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Technical Efficiency and Profitability of Organic Horticulture: A Case Study of Pineapple Growers of Lakhipur Sub-Division of Assam

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ABSTRACT

The study examines the technical efficiency and profitability of pineapple farmers in the Hmar-dominated tribal region of Lakhipur in Cachar district, Assam, using primary data from 335 households. Employing the Stochastic Frontier Model, Gross Profit analysis, and Multiple Linear Regression, the findings reveal a low average technical efficiency of 0.38, indicating considerable scope for improvement. Inefficiency is largely driven by the underutilisation of family labour, particularly among marginal farmers, which adversely affects profitability when labour costs are imputed. The study highlights the close link between efficiency and profitability and recommends labour diversification, improved market infrastructure, and promotion of processing and micro-enterprises.

Keywords: Pineapple, horticulture, Lakhipur, technical efficiency, profitability, Family labour

JEL Codes: Q12, D24, Q13, C21

I

INTRODUCTION

Diversification of agriculture towards high-value horticultural crops has been considered to be an important pathway for increasing farmers' income and achieving poverty reduction in developing countries (Birthal et al., 2015; Weinberger, 2007; Chand et al., 2008).Numerous studies have documented that changes in cropping patterns towards horticultural crops have reduced the uncertainty of agricultural incomes and promoted the welfare of farming households (Broeck et al., 2017; Hewett, 2012).However, emphasis has been laid on securing wider participation among farmers so that the benefits of the horticultural revolution do not remain outside the reach of the small and marginal farmers (Ali, 2008; Reardon, 2009; Birthal et al., 2020,). In India, the horticultural sector has received renewed emphasis in recent times. In fact, diversification towards high-value crops is considered one of the strategies for achieving the objective of Doubling Farmers' Income (DFI) in India. The Committee on DFI in India found that while the share of horticultural crops in the net sown area in India was only 7 per cent, their share in the value of agricultural produce was 25 per cent, revealing their potential to contribute to the rejuvenation of agricultural incomes. Further, with rising per capita income, there is likely to be a shift in consumption patterns, and demand for fruits and vegetables is likely to surpass that for cereals in the years to come. According to a study done by Kumar et al. (2016), the demand for fruits in India is likely to grow by 196 per cent between 2030 and 2050, while the demand for cereals is projected to grow by only 26 per cent. Besides, there are opportunities to tap the growing international market in

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addition to the domestic market. According to the Horti Vision 2020 report, the horticultural sector is known as the "sunrise area" because of its potential for massive job creation, improving rural diets with minimal investment, and opening new value-added pathways. Thus, there is a need to balance the allocation of net sown area between horticultural and non-horticultural crops so that the twin objectives of the country's food and nutritional security and the generation of sustainable livelihoods for the farming community can be met simultaneously. However, the ability of the horticultural sector to deliver the goals on the development agenda typically depends on the efficiency and profitability of the farmers engaged in horticultural farming. This paper uses data collected from 335 tribal households in Lakhipur Sub-Division of Cachar district in the North Eastern state of India to assess the levels of technical efficiency and profitability among pineapple growers in the area. Here, it may be noted that Lakhipur Sub-Division in Cachar district of the northeastern state of Assam, India, is renowned for its pineapple cultivation. The undulating topography and climatic conditions prevalent in the region make it ideally suitable for the cultivation of this tropical fruit. Not only is this horticultural product known for its juiciness and sweetness, but it is also grown organically, making it the ultimate choice for health-conscious consumers for its nutrition and taste. Over the years, pineapples from the area have become a sought-after item not only in other parts of the country but in also international markets such as Dubai. Around 2000 farming families belonging chiefly to the Hmar (pronounced Mar) community are engaged in pineapple cultivation in the region. However, due to limited research, very little is known about the economics of pineapple cultivation in this area and the constraints faced by cultivators. Therefore, assessing the two interrelated aspects of technical efficiency and profitability in pineapple production in the study area, along with their determinants, is an interesting area to study. Such an analysis will not only help to pave the way for the development of a viable agribusiness model for pineapples but also for other horticultural crops in this remote area of the Barak Valley region of Assam. Besides, the conclusions of the research are likely to have concomitant developmental ramifications in terms of the generation of gainful employment opportunities for the local population. The objectives of the research are: a. To assess the technical efficiency of pineapple growers in the study area and, further, to identify the factors influencing technical efficiency. b. To assess the profitability of pineapple growers in the study area and to identify the factors that influence profitability, with particular emphasis on the impact of technical efficiency on profitability. The paper is organized in five sections including the introduction. A brief outline of the study area is given in Section 2. Section 3 contains details about the sampling design and the econometric tools used in the study. The analytical findings of the study are contained in Section 4. In light of the findings, the final section outlines the policy requirements to remove constraints that stymie gains in pineapple cultivation in the study area.

II

LOCATION OF THE STUDY AREA

Lakhipur Sub-Division is located in Cachar District in the southern part of Assam in North-East India (Fig. 1). According to the report of Strategic Research and Extension Plan 2016-17, Agricultural Technology Management Agency Cachar District, the soil quality, rainfall, and temperature in the district are ideal for the cultivation of high-value horticultural crops. Soil types in the district range from alluvial to lateritic. The pH level in the area ranges from 4.5 to 6.0, making it ideal for pineapple production (Hossain, 2016; Yusi, 2016). Here, it may be noted that while India ranked sixth, accounting for approximately 8 per cent of global pineapple production in 2015-16, the state of Assam has the largest area under pineapple cultivation in the country (Afzal et al., 2018). The economic importance of pineapples arises from the fact that it is the world's third most valuable fruit, trailing only bananas and citrus fruits (Enibe & Raphael, 2020). Lakhipur Sub-Division of

FIGURE 1. LOCATION OF LAKHIPUR SUB-DIVISION IN ASSAM
Source: https://www.dreamstime.com/illustration/assam-map.html

Cachar district is home to one of Assam's most extensive pineapple orchards. It is a remote, hilly, and predominantly rural region in southern Assam. The indigenous Hmar tribe of the region cultivates pineapples in a natural, traditional, and organic manner. According to the Chairman of Hmar Agro Organic Producer Company Limited (HAPCOL), Lakhipur, there are over 2000 pineapple growers, the majority of whom are from the Hmar community and some from the Kuki and Chiru communities. They adhere to Christianity. The pineapple growers do not use pesticides, fertilisers, or organic manure. They believe the soil is naturally fertile and do not attempt to disturb its fertility. It is important to note that the pineapple growers in the region practice mixed cropping as a variety of horticultural crops are often cultivated on the same plot of land. Besides, pineapple is grown from May to August; crops such as sticky beans, oranges, maize, pumpkin, broom grass, and rubber are grown during the remaining months, which helps them manage their income throughout the year.

III

DATA AND METHODS

3.1 Sampling design

The study is based on primary data. The rural pineapple-growing households in Lakhipur Sub-Division constituted the final sampling units. A multistage mixed sampling method was used to select the sample. In the first stage, two blocks from Lakhipur Sub-Division were purposively chosen for the survey. Here, it may be pointed out that the administrative setup of Cachar district consists of two sub-divisions, viz., Lakhipur Sub-Division and Silchar Sub-Division. Further, Lakhipur Sub-Division is divided into four Community Development (C.D.) blocks, viz., Lakhipur, Rajabazar, Banskandi, and Binnakandi. Out of these, Lakhipur and Rajabazar are the two principal pineapple producing blocks. Hence, these two blocks were purposively chosen as the study area. According to information obtained from the Chairman of the HAOPCL, there are currently 14 villages in Lakhipur block and 8 villages in Rajabazar block where pineapple cultivation is intensively practiced. Hence, in the second stage, two-thirds (i.e., 67%) of the pineapple-growing villages in each block were surveyed. Thus, nine villages were selected from the Lakhipur block, and five from the Rajabazar block[2]. The villages were selected randomly using the lottery method. The villages surveyed in Lakhipur block were Chalitartol, Dakhin Fulertol, Digor Fulertol Pt-I, Digor Fulertol Pt-II, Digor Fulertol Pt-III, Kalam Naga Punji, SaiselPunji,U.S. LabongkhalPt-IV and Uttar Lalpani; the five villages surveyed in Razabazar block were DiglangPhailen Punji, Naithang Punji, Phailen Punji, U. S. Chiru Punji and U. S. Chur Punji Pt-III. In the final stage, 20 per cent of households in each village were randomly surveyed, yielding a final sample of 335 pineapple-growing households. The field survey was carried out between April 2022 and November 2022, and information on various aspects of pineapple cultivation and marketing was collected for the preceding cropping season, viz., 2021. A well-structured schedule was used to collect the required information from the respondents.

[2]The sampling design ensures a self-weighted sample; hence, no sampling weights are required

3.2 Econometric and statistical tools

3.2.1 Measurement of Technical Efficiency and its determinants

An analysis of technical efficiency and its determinants has been carried out using the Stochastic Frontier Model (SFM). Although Data Envelopment Analysis (DEA) is also frequently used to ascertain technical efficiency, SFM is generally considered suitable for agricultural applications. This is because DEA assumes that all deviations from the frontier are associated with inefficiency; however, in studies of agricultural production, this assumption is untenable, as weather conditions, pests, and diseases introduce variability in agricultural output. Further, because many farms do not keep accurate records, much of the available production data is likely to be subject to measurement errors (Coelli & Battese, 1996). Thus, following Battese and Coelli (1995), a Cobb-Douglas stochastic frontier model with inefficiency effects has been employed to measure the technical efficiency of pineapple growers in the study area long with its determinants. This one-stage maximum likelihood approach is statistically consistent with the Kumbhakar et al. (1991) approach and yields more efficient parameter estimates (Coelli & Battese, 1996). Since the pineapple growers in this area are primarily marginal and small farmers who use traditional cultivation methods (without fertilisers or insecticides), the production process relies on three inputs: suckers, labour, and land. However, the producers are unable to report the exact number of suckers that are currently planted in the orchards. Instead, a rule of thumb is stated wherein the number of pineapple suckers planted per hectare is around 45000. As there is no variation in the data in terms of the number of suckers per hectare and the total number of suckers is exactly proportional to the total area planted, two inputs are considered for the purpose of estimation, viz., the total labour in man-days (TL) and the farm size (FS) under pineapple cultivation. Here, it has been noted that larger farm sizes require more farm inputs. This may lead to multicollinearity. Therefore, the output and the inputs are normalized by land area. The use of input per hectare gives a better comparison of efficiency with various farm sizes (Coelli et al., 1998; Kumbhakar & Lovell, 2000). Hence, in the estimation model, the study considers the number of pineapples per hectare (Y) as the dependent variable and labour mandays per hectare (L) as the independent variable. Therefore, the stochastic frontier production function is:

$$\ln(Y_i) = \beta_0 + \beta_1 \ln(L_i) + V_i - U_i \qquad (1)$$

Where β_i*'s* are the coefficients to be estimated, V_i is the stochastic error term such that V_i is $iidN(0, \sigma_v^2)$; U_i is the non-negative random variable associated with the technical inefficiency of production, which is assumed to be independently distributed; it is obtained by truncation (at zero) of the normal distribution with mean $Z_i\delta$ and variance σ^2. Z is a $(1x\ m)$ vector of explanatory variables associated with the technical inefficiency of production, and δ is an $(m\ x\ 1)$ vector of unknown coefficients.

Equation (1) specifies the stochastic frontier production function in terms of the original production values. But the technical inefficiency effect U_i is assumed to be a function of a set of explanatory variables Z and an unknown vector of coefficients δ. Thus, the technical inefficiency effects U_i in the stochastic frontier model (1) can be specified as:

$$U_i = \delta_0 + \delta_i Z_i + W_i \qquad (2)$$

Where, the random variable W_i is defined by the truncation of the normal distribution with zero mean and variance σ^2such that the point of truncation is $-Z_i\delta$, i.e., $W_i >= -Z_i\delta$. These assumptions are consistent with U_i being a non-negative truncation of the $N(Z_i\delta, \sigma^2)$ distribution.

The model for the inefficiency effects can only be estimated if the inefficiency effects are stochastic and have a particular distributional specification. In this regard, the study seeks to test the following four hypotheses:

a. Hypothesis 1: γ=0 indicating the stochastic frontier model as defined in equation (1) is equivalent to traditional response function i.e., variance in the inefficiency effects is zero.[3]
b. Hypothesis 2: μ=0 indicating the technical inefficiency effects have half-normal distribution.[4]
c. Hypothesis 3: $\gamma=\delta_0=\delta_1=\delta_2=\ldots=\delta_9=0$; indicating inefficiency effects are absent in the model.
d. Hypothesis4: $\delta_0=\delta_1=\delta_2=\ldots=\delta_9=0$; indicating the explanatory variables in the inefficiency effect do not contribute significantly to explain inefficiency in the model.

To test the above null hypotheses, the Likelihood Ratio Test has been applied. The Likelihood Ratio Test is based on the likelihood ratio statistic defined as

$$\lambda = -2\ln[L(H_0) / L(H_1)] \qquad (3)$$

Where, $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null hypothesis H_0 and alternative hypothesis H_1 respectively. The test statistic λ has approximately chi-square distribution with degrees of freedom (df) equal to the number of parameters assumed to be zero in the null hypothesis H_0 (Battese&Coellie, 1995).

3.2.2 Profitability and its determinants

[3]The likelihood function is expressed in terms of the variance parameters as $\gamma = \frac{\sigma_u}{\sigma_v}$ (Battese& Corra, 1977).
[4]μ is the parameter which shows lower limit of the half-normal distribution.

The profit from any crop is calculated by deducting the cost from the value of crop output. However, as Narayanamoorthy (2013) pointed out, the Commission on Agricultural Cost and Prices (CACP) provides different cost concepts for ascertaining the profitability of crop cultivation. Nevertheless, owing to certain peculiarities of cultivation in the study area, many of these alternative cost concepts overlap. For instance, it was found that no capital equipment was used either during cultivation or harvesting. Hence, interest on the value of owned capital assets (excluding land) is absent. Also, the land lease market was non-existent in the study area as none of the 335 sample households had either leased in or leased out land for pineapple cultivation. Therefore, the rental value of owned land and rent paid for leased-in land is irrelevant in the study area. Further, due to the adoption of organic farming by the sample households, expenditure on chemical fertilizers and pesticides is non-existent[5]. Following Balogun et al. (2018) and Akhilomen *et al*. (2015), the Gross Profit (in INR) is therefore calculated as

Gross Profit=Total Revenue -Total Variable Cost (4)

Where, the total revenue (in INR) is the product of total number of pineapples sold by a household during the cropping season and per unit price of pineapple. The total variable cost (in INR), on the other hand, consists of the following items.

a. Cost of sucker (including imputed cost of suckers provided by producer organisations and the imputed cost of existing suckers)

b. Cost of Transportation

c. Cost of Hired Labour

d. Cost of own labour (imputed)

There is some concern on the inclusion of imputed cost of family labour in the total variable costs. According to the manual on cost of cultivation surveys, imputed costs of family labour should be included only when alternative employment opportunities are available. However, if alternative employment is not available, cost of unpaid family labour should not be included. Given the underdeveloped status of the local economy in the study area, the second approach seems more appropriate. For analysing the profitability outcomes, we present statistics for both approaches. However, for regression analysis of profitability, imputed value of family labour is considered as part of costs. Several studies aimed at ascertaining the determinants of profitability across various crops typically rely on linear regression models (Waziri & Tiku, 2017; Enibe & Raphael, 2020; Ayeni et al., 2023). Therefore, the Multiple Linear Regression Model (MLRM) has been used to determine various factors influencing profitability. Specification of the model is as follows:

[5]The respondents informed the researcher that although chemical fertilizers were supplied to them by the government through the producer's organization, these were not applied to the fields.

$$PROFIT_i = \alpha + X_i\beta + e_i \qquad (5)$$

TABLE 1. DESCRIPTION OF THE VARIABLES USED IN SFM AND MLRM MODEL

Variables	Description
Y	Number of pineapples per hectare
L	Labour in man-days (including both hired labour and imputed family labour) per hectare
FS	Farm size under pineapple cultivation (in hectare)
FS-square	Square of farm size under pineapple cultivation (in hectare)
TES	Technical efficiency scores range between 0 to 1
PROFIT	Profit per hectare (in INR 000')
AGEHH	Age of household head (in completed years)
EDUHH	Education of household head (in completed years)
HHS	Household size (number of people in the household)
MARITALHH	Marital status of household head (dummy=1, if married; 0 otherwise)
MEMBER	Any member of the household has a membership in the Producer's Organisation (dummy=1, if yes; 0 otherwise
EXTENSION	Household has access to extension services (dummy=1, if yes; 0 otherwise)
INFO	Access to up-to-date price and market information (dummy=1, if yes; 0 otherwise)
DISTANCE	Distance to nearest market (in km)
BID	Sample blocks (Dummy=1, if Rajabazar block; 0 otherwise)
PS	Proportion of large sized pineapple (14 inches or more) to total number of pineapples produced

IV

RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The socio-economic characteristics of the sample households are described in Table 2. For the purpose of analysis, the individual responsible for making decisions with regard to pineapple cultivation in the household is treated as the head of the household. It is observed that only 16.42 per cent of the households are headed by females, thereby revealing the literal dominance of male pineapple growers in the study region. The mean age of the household head is about 50 years. The average education of the household head is about 6.45 years, while the mean farming experience is 22.5 years. However, considerable differences in farming experience are noted between the two blocks, indicating that farmers in the Rajabazar block are relatively new to pineapple cultivation. Besides, notable differences are evident in the availability of various farming-related services, such as training and extension, between the two blocks. This is likely to have repercussions on the economic outcomes. Furthermore, sub-marginal and marginal farmers owning up to one hectare of land dominate the scene, with 79 per cent of the pineapple growers belonging to this category[6].

TABLE 2. SOCIO-ECONOMIC PROFILE OF SAMPLE HOUSEHOLDS

Indicators	Statistics
1. Mean age of head of household (in years)	50.5
2. Average size of household (in number of persons)	5.6
3. Percentage of female headed households	16.42
4. Mean education of household head (in completed years)	6.45
5. Mean years of farming experience of the household head (in completed years)	22.55
a. Lakhipur Block	25.2
b. Rajabazar Block	11.52
6. Percentage of sub-marginal farmers	41.19
7. Percentage of marginal farmers	37.61
8. Percentage of small farmers	13.73
9. Percentage of semi-medium farmers	6.86
10. Percentage of medium farmers	0.60
11. Percentage of sample households with access to farming training	28.66
12. Percentage of sample households with access to off-farm income	45.67
13. Percentage of sample households having membership of producer's organisation	29.55
14. Percentage of sample households with access to extension services	50.15
a. Lakhipur Block	53.33
b. Rajabazar Block	36.92
15. Percentage of sample households with access to up-to-date price and market information	91.94
16. Average distance to the nearest market (in km)	10.99
17. Percentage of Hmar households	92.24
18. Percentage of Kuki households	4.18
19. Percentage of Chiru households	3.58

It is observed that around 29 per cent of the cultivating households have at least one member who has undergone training in various aspects of pineapple cultivation from an extension agency. With animal husbandry being quite common in the study region, it is not surprising to find that around 45 per cent of households have access to off-farm income. Furthermore, more than 90 per cent of the sample households belong to the Hmar tribe. This signifies the dominance of Hmar pineapple growers in the study area.

[6]In the study, sub-marginal farmers refer to farmers with landholding below 0.5 hectare, marginal farmers refer to farmers with landholding between 0.5 to below one hectare, small farmers refer to farmers having landholding between one to below two hectares, semi-medium farmers refer to farmers with land holding of two to below four hectares and medium farmers refer to farmers having landholding four to below ten hectares, and large farmers refer to farmers having landholding ten hectares and above. It is to be mentioned that the growers with large landholdings are non-existent in the sample.

4.2 Analysis of Technical Efficiency

Estimation of the SFM facilitates the prediction of Technical Efficiency Scores (TES) for each household. While the TES ranges from an extremely low 0.2 to a high of 0.93, the average TES across all sample households is very low at 0.38. This implies that, in general, the sample households are producing 62 per cent less than they could have using the existing inputs. The standard deviation of TES is 0.22. Further, the compilation of average TES values by size class of cultivated area reveals that average levels of technical efficiency are lowest for sub-marginal farmers. An important observation is that the average TES rises monotonically across larger landholding categories, with semi-medium farms having the highest efficiency (Figure 2).[7]

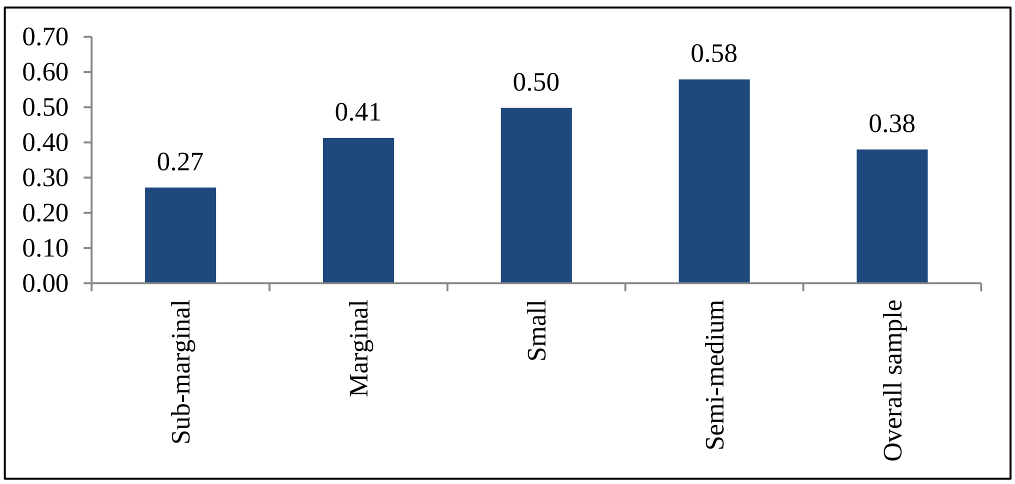

FIGURE 2. DISTRIBUTION OF MEAN TES BY SIZE CLASS OF PINEAPPLE FARMS

Thus, contrary to the conventional perception that smaller farms are generally more efficient, the findings contradict this view. We will return to this argument when we discuss the results of the determinants of technical inefficiency (Table 4). The distribution of sample households across various levels of TES is shown in Table 3. It is disheartening to find that only about 11 per cent of pineapple growers have TES values exceeding 0.7, while 89 per cent of the sample households have TES values below 0.7. Hence, despite being an important nerve centre for pineapple cultivation, there is considerable scope to improve the technical efficiency of pineapple cultivation in the study area.

[7]Since in the study sample, semi-medium and medium farmers constitute a small proportion, therefore, the study considers both the landholding categories into a single category i.e., semi-medium land holdings

TABLE 3. DISTRIBUTION OF SAMPLE HOUSEHOLDS BASED ON TES

TES	Frequency	Percentage	Mean Efficiency	Standard Deviation
0-0.3	143	42.69	0.38	0.22
0.3-0.5	110	32.84		
0.5-0.7	44	13.13		
0.7-0.9	34	10.15		
0.9-1.0	4	1.19		
Total	335	100		

Source: Based on authors' calculation from primary data

The results of the SFM are presented in Table 4. The first observation that is evident is that the input coefficient of the production function, viz., labour per hectare, is positive and statistically significant at one per cent. This indicates that labour employed per hectare has positive marginal productivity in pineapple cultivation.

TABLE 4. STOCHASTIC FRONTIER MODEL (SFM) AND TECHNICAL INEFFICIENCY MODEL

Stochastic Frontier Model (SFM)				
Variables	Coefficients	Standard error	z	P>|z|
Ln(L)	0.460***	0.120	3.840	0.000
Constant	8.022***	0.650	12.350	0.000
Technical Inefficiency Model				
Variables	Coefficients	Standard error	z	P>|z|
EDUHH	0.026	0.013	1.920	0.054
HHS	0.033	0.023	1.440	0.149
MEMBER	-0.373***	0.139	-2.680	0.007
MARITALHH	0.044	0.124	0.360	0.721
INFO	-0.733***	0.161	-4.540	0.000
DISTANCE	0.002	0.005	0.370	0.715
BID	0.911***	0.140	6.510	0.000
FS	-0.467**	0.191	-2.450	0.014
FS-square	0.039	0.029	1.340	0.180
Constant	1.574***	0.336	4.690	0.000
Model Diagnostic				
Parameters	Coefficients	Standard error	z	P>|z|
σ_u	0.661***	0.049	13.480	0.000
σ_v	0.161**	0.076	2.140	0.033
γ	4.098***	0.077	53.350	0.000
Number of observations = 335 Wald chi2(1) = 14.76*** Prob>chi2 = 0.000 Log likelihood = -288.823				

*Note: *** denotes significant at 1 percent and ** denotes significant at 5 percent*

The technical inefficiency model identifies four key factors that have a statistically significant impact on the technical efficiency of pineapple farmers in the study area viz., membership in producer organizations, updated information related to various aspects of pineapple production and marketing, a block-level location dummy, and farm size. Households that have membership of Farmer Producer Organisation (FPO) are likely to be less technically efficient compared to non-members. This is reflected by the negative and statistically significant value of the MEMBER coefficient. Membership in an FPO helps reduce inefficiency in production by providing critical resources such as soil testing, technical information, and other logistical support. Similarly, the availability of up-to-date information relating to production and marketing (INFO) is associated with reduced technical inefficiency. Further, the block dummy variable (BID) is positively and significantly associated with inefficiency, indicating that farmers in the Rajabazar block face greater technical inefficiency. This can be attributed to the block's remoteness, limited access to extension services, and a high proportion of new entrants to pineapple farming. Lastly, farm size (FS) and technical inefficiency are negatively related, indicating that larger farm size is associated with lower technical inefficiency. This aligns with a growing body of literature which contradicts the traditional view that small farms are more technically efficient (Bagi, 1982; Ayaz & Mughal, 2024).

Mean TES by size class of land holding, given in Fig. 2, showed that larger farms have higher average TES than smaller ones. Additionally, the estimated parameters σ_u and σ_v are statistically significant at the 1 per cent and 5 per cent levels, respectively, indicating a good fit of the estimated model and the validity of the distributional assumption for the composite error term. In addition, the estimated γ is statistically significant and greater than zero. This suggests that the inefficiency term plays a significant role in the total error term, i.e., the majority of the deviation from the frontier is attributable to inefficiency, while the remainder is due to random noise.

TABLE 5. LIKELIHOOD RATIO TEST FOR THE PARAMETERS OF THE INEFFICIENCY MODEL

Null Hypothesis (H_0)	LR-test statistic (λ)	df	Critical value ($\chi2_{\ 0.05}$)	Decision
H_0: γ= 0	72.53	1	3.84	Rejected
H_0: μ = 0	11.19	1	3.84	Rejected
H_0: $\gamma = \delta_0=\delta_1=\delta_2=\ldots=\delta_9=0$	109.31	11	19.68	Rejected
H_0: $\delta_0=\delta_1=\delta_2=\ldots=\delta_9=0$	120.50	10	18.31	Rejected

Source: Based on authors' calculation from primary data

Table 5 reports the test results for the four null hypotheses outlined in the methodology section to assess the appropriateness of the technical inefficiency model. The first null hypothesis, which states that the inefficiency effects are not stochastic, is rejected. This implies that the traditional response function does not adequately represent the technical inefficiency of pineapple growers in the study area; hence, the use of the SFM is appropriate. The second null hypothesis, which states that the technical inefficiency has a half-normal distribution, is also rejected. This implies that the technical inefficiency follows a truncated normal distribution. The third null hypothesis specifies that the inefficiency effects are absent in the model, which is again firmly rejected, indicating their presence. The fourth null hypothesis, which states that the explanatory variables in the inefficiency model do not contribute significantly to explaining inefficiency, is also rejected. Therefore, the explanatory variables in the inefficiency effects model play a significant role in explaining inefficiency in pineapple production in the study area. Given the results of the various null hypothesis tests, it may be concluded that the model used in the study is adequate for analysing technical inefficiency in pineapple production and its determinants in the study area.

The inverse relationship between farm size and technical inefficiency warrants closer scrutiny of the underlying factors. Some of these underlying factors are examined in Table 6. The low level of technical efficiency among sub-marginal and marginal farms is attributable to inefficient labour use. As shown in Table 6, sub-marginal and marginal farms on average employ 975 and 676 labour-man-days for the entire pineapple season per hectare, while for the small and semi-medium farms, the deployment of labour per hectare is half of these figures. This is indicative of underemployment and labour wastage by the former group of producers. Workers from marginal households regard their work in pineapple orchards as their primary vocation and do not seek employment elsewhere. As such, the deployment of family labour on these farms is tantamount to under-employment. This is the primary reason behind the low technical efficiency scores. Further, production of pineapples per hectare for sub-marginal and marginal farmers is lower than that of the larger farms. A labourmanday engaged in sub-marginal farm produces 21 pineapples during a cropping season as compared to 57 and 77 units for the larger group of farms. Besides employment of excess labour, there could also be economies of scale enjoyed by larger farms. However, given that labour per hectare is the only input considered in the production function, this hypothesis could not be statistically tested.

TABLE 6. PINEAPPLE AND LABOUR PER HECTARE BY SIZE CLASSES OF PINEAPPLE FARMS

Farm size classes	Number of Mandays per hectare	Number of Pineapples produced per Labour manday	Number of Pineapples produced per hectare
Sub-marginal	975.22	20.80	20284.26
Marginal	676.53	38.68	26170.48
Small	478.63	57.34	27442.76
Semi-medium	351.66	76.52	26908.49

Source: Based on authors' calculation from primary data

4.3 Analysis of Profitability

Before analysing the profitability status of the cultivating households, it would be intuitive to consider the composition of overall cost and evaluate how the relative importance of different cost components varies across different cultivating groups. At the outset, taking all pineapple cultivating households together, it is observed that imputed value of labour cost supplied by the farmer and family members comprise nearly 50 percent of the entire cost structure while expenditure made on hired labour constitute another 32 percent of the cost (Table 7). Cost of sucker and cost of transportation constitute less than 20 percent of the total cost of cultivation. However, an analysis of the cost components across different landholding categories reveals subtle differences in cost composition. For marginal landowners, the share of the imputed value of their own labour costs is much higher, at about 59 per cent. As the size of landholding increases, the share of own labour in the overall cost decreases and that of hired labour increases. However, for all categories of cultivators, labour costs constitute the single largest cost component, ranging from 75 per cent to about 85 per cent.

Revenue, cost, and profits per hectare (in INR 000') of cultivated area for different land-owning groups are presented in Fig. 3. It is observed that sub-marginal landowners experience the highest cost per hectare. It is further seen that the cost of cultivation per hectare declines progressively for marginal, small and medium landowners, indicating a step function.

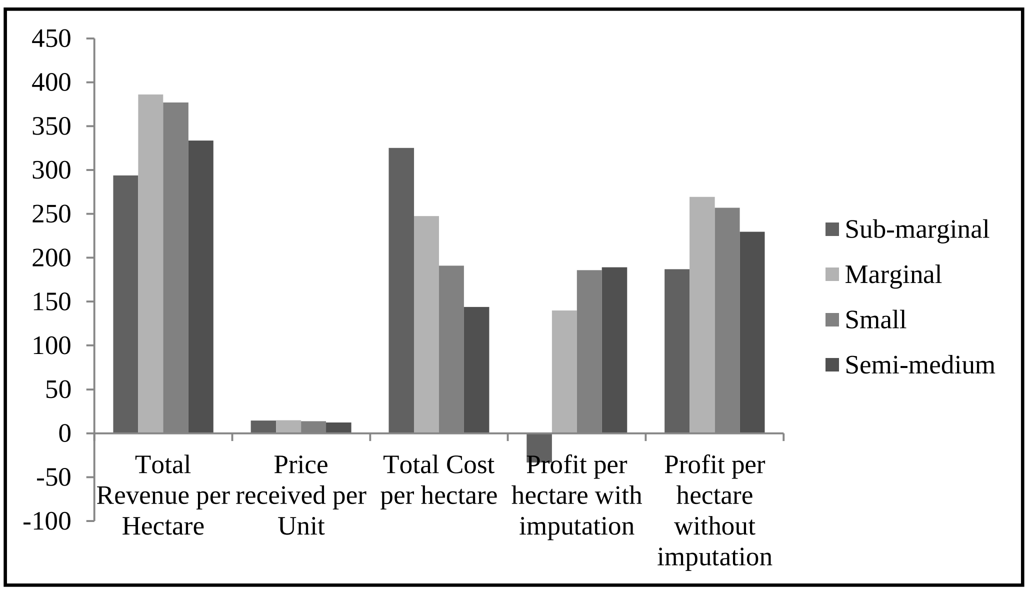

FIGURE 3. REVENUE, COST AND PROFIT PER HECTARE (IN INR 000') BY CATEGORY OF LAND OWNED

The reason behind this is the inefficient allocation of labour on sub-marginal and marginal farms, as discussed in the preceding section. Also, average value of total revenue per hectare is lowest for sub-marginal farmers. This is primarily due to low average production per hectare, not to price differences. Average price received by sub-marginal and marginal farmers is INR14.49 and INR14.76, compared to INR13.73 and INR12.79 for small and semi- medium farmers, respectively. Marginal farmers, therefore, have a minuscule advantage over the relatively larger farms in terms of the price procured per unit, probably because bulk sales by the latter group result in lower unit prices. The interaction between revenue and costs results in sub-marginal farmers, on average, incurring losses of about 33 thousand per hectare when imputed labour costs are included. However, when the cost of family labour is not imputed, average profits per hectare no longer remain negative for the sub-marginal farmers. Further, when imputed labour costs are ignored, profits per hectare are highest for marginal farmers. This is quite natural as marginal farms mostly use family labour and leaving that out results in lower costs per hectare, which in turn manifests in higher profits. As pineapple farms provide employment to the locals, the situation may not be as dire as indicated by the profit estimates when the imputed cost of family labour is included.

TABLE 7. COMPONENTS OF CULTIVATION COST BY CATEGORY OF LAND OWNED (IN PERCENT)

Cost Component	Marginal	Small	Medium	Overall Sample
Sucker	8.62	12.71	14.67	10.40
Transportation	6.74	12.09	12.09	8.65
Own Labour	58.71	37.20	27.71	49.48
Hired Labour	25.93	38.01	45.52	31.47
Total	100	100	100	100

Source: Based on authors' calculation from primary data

Table 8 highlights the critical role of family labour in sustaining small and marginal farms, especially when assessed through the lens of imputed labour costs. When imputed family labour is not accounted for, a much smaller percentage of sub-marginal (14 per cent) and marginal (6 per cent) farms face losses. Some marginal farms show improved profitability with 30.16 per cent earning between INR 1 Lakh to 5 Lakh without imputing family labour. However, when the value of family labour is included, profitability declines across all categories, with sub-marginal farms showing a 67.89 per cent loss. This contrast reveals that family labour is a hidden pillar of small farm viability, enabling operations to stay afloat despite low market returns.

Although pineapple cultivation is the primary source of livelihood in the study area, some workers also engage in non-agricultural activities. The occupational distribution of workers by Usual Principal and Subsidiary (UPS) status is shown in Table 9. The findings show that only a quarter of the workers aged 15-64 reported pineapple cultivation as their primary activity. The majority of the workers were employed as unpaid family labour. The incidence of casual daily-wage labour was low. Engagement in salaried employment was higher among younger workers (21-31 years).

TABLE 8. PERCENTAGE DISTRIBUTION OF HOUSEHOLDS MAKING PROFIT (OR LOSSES) BASED ON LABOUR CATEGORIES ACROSS LAND CLASSES

Land classes	Labour categories	Losses	0-25	25-50	50-100	100-500	Above 500
Sub-marginal	With Imputed Labour	67.39	12.32	7.97	7.97	4.35	0.00
	Without Imputed Labour	13.77	16.67	15.22	28.26	26.09	0.00
Marginal	With Imputed Labour	28.57	13.49	8.73	15.08	30.16	3.97
	Without Imputed Labour	6.35	6.35	3.97	18.25	60.32	4.76
Small	With Imputed Labour	21.74	2.17	2.17	6.52	52.17	15.22
	Without Imputed Labour	12.00	0.00	8.00	4.00	24.00	52.00
Semi-medium	With Imputed Labour	24.00	0.00	0.00	4.00	28.00	44.00
	Without Imputed Labour	13.04	4.35	0.00	6.52	54.35	21.74
All Farms	With Imputed Labour	43.28	10.45	6.87	10.15	22.39	6.87
	Without Imputed Labour	10.75	9.85	8.36	19.70	42.69	8.66

TABLE 9. OCCUPATIONAL DISTRIBUTION OF WORKERS (UPS)

Occupational status	≥ 15 & < 21	≥ 21 & < 31	≥ 31 & < 41	≥ 41 & < 51	≥ 51 & ≤ 64	Overall Sample
Pineapple Farmers	0.00	27.70	39.36	50.43	61.22	25.30
Unpaid Family Labour on Pineapple Farms	84.71	54.73	48.65	42.36	34.69	57.32
Daily Wage Labourer in other farms	4.71	4.12	2.70	2.02	0.69	4.17
Salaried	8.24	10.79	6.93	3.17	2.72	10.57
Self-Employed in Services	2.34	1.78	1.35	0.58	0.00	1.83
Self-Employed in Business	0.00	0.88	1.01	1.44	0.68	0.81
Total	100.00	100.00	100.00	100.00	100.00	100.00

A key objective of the research is to determine the relationship between technical efficiency and profitability among pineapple farmers in the study region. The results of the MLRM used to analyse the determinants of profitability are presented in Table 10. The findings reveal that TES have a positive and significant impact on the profitability of the pineapple growers in the study area. A somewhat similar result is also suggested by Ferrazza *et al.* (2020); Sintori*et al.* (2023). When inputs are utilised efficiently, waste is reduced and output per unit of input increases. This results in a lower average production cost, which can lead to increased profit margins. Farmers who are technically efficient typically possess better training, experience, and skills. They are more adept at minimizing the risks associated with crop failure through adaptive strategies. A decrease in production risk translates to more stable incomes and enduring profitability. In other words, technically efficient farmers are better positioned to take advantage of economies of scale and respond effectively to market incentives, which in turn leads to increased profitability. Moreover, two additional factors that significantly affect the profitability of pineapple growers in the study area are: access to extension services and proportion of large sized pineapples (14 inches or more) to the total number of pineapples produced.[8] Access to extension services (EXTENSION) has a positive and significant impact on profitability.

TABLE 10. RESULTS OF THE MULTIPLE LINEAR REGRESSION MODEL (MLRM)

Variables	Coefficients	Standard error	t	P>|t|
TES	805.586***	32.797	24.560	0.000
AGEHH	-0.261	0.515	-0.510	0.612
EDUHH	-0.152	1.766	-0.090	0.932
EXTENSION	29.851**	14.388	2.070	0.039
INFO	17.268	25.133	0.690	0.493
FS	-0.027	10.086	0.000	0.998
PS	74.058***	16.602	4.460	0.000
Constant	-298.705***	34.737	-8.600	0.000
Model diagnostic				
Number of observations = 335				
F(7,326) = 124.35***				
Prob>F = 0.000				
R-squared = 0.7269				
Adj. R-squared = 0.7211				
Root MSE = 114.4				
Mean VIF = 1.24				

*Note: *** denotes significant at 1 percent and ** denotes significant at 5 percent*

It therefore follows that provision of extension services to pineapple growers in the form of supply of pineapple suckers, training, soil testing, improved market information, contact with export agencies, and logistic services has a significant impact on their profitability. Furthermore, the proportion of large-sized pineapples to

[8]It is to be noted that the growers in the study area categories two grades of pineapples such as pineapple length more than 14 inch and other less than 14 inch.

the total number of pineapples produced (PS) has a positive and significant impact on profitability. This indicates that pineapple farmers in the study area achieve higher profits by producing large-sized pineapples. The rationale is that, when adhering to natural and organic farming practices, larger fruits often command higher market prices, thereby increasing the farmer's profitability. Additionally, in certain markets, especially those export-oriented like the Middle East, larger pineapples are preferred for individual consumption, convenient packaging, and retail display. Consequently, large pineapples often achieve higher prices in the export sector, yielding higher profits.

V

CONCLUSION AND POLICY RECOMMENDATIONS

The research has served to shed light on important aspects of pineapple cultivation in the study area. The findings are relevant given that no research on efficiency and profitability has been conducted in this region to date, despite it being a hotspot for pineapple cultivation. The SFM assessment indicates an average technical efficiency score of 0.38, suggesting a substantial opportunity to improve technical efficiency in pineapple cultivation in the study region. The negative relationship between farm size and technical inefficiency stems from the inefficient use of family labour on small farms. As pineapples are the mainstay of workers in the region, they remain engaged in pineapple cultivation without any consideration for labour productivity. These factors, taken together, affect the profitability of farming households in the surveyed villages. When the cost of family labour is imputed, the situation appears extremely grim for the sub-marginal and marginal farmers, as they employ large amounts of family labour even when there is no requirement. Again, when family labour is not imputed into the costs, the situation appears less challenging. The study has shown that profitability is inextricably intertwined with efficiency. Hence, technically efficient farmers are better positioned to benefit from economies of scale and respond appropriately to market incentives, resulting in enhanced profitability. Therefore, in light of the findings, it is recommended that practical steps need to be taken to wean away family labour from the pineapple field and employ them in more productive vocations. Workers in the sub-marginal and marginal farmer categories need to be employed in other farm or non-farm jobs, resulting in better utilisation of available labour both on and off pineapple farms. A well-established marketing infrastructure in the region could help pineapple farmers expand their agribusinesses and increase their income. This would provide an alternative avenue to employment for local youth. Setting up processing units or providing incentives for setting up micro-enterprises are viable options.

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