TECHNICAL EFFICIENCY IN THE TRANSLOG PRODUCTION FRONTIER MODEL: AN APPLICATION TO THE PADDY FARMING IN KILINOCHCHI DISTRICT, SRI LANKA

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INTRODUCTION

Among the agriculture sector, the paddy sector in Sri Lanka played a significant role in supplying food requirements, contributing to the gross domestic product, and providing job opportunities for the labor force in Sri Lanka. Kilinochchi District in the Northern Province of Sri Lanka heavily depends on agriculture for economic survival. Paddy is the main crop of this district. The average yield of this paddy is 4620 kg /ha in the 2020/21 Maha season and 3500 kg/ha in the Yala season (District Handbook, 2023). However, experiencing low productivity in the agriculture sector, especially in paddy farming, is the primary factor causing poverty in the district.

Many scholars suggest in the literature that farmers in developing countries need to fully utilize technology and commit allocative errors (Basnayake & Gunaratne, 2012; Amaechi, 2014; Wudineh et al., 2016). Many studies have been carried out to analyze the efficiency of agricultural production worldwide. However, a few empirical studies have been done by researchers to estimate the technical efficiency of paddy production among smallholder farmers, particularly in the Kilinochchi district, using the stochastic frontier model. In this background, there is a need to do a study related to paddy production in the district, which may contribute to identifying the factors influencing the efficiency of the output in the area.

Technical efficiency is an essential factor that affects the amount of production in paddy, and that helps raise the farmers' income and improves their living standards. For smallholder farmers, variation in productivity due to the difference in efficiency may be affected by socioeconomic characteristics and various regional and farm-specific characteristics (Tiruneh & Geta,2016). Nowadays, smallholder farmers face the problem of inefficiency in cultivating paddy in the Kilinochchi district. Those inefficiencies may depend on factors like socio-economics, farming, and farm management practices among the farmers in the study area.

By improving their usage of inputs and their demographic and farming practice, they can improve their efficiency towards the frontier curve with given inputs and the state of technology in the future. Thus, to identify how a farmer becomes efficient and how the above factors influence technical efficiency, a study is needed to focus a study is needed to focus on these aspects in Sri Lanka. This study aims to identify the technical efficiency and determinants of paddy cultivation in the Karachchi DS Division in Kilinochchi district.

The main objective of this study is to estimate the technical efficiency and its determinants of paddy farmers in Kilinochchi district, Sri Lanka. The specific objectives are: a) To identify the factors of inputs that determine paddy production in Kilinochchi district; b) To estimate the technical efficiency scores among smallholder paddy farmers in Kilinochchi district**;** and C) To examine the impact of socioeconomic characteristics and farm management practices that influence the technical efficiency in paddy production.

METHODOLOGY

Sample farmers from the study area were selected using a multistage sampling technique. In the first stage, the Kilinochchi district was purposely selected in the country's Northern province based on the extent of paddy cultivation. Kilinochchi district has four Divisional Secretariats (DS), and in the second stage, only one DS division, Karachchi, was selected from the four divisions. In the third stage, four villages have been chosen where most farmers have been involved in paddy cultivation in the selected DS division. Finally, 120 farmers from the village cultivating paddy were randomly selected as the study sample, and those sample farmers and relevant information were gathered during the year 2022/2023.

To measure the efficiency scores of individual farmers, the Cobb- Douglas production function was used in the study where the paddy production was taken as output, and six inputs, such as land size, cost of labor, and cost of material cost, were defined as production inputs. The empirical model of the Cobb-Douglas functional form is given by:

$$lnY_i = \beta_0 + \beta_1 lnx_{1i} + \beta_2 lnx_{2i} + \beta_3 lnx_{3i} + \beta_4 lnx_{4i} + \beta_5 lnx_{5i} + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where Y_i = Production of Paddy (kg), X_{1i} = Size of land (Acre), X_{2i} = cost of labor (Rs), X_{3i} = cost of the machinery (Rs), X_{4i} = cost of fertilizer (Rs), X_{5i} = Cost of Chemicals (Rs), X_{4i} = cost of seed (Rs), β_0 = Constant term, ε_i = Error term. β_1, β_2, β_3, and β_4 are the respective unknown parameters of each explanatory variable to be estimated from the model.

The translog production function is the generalized form of the Cobb – Douglas production function used in the study to estimate the technical efficiency of paddy. The model can be shown as:

$$\ln y = \alpha + \sum_{k=1}^{K} \beta_k \ln x_k + \tfrac{1}{2} \sum_{k=1}^{K} \sum_{m=1}^{K} \gamma_{km} \ln x_k \ln x_m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where α is constant, β is the production function parameter estimated for each input, and X's are the explanatory variables mentioned in function (1). At the same time, lnY is the quantity of paddy output produced in logarithm. The following inefficiency model was estimated in the study to investigate demographic characteristics and farming characteristics affecting technical efficiency.

$\mu_i = \delta_0 + \delta_1$age + $\delta_1$gender+ δ_2 education + δ_3 household size + δ_4 farming experience + δ_5 extension services + δ_6 ownership of land + δ_7 credit access + δ_8 farm income……………...(3)

Where μ_i is technical inefficiency, and δ is the regression coefficient. Eight factors were included in the inefficiency effect model.

RESULTS AND DISCUSSION

This study seeks to estimate the technical efficiency scores and identify the determinants of technical inefficiency of paddy farmers in Kilinochchi district, Sri Lanka. The sigma squared is 0.318, statistically significant at the 1% level, indicating a good fit for the model. At the same time, the value of gamma in the model is 0.99, and it is statistically different from zero at the 1% level, which showed that 99% of the deviation in paddy output is attributed to the presence of technical inefficiency in the six inputs used during the production period. The estimated parameter gamma (γ) was close to 1.0 in the Translog stochastic frontier and statistically significant at the 1 percent level, suggesting that inefficiency effects are highly significant in the analysis of the production of paddy by the farmers.

Table 1

Results of maximum likelihood estimate of Translog production frontier

Variable	Coefficient	Std. error	t - ratio
Intercept	35.677	0.994	35.899*
ln labor (hired)	-48.766	1.025	-47.586*
ln machinery	16.906	0.955	17.699*
ln Land	0.739	78.231	0.026
ln seed	28.571	1.009	28.307*
ln fertilizer	1.016	9.727	1.044
ln pesticide	- 3.387	1.284	-2.637**
ln $Labour^2$	-0.623	0.733	-0.850
ln $Machinery^2$	0.801	0.085	9.461*
ln $Land^2$	-0.124	0.775	0.160
ln $seed^2$	2.348	0.373	6.301*
ln $fertilizer^2$	0.577	0.537	1.075
ln $pesticide^2$	-2.185	0.861	-2.538*
ln labour*ln machinery	-22.634	0.908	-24.923*
ln labour* ln Land	-3.588	0.931	-3.852*
ln labour* ln Seed	-3.554	0.804	-4.441*
ln labour* ln fertilizer	-1.467	0.902	-1.625
ln labour* ln pesticide	-0.815	1.157	-0.704
ln Machinery* ln land	2.307	1.105	2.088**
ln Land* ln seed	12.439	81.259	15.307*
ln Land* ln fertilizer	4.681	0.672	6.964*
log-likelihood function			
sigma square (σ^2)	0.318		2.826*
gamma (γ)	0.99	0.011	90.90*
Sample size	120		....

** $p<0.01$ * $p<0.05$

The above results showed that out of six inputs, labor, machinery, seed, and pesticide costs have statistically significant impacts on paddy production. At the same time, cultivated land area and fertilizer are insignificant in the study area. In the frontier model, the coefficients of labor cost were negative and significant, implying that hired labor does not effectively contribute to paddy production. The coefficients for costs of machinery and seed were positive, indicating that an increase in these input costs would increase the average production of paddy in the district. On the other hand, the negative sign of pesticides (-3.387) significantly impacts output. This may be due to the overuse of pesticides by paddy farmers (Amaechi et al., 2014).

Further, the interaction between machinery cost and labor cost and between labor and seed and labor and land have negative signs with statistical significance, implying that a competitive relationship exists among these pair inputs in the model. The negative substitution elasticity for pair inputs of land and labor cost is 3.58. For labor and seed costs, it is 3.554, indicating a substitution effect existing among these pair inputs. This implies that the reduction of other inputs could compensate for an increase in the usage of one input, and when the pairs of these inputs are jointly increased, the output of paddy will reduce in the study area. A positive sign of the estimated elasticity for cultivated land and seed (12.439), land and fertilizer (4.681), implying the complementary relationship; thus, these inputs need to be increased together to increase production.

Table 2

Frequency distribution of technical efficiency estimates

Range of technical efficiency (%)	Frequency	Percentage
Less than10	00	00
20-29	2	1.7
30-39	3	2.5
40-49	7	5.8
50- 59	9	7.5
60-69	18	15.0
70-79	22	18.3
80-89	34	28.3
90 and above	25	20.8
Total	120	100
Mean efficiency	**0.758**	
Minimum	0.265	
Maximum	0.985	

The technical efficiency ranges from 0.985 to 0.265 with a mean efficiency of 0.758 for the average efficiency farmers in the study area, which implies that, on average, paddy farmers have an opportunity to increase the output by 25% with a given production technology and input combinations, to achieve the TE level of the most efficient farmers could only bring about (0.98-0.75/0.98) = 23 % increase in production. The least efficient farmers can increase their production by 73% (0.98-0.265/0.98) to achieve the required technical efficiency of the most efficient farmers. Among the farmers, 28.3 % produced at 80- 89 percent efficiency.

Factors affecting technical efficiency:
Determinants or sources of the technical inefficiency for paddy production are identified by the estimated coefficients of the inefficiency effect model and its results in Table 3.

Table 3

Determinants of Technical inefficiency of Paddy cultivation

Variable	Coefficient	t – ratio
Constant	7.791	5.585*
Age	0.109	1.885**
Education	-0.755	-9.025*
Gender	-1.447	-2.831*
Household size	-0.495	-2.773*
Farming experience	-0.018	-0.249
Off-farm income	-0.007	-1.034
Extension services	-1.547	-1.593
Ownership of land	-0.573	-1.966**
Credit accessibility	-2.096	-3.347*
Training from agri	1.068	1.708**

** $p<0.01$ * $p<0.05$

Table 3 reveals that age, education, gender, land ownership, credit accessibility and training, and number of family members are statistically significant at a 1% level. The factors of farming experience, off-farm income, and extension service are found to have no significant effect anymore. The variable age of farmers was positive. This indicates that older farmers contribute to inefficient farming compared to young farmers. Older farmers tend to be more conservative and thus less willing to adopt new farming practices, perhaps having more significant inefficiencies in paddy production.

The coefficient of education in years of schooling is negative and significant at a 5% level in paddy cultivation as a priori expectation, implying that an increase in education helps the farmers to adopt new techniques and skills, which reduces technical inefficiency. Thus, this finding suggests that education is one of the factors in determining the technical inefficiency of paddy production.

However, among selected technical efficiency variables, credit accessibility in paddy farming was the most influential variable for the technical efficiency of paddy farming. Credit access can remove farmers' financial constraints and increase farm-level efficiency. Being a member of a farm organization helps farmers improve managerial skills as it provides training programs with necessary information during the crop season.

The results also show that land ownership has a negative impact on inefficiency. This implies that farmers who cultivate their land are more efficient than those who cultivate leased land. This is because farmers who own land have added motivation to cultivate more efficiently as they have an incentive to maintain their land for long-term benefits. Furthermore, extension awareness is also insignificant in an efficient model. Thus, extension officer contribution may need to be more efficient.

CONCLUSION AND IMPLICATIONS

This study examined the estimation of the technical efficiency and its determinants of paddy farming in Kilinochchi district, Sri Lanka. By applying the stochastic frontier production model, inefficiency scores were measured to identify the factors causing inefficiency over the reference period 2022/23. Inefficiency effects were also used in the study. Results obtained from the stochastic frontier estimation concluded that the average technical efficiency score of paddy production given by the translog model is 0.75, indicating that farmers only produce nearly 75% of their maximum possible output on average. There is a scope to further increase the output by 25% without increasing the levels of inputs. From the maximum likelihood estimates, the value of gamma (γ) is 0.99, and it is statistically different from zero at the 1% level, interpreted that 99% of random variation is the value added among the paddy production due to inefficiency than random variability. The inefficiency effects model identified the determinants of technical inefficiency, and its results showed that education, household size, ownership of land, and credit accessibility have significantly contributed to improving the technical efficiency in paddy production. The rest of the demographic and farming characteristics were insignificant, implying that these variables are not essential factors in determining the technical inefficiency of paddy production in the Kilinochchi district, Sri Lanka.

The study has observed that government efforts through agriculture extension programs have yet to be able to have a significant effect on technical efficiency. Government policies should strengthen the extension machinery to improve farmers' practices through extension service and training programs so farmers can apply available agricultural technology more efficiently. It will help increase the national pool of paddy and its productivity and the farm income of the small farmers in the study area. Although the government has established several extension programs to support the paddy industry during the last decades, they are still functioning below the frontier level due to mismanagement of resources and technology.

Keywords: Maha season, small paddy farming, translog frontier model, technical efficiency

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