Ratnapura District	0.056	0.097	0.573
Age	0.006	0.004	1.720***
Education	1.290	0.017	0.740
Primary employment	0.009	0.117	0.079
Involvement in paddy cultivation	-0.074	0.098	-0.757
Thattumaru - *Kattimaru* rotation in years	-0.009	0.022	-0.424

*Significant at 1% level, **significant at 5% level, significant at 10% level

Source: Authors' estimations

Estimated coefficient for the variable representing seed quantity used was positive and significant at one percent significant level implying that by keeping all other variables constant, 10 percent increase in quantity of seeds used will increase the paddy yield by approximately 6.06 percent on an average. Seed quantity and quality are major factors that contribute to the ultimate yield. Though almost all the farmers' practice broadcasting as a labour-saving technique, it leads to higher loss of seeds before germination due to damage caused by pests, mainly the birds. Further, farmers reiterate that damage by bird increases at planting stage.

More than 99 percent of the farmers used synthetic fertilizers provided through the government fertilizer subsidy scheme. Fertilizer quantity showed a positive impact on the yield, but this relationship is not statistically significant. Yet again, hired labour man days used for cultivation practices show positive but not statistically significant relationship to the yield.

The variable family labour shows negative and a statistically significant relationship to the paddy production. By keeping all other variables constant, 100 percent increase of the family labour will reduce the paddy yield approximately 5.89 percent on an average. This is an indication of the overuse of family labour in paddy production in the study area since most of the activities that can be replaced with machinery also fulfilled by human due to lack of availability in machinery. Remarkably, extent under cultivation shows negative and significant relationship to the paddy production in rotational tenure paddy lands in Wet zone.

According to the estimated results one percent increase of land area under cultivation would lead to an approximately 0.131 percent reduction in paddy yield on an average. This finding explains that with increasing extent farmers would face difficulties in management practices, especially with poor level of mechanization and high cost of labour. Wijetunga (2011) from a study on this subject has also suggested that labour saving mechanisms should be introduced in paddy cultivation as a solution to the problem of labour shortage and accompanying high wage rates. This was further highlighted by Wijesinghe and Wijesinghe (2015) by mentioning that the degree of mechanization has a positive correlation with production and therefore mechanization when and where appropriate would enhance the paddy yield in the low country wet zone region.

Determinants of the Inefficiencies

Socio-economic factors, farm characteristics, environmental factors and non-physical factors are likely to affect the efficiency of agricultural production (Kumbhakar et al 1991). Results of the maximum likelihood estimation of the inefficiency model are summarized in Table 1. According to estimated coefficients dummy variables representing district Galle and age are the only included factors that affect the level of inefficiency persisting in the paddy production in study location.

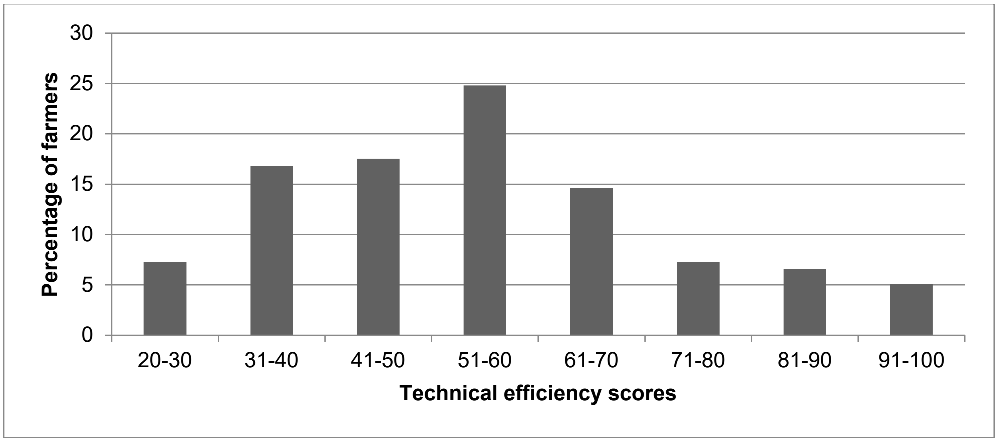
Significant relationship and positive sign of age variable indicate that young farmers are more efficient than the older farmers, which implies that younger farmers are more efficient in input usage and management practices related to paddy cultivation. It is also important to highlight that majority of the sample farmers are over 60 years of age. Hence, older farmers are less efficient because of their inabilities in actively involved in agricultural practices and they have to use hired labour which is not economical. Literature also supports this finding that the productivity of a farmer increases with age, reaches some mid age peak, and then decreases with further age (Tauer, 1995).

The Dummy variable representing Galle district has negative signs and significant relationship in inefficiency models, and it implies that the Galle district farmers are more efficient than the Kalutara and Ratnapura district farmers. Galle district farmers have the highest yield and low cost of production compared to the other two districts.

Technical Efficiency in *Thattumaru* – Kattmaru Tenure Paddy Lands in Wet Zone

Individual property rights also directly affect efficiency since efficiency required for land development and maintenance are related to land ownership-tenureship (Wijesinghe & Wijesinghe, 2015). The mean technical efficiency of *Thattumaru*- kattumaru land tenure paddy farmers was estimated as 55 percent which indicates that the average paddy farmers cultivated in rotational tenure paddy lands in selected three districts produced 55 percent of the maximum attainable output for a given input level. In other words, there is an average of 45 percent of production lost due to inefficiency.

Figure 1: Distribution of Farmers' Technical Efficiency Indices



Source: Authors' estimations

Even though the mean technical efficiency of the selected farmers under rotational land tenure was 55 percent, the value ranges from 22 percent to 100 percent. This shows a wider difference in the individual farms' efficiency level. Therefore, the mean technical efficiency level may not indicate the actual picture of the distribution of individual farm efficiency levels. Figure1 illustrates the frequency distribution of individual farms' technical efficiencies.

Returns to Scale

The summation of estimated production coefficients (β_i) indicates the return to scale. The return to scale of paddy cultivation in rotational tenure paddy lands was found around 0.441 which indicates the diminishing return to scale. It means paddy farmers allocated their resources in the rational stage of production (Stage-II) where a lower amount of return would be added to the gross return by using each additional unit of input to the paddy cultivation.

Agricultural policies tend to focus more on fostering productivity through technological change than through better use of the existing technology. However, rebalancing the focus of agricultural policies towards improving efficiency is necessary in the context of limited availability of natural resources, such as land and water, and given the necessity to limit the environmental footprint of agricultural production. Equivalent physical productivity gains and perhaps even larger economic gains may be expected from better use of existing technology than from shifting to new technology.

CONCLUSION

Production function analysis shows that technical inefficiencies do exist in paddy cultivation in rotational tenure lands in all Kalutara, Galle and Ratnapura districts. Inefficiency in paddy farming under rotational tenure causes production loss of 45 percent. Estimated coefficients related to production process shows increased usage of seed paddy which would increase the yield. Negative and significant relationship with family labour to the yield indicates the possibility of reduced use of family labour. Further, cultivation of larger land extents shows reduction in the yield.

Paddy production in the wet zone has played a significant role in sustaining people's livelihoods and providing food security. Therefore, identified barriers in improving productivity and continuous cultivation should be addressed for the sustenance of the system. Study revealed that current level of paddy yield under rotational tenure systems is much lower hence there is room to shift existing agricultural system towards more production and profit-oriented farming. Existing low levels of yield are mostly due to institutional gaps that could be addressed without increasing cost of production to farmers. Further highlighting, the inherent characters related to rotational tenure and the changes in economic and social conditions have rendered the rotational land tenure system not only economically redundant, but positively harmful to sustainable agricultural development in the present context.

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