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Estimation of Technical Efficiency in Tea Farms at Plantation Level: A Review

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Abstract

The systematic literature review of 111 abstracts has been conducted to comprehensively compile the empirical studies of 21 complete text papers from all over the globe in context to estimation or determination of the technical efficiency (TE) at plantation level of tea production system (TPS), by adopting two methodologies *viz*., stochastic frontier analysis (SFA) and data envelopment analysis (DEA) during the period 2012-2022. Investigation from these empirical studies revealed that the average TE (TE_{mean}) tea growers TGs all around the globe computed by using both the approaches is around 67.98%, which showcased that the TGs have ability to increase the green tea leaf (GTL) production by 32.02% through better utilization of available resources and technology. The influence of various factors on TE of these TGs had contradictory outcomes, which broke new ground for future research. Computation of TE will enable an investigator to benchmark the best performing TGs in a particular area, which may be referred by the inefficient TGs to enhance their performance.

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Data Envelopment Analysis; Stochastic Frontier Analysis; Tea; Technical Efficiency.

Introduction

Production Efficiency as a Powerful Tool in Measuring the Performance of a Tea Garden

Like any other agricultural production, the tea production at plantation level involves transformation of some goods and services called input into other goods called products or output.[1] Agricultural productivity (AP) is defined in agricultural geography as well as in economics as "*output per unit of input* " or "*output per unit of land area*", and the improvement in AP is generally considered to be the results of a more efficient use of the factors of production, *viz*. physical, socioeconomic, institutional and technological.[2] The AP depends on two components, which are as follows.[3]

Production Technology (PT)

It is characterized by the type and quality of inputs and resources used in the production process. For a given commodity like tea, many different

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technologies may exist, reflecting different economic, environmental and agronomic conditions.

Technical Efficiency (TE)

It refers to ability of the production process to combine the available resources or inputs to produce maximal output (GTL). A tea farm is technically inefficient when it does not produce the maximum level of output that can be expected given the type of available inputs.

The productivity variation has a significant impact on the production of tea in the case of TGs. Productivity in the case of any STG is defined as the *"yield of tea grown per hectare or per area of land".*[1] The overall efficiency (OE), consisting of both the consisting of both the TE and allocative efficiency (AE)[1] of individual TG[4] is known as the economic efficiency (EE) of the individual TG. It refers to the ability of the TG to minimize the cost of cultivation without altering the desired yield of GTL from the farms. Lowering costs while preserving productivity means higher profits, which is why EE is a common strategic goal.[5] In practice, a technically efficient farm can be economically inefficient, whereas the reverse may not be true. It is especially true in developing countries where markets are often thin or inexistent, inputs are constrained (unavailable or difficult to access), and transaction costs are high.[3] The term "*efficiency (η)*" signifies a peak level of performance that uses the least amount of inputs to achieve the highest amount of output. Efficiency analysis serves as one of the most powerful tools to understand how inputs are translated into valued outputs.[6] An efficient TG will reduce the number of unnecessary resources used to produce a given output (GTL), including personal time and energy. Efficiency is a measurable concept that can be determined using the ratio of useful output to total input. It minimizes the waste of resources such as physical materials, energy, and time while accomplishing the desired output.[7]

Benchmarking – A Technique for Establishing Gaps in Performance of a Tea Garden

The word 'benchmark' originated from a surveyor's mark cut to indicate a level for the determination of altitude.[8] Benchmarking of tea productivity (TP) may be considered as a management technique, in which measurement is primarily comparative. A TG could attempt benchmarking at several levels using all the different types of benchmarking with the purpose to find out the best practices so that it could confirm to it. Typically to benchmark TP among a homogenous set of TGs, the "best practice benchmarking or process benchmarking" technique is generally applied to compare the methods and practices for performing tea production processes.[9] Our study mainly focuses on the benchmarking TP of TGs on the basis of TE, assuming that the TGs use same quality of inputs and resources in the production process. The optimal productivity target which has to be compared to observe TP to measure the degree of TE {or technical inefficiency (TI)} at the farm-level is theoretically known as the production frontier.[3] From the definition of TE, it is clear that it is a relative measure, not an absolute measure and can be measured by two different ways *viz*. output oriented technical efficiency (TE_{oo}) and input oriented technical efficiency (TE_{io}).[10]

Methods for Benchmarking of Tea Farms

In modern benchmarking the two main approaches are SFA and DEA.[11]

Parametric Stochastic Frontier Analysis (SFA)

The first prominent concept on modeling and estimation of SFA is forwarded by the empirical work of the concept of a stochastic production frontier (SPF) was developed and extended by Aigner, Lovell, and Schmidt in 1977. Further, Battese and Coelli in 1995, Greene in 1990 and Wim and Broeck in 1977 provided a significant contribution for the progress of SFA considering different distributional assumption of the error term.[12] Typically, the production or cost model is based on a Cobb – Douglas (CD) function[13] or translog (TL) function.[4] Based on the different distributional assumption of the error terms, the SFA approaches can be modeled in the different ways *viz*., Half Normal model, Truncated Normal model, Exponential model[14] and Gamma model.[15] The production function under stochastic frontier distinguishes the error term associated with the production function in to statistical noise and inefficiency components. It is assumed that each component has their influence in deviating output from the most possible maximum level. The statistical *noise or uncontrolled component* is the error due to randomness which is two-sided. For example noise components like weather, climatic condition or any unexpected event may either increase or decrease the yield of tea in the tea farm, which is beyond the control of the cultivator. On the other hand, *production inefficiency component* is only due to inefficiency in allocating resources which is a one-sided error. This error has a negative impact on the production function and can be controlled by the cultivator with appropriate measures.[12]

The focus of all 15 papers (71.43%) utilizing the SFA techniques is to examine the efficiency levels of TGs through the estimation of TE.[16] has foreground benchmarking of TGs of Vietnam on the basis of Resource Use Efficiency (RUE) of these by application of this method. In addition to the estimation of TE,[17] used the SFA cost function to find out the reason for variation in the Total Cost of Production (TCP) of GTL, Further the researcher calculated the EE of two different sets of small tea growers (STG)s and used the Mann-Whitney U Test (Wilcoxon Rank-Sum Test) to find the difference in the efficiency levels of the two independent groups of STGs. Similarly,[18] used the Aigner *et al.* (1977) and Meeusen & Broek (1977) SFA production and cost functions in CD form to calculate the TE_{mean} and average Cost Efficiency (CE)[2] {CE_{mean}} scores of the levels of organic STGs respectively. The researchers subsequently used these values to estimate the EE levels of the set of STGs.

Non - parametric Data Envelopment Analysis (DEA)

Initially put forward by Charnes, Cooper and Rhodes in 1978 and further enhanced by Banker, Charnes and Cooper in 1984,[19] DEA being a nonparametric approach does not require a functional form specification and is easy to compute using linear programming. In case of tea industry, it considers each tea farms (termed as ‘*decision making units’* or DMU) and calculates a discrete piecewise frontier determined by the set of efficient tea farms or best practice units. It makes a comparative analysis of the tea farms that utilizes multiple inputs to produce multiple outputs which can be quantified using different units of measurements. Each DMU has the flexibility with respect to some of the decisions it makes, but not necessarily complete freedom is given with respect to these decisions. This method cannot separate the effect of noise and effects of inefficiency during the calculation of TE, and is less sensitive to the type of specification error. The most popular models of DEA widely used to carry out research work 20 are as follows

CCR Model

This was the first DEA model was suggested by Charnes, Cooper and Rhodes in the year 1978 and is based on the constant return to scale (CRS) assumption. The efficiency measured under CRS assumptions represents the technical efficiency (TE or TE_{CRS}).

BCC Model

Banker, Charnes and Cooper (1984) further extended the work of Charnes, Cooper and Rhodes, keeping into consideration the various factors might cause a tea farm to deviate from its optimal scale of operations, thus accounting for variable returns to scale (VRS). The efficiency measured under CRS assumptions represents the pure technical efficiency (PTE or TE_{VRS}).

Both the models are used simultaneously in various empirical studies on TE of tea farms to estimate their scale efficiency (SE)[3]. The focus of the majority of the studies by application of DEA is on evaluating TE scores. However, [21] and [22] used DEA method for determination of SE scores in addition to TE scores. Later on [23] benchmarked TGs of Turkey on the basis of TE, SE, AE, EE and PTE scores by application of this method.

Determinants of Technical Efficiency

The various factors affecting the TE of TGs can be determined using different models of Multiple Regression (MR).[4] Our studies revealed that the TE of the TPS at plantation level is dependent on numerous factors which are stated as follows.

A. Moment or time at which the TE is evaluated (t)
B. Tea farm characteristics (F)

- location of tea farm ($F_{LOCATION}$),
- age of tea farm or bushes (F_{AGE}),
- tea clone or variety ($F_{TEA\ VARIETY}$),
- uninterrupted operation status of farm ($F_{OPERATE}$),
- extent of commercialization of tea farm ($F_{COMMERCIALIZATION}$),
- certification of tea farm ($F_{CERTIFICATION}$),
- farm’s contract to sell product or with Government Cooperatives ($F_{CONTRACT\ TYPE}$)

C. Environmental factors (E)

- slope of tea land ($E_{LAND\ SLOPE}$),
- altitude at which the tea farm is located ($E_{ALTITUDE}$),
- erosion risk ($E_{EROSION\ RISK}$)

D. Socio-economic characteristics of tea farmers (P)

- farmer's age (P_{AGE}),
- farmer's access to extension service[5]
- ($P_{EXTENSION\ SERVICE}$),
- farmer's experience in tea farming ($P_{EXPERIENCE}$),
- farmer's educational qualification ($P_{EDUCATION}$),
- farmer's gender as masculine (P_{GENDER}),
- farmer's primary occupation as tea ($P_{OCCUPATION}$),
- farmer's income level (P_{INCOME}),
- farmer's perception or adaptation on/of resource conservation or waste management methods or resource conservation technology ($P_{RESOURCE\ CONSERVATION}$),
- famer's household size ($P_{FAMILY\ SIZE}$),
- farmer's affiliation to any group or organization ($P_{AFFILIATE}$),
- farmer's registration with concerned Tea Board (P_{REGD}.),
- farmer's ethnicity ($P_{ETHNICITY}$),
- farmer's adaptation of good agricultural practices (GAP) {(P_{GAP})},
- farmer's migration status ($P_{MIGRATION\ STATUS}$)
- farmer's access to marketing channel to sale green leaf ($P_{MARKETING\ CHANNEL}$),
- farmer's dependency ratio ($P_{D\text{-}RATIO}$),
- farmer's access to credit (P_{CERDIT}),
- availability of livestock at farmer's household ($P_{LIVESTOCK}$)

E. Availability of infrastructure facilities (INFRA)

- irrigation facilities ($INFRA_{IRRIGATION}$),
- own transport facility ($INFRA_{OWN\ TRANSPORT}$)

F. Total value of farm produce of yield from tea farms (Y)

G. Status of labour employed in tea farms (N)

- outsourced or hired labour (N_{HIRED}),
- family labour or household labour (N_{FAMILY}),
- age of the agricultural labour force (N_{AGE})

H. Status[7] of land under cultivation (T_{STATUS})

I. Mode[8] of cultivation (C_{MODE})

J. Resources for production of green tea leaf (Q)

- area under tea cultivation (Q_T),
- quantity of labour engaged (Q_{LABOUR}),
- quantity of fertilizer applied ($Q_{FERTILIZER}$),
- quantity of foliar nutrients ($Q_{FN)}$,
- quantity of pesticides (Q_{PEST}),
- quantity of green leaf outsourced ($Q_{GL\text{-}OUT}$),
- number of outsourced tea gardens or STGs ($Q_{OUT\text{-}STG}$),
- amount of capital expenditure (C_{apEx})

Objective

The intention of this study is to find the limitations and ambiguity in the existing investigations carried out in estimation or determination of TE of TGs, and subsequently finds the impact of various factors on the TE of these TGs. These significant research works may be referred by other researchers to investigate the performance of the STGs in other unexplored regions of the world, where there has been no study conducted so far. Also, a significant statement was made by the erstwhile Commerce Secretary, Government of India that the tea industry should benchmark itself against best practices so that it can compete in international market against countries like Kenya and Sri Lanka.[24] This will help the industry to solve its fundamental challenges on decline in productivity. With a steep hike in the input cost, the tea industry should make an attempt to utilize the available resources judiciously, *i.e*., without making any wastage of the resources and achieve the optimal level of production for its self sustainability in the competitive environment. It may be noted that these literatures will enable the researchers to identify the factors which are responsible for causing the (in) efficiency in the tea production system and subsequently adopt strategies to rectify the same.

Methodology

To systematically highlight the quantity, status of research work done, and the scope for the future research, an investigation for the TE for the tea sector was searched from all the accessible/available published paper using "technical efficiency (of) OR (in) tea" as the phrase with the above mentioned keywords in the academic search engine

Google Scholar was used for retrieving relevant literature. In addition to this records were identified through other sources. From retrieved literature, relevant investigations carried out during the period 2012-2022 in top tea producing counties in the world were taken into consideration. The studies which investigated the TE of only the TGs {special focus on small tea grower/ gardens (STG)} were included for the systematic review, excluding the tea processors and tea estates. The results from the academic search engine and other sources were filtered by using inbuilt advanced searched operators[25] and Boolean operators.[26] The empirical works carried out using only the two common methodologies *viz.*, Parametric SFA and Non - parametric DEA were taken into consideration. The following diagram is the pictorial representation of the systematic literature review methodology using PRISMA flow diagram.

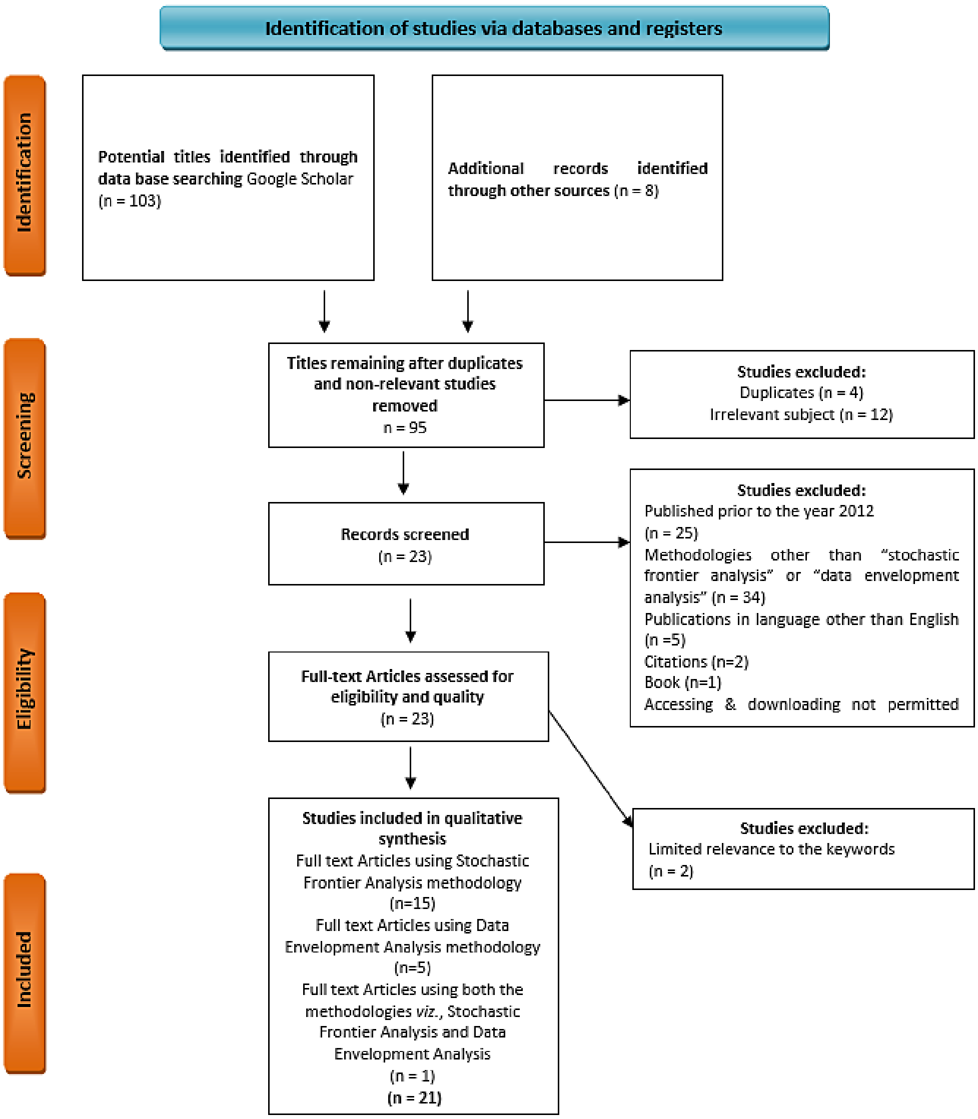

Fig. 1: Graphical representation of systematic literature review using PRISMA flow diagram[27]

Table 1: Tabulation of Empirical Work on Estimation of Technical Efficiency of Tea Farming System using Stochastic Frontier Analysis (SFA)

Sl. No.	Auth-or(s)	Year	Period	Sample Size	Methodology	Country	Sector	Remarks: Factors having positive impact on TE	Remarks: Factors having negative impact on TE	Remarks: Others
1	30	2014	May 2013	244	SFA: Estimation of TE Bootstrapping: Determinants of TI Descriptive Statistics: Categorization of TE based on the type of output (O/P).	Vietnam 	TG	$P_{EXTENSION\ SERVICE}$, $P_{EDUCATION}$, P_{INCOME}, $F_{TEA\ VARIETY}$	$P_{ETHNICITY}$ (minority religion)	TE_{mean} = 0.322 →High potential to improve TE TE_{mean} (BT) > TE_{mean} (GT)
2	28	2014	June and July, 2013	200	SFA: Estimation TE MLE & OLS Estimates: of Determinants of TI Descriptive Statistics: Categorization of TE based on the migration experience of labour	Sri Lanka 	STG	$M_{EDUCATION}$, $M_{REMITTANCE}$	$P_{EDUCATION}$, P_{AGE}, $P_{D\text{-}RATIO}$, M_{AGE}, M_{GENDER}, $M_{DURATION}$	$(TE_{mean})_{MIGRANT}$ = 0.7767 > $(TE_{mean})_{NON\text{-}MIGRANT}$ = 0.6269 → Scope to improve TE in both the cases
3	31	2015	N/A	84	Descriptive Statistics: Classification of STGs on basis of GAP adaptation SFA: Estimation of TE MLE: Determinants of TI	Sri Lanka 	STG	$P_{EDUCATION}$, P_{GENDER}, $P_{AFFILIATE}$, $P_{EXPERIENCE}$, P_{GAP}	P_{AGE}, $P_{EXTENSION}$ S_{ERVICE}, $P_{OCCUPATION}$, F_{AGE}	TE_{mean} = 0.6317
4	16	2015	2014	243	SFA: Estimation of both TE_{io} and TE_{oo} Elasticity of output	Vietnam 	TG	P_{GENDER}, $P_{EXPERIENCE}$, $P_{ETHNICITY}$,	$P_{OCCUPATION}$, P_{AGE}, $P_{EDUCATION}$,	$(TE_{oo})_{mean}$ = 0.9229 > $(TE_{io})_{mean}$ = 0.8221 → TGs have more

					(O/P) with respect to input (I/P): ε = Δ(O/P)/Δ(I/P) Estimation of Resource Use Efficiency (RUE) MLE: Determinants of RUE			$P_{FAMILY\ SIZE}$, F_{AGE}, $P_{RESOURCE\ CONSERVATION}$ (application of soil & water conservation - SWC technology), Y, $INFRA_{IRRIGATION}$ (well water utilization & stream water utilization)	$P_{AFFILIATE}$	ability to reduce resource (I/Ps) use by 79% without altering the level of current O/P, than they do to increasing the O/P. ∑(εmean) = 0.323 → Presence of decreasing returns to scale among the TGs.
5	17	2016	June 2016 to July 2016	90	SFA: Estimation of TE_{oo}, CE, SE and EE MLE: Determinants of TE and CE Wilcoxon Rank-Sum (Mann-Whitney): Test the difference in EE between two categories of STGs	India 	STG	P_{GENDER}, $P_{EXPERIENCE}$, $P_{FAMILY\ SIZE}$, $P_{EDUCATION}$	$P_{EXTENSION\ SERVICE}$ (Training)	$(TE_{oo})_{mean} = 0.83 < CE_{mean} = 1.11$ → STGs have more ability to increase production (O/P) by 17% by effectively utilizing the available resources (I/Ps) • 67% variations in O/P was due to technical inefficiency • 66% variations in O/P were due to cost inefficiency • $P_{AFFILIATE}$ negatively influence CE • $P_{EXPERIENCE}$, $P_{EDUCATION}$, $P_{OCCUPATION}$ positively influence CE $SE_{mean} = 1.72$ and $EE_{mean} = 0.776$ • There is No difference in

										EE levels between two categories of STGs individual ($EE_{INDIVIDUAL\ STG}$) and in groups ($EE_{GROUP\ STG}$)} 0.737 chances are there that $EE_{INDIVIDUAL\ STG}$ > $EE_{GROUP\ STG}$
6	32	2017	May 2012 to June 2012	230	OLS: Estimation of elasticity of production (ε) MLE: Estimation of Production Frontier SFA: Estimation of TE_{oo} Tobit Regression Model: Determinants of TE	Malawi 	STG	$P_{EDUCATION}$, $P_{EXPERIENCE}$, $P_{OCCUPATION}$ $P_{FAMILY\ SIZE}$, $F_{LOCATION}$ (farm – factory distance), N_{HIRED}	$F_{CONTRACT\ TYPE}$ (with government cooperatives), $P_{EXTENSION\ SERVICE}$ (visits)	TE_{mean} = 0.67 → STGs have ability to increase the green leaf production by 33% by effectively utilizing the available resources (I/Ps)
7	29	2018	January 2016 to March 2016	93	SFA: Estimation of TE MLE: Determinants of TE Descriptive Statistics: Categorization of TE based on the UTZ certification status of STG	Sri Lanka 	STG	P_{GAP} (harvesting with different plants over a period of time)	$F_{CERTIFICATION}$ (UTZ Certification)	TE_{mean} = 0.533 → STGs have ability to increase the green leaf production by 46.7% by effectively utilizing the available resources (I/Ps) $TE_{mean-UTZ}$ = 0.517 < $TE_{mean-Non-UTZ}$ = 0.596 • $Q_{FERTILIZER}$, Q_{LABOUR} positively and Q_T negatively affects Y
8	33	2018	June to August 2016	120	SFA: Estimation of TE Regression Analysis:	Vietnam 	STG	$P_{EDUCATION}$, $P_{EXPERIENCE}$, $P_{EXTENSION\ SERVICE}$	F_{AGE}	$(TE_{mean})_{CTP}$ = 0.701 > $(TE_{mean})_{OTP}$ = 0.652 → CTP and OTP

					Determinants of TE Binary Logit (Discrete Choice Model): Influencing factors of the tea farmer's choice (decision) on OTP					(have ability to increase the green leaf production by 29.9% and 34.8% by effectively utilizing the available resources (I/Ps) and technology • A Farmer's decision to opt for OTP is positively influenced by $P_{EXTENSION\ SERVICE}$, Q_T, $F_{CONTRACT\ TYPE}$ (contract to sell product) and negatively influenced by $P_{EXPERIENCE}$
9	34	2019	N/A	200	SFA: Estimation of technical TE MLE: Determinants of TE	Sri Lanka 	STG	P_{AGE}, $P_{EDUCATION}$, $P_{EXPERIENCE}$, $P_{OCCUPATION}$, $P_{AFFILIATE}$, P_{CERDIT}, F_{AGE}	N/A	TE_{mean} = 0.8736 → STGs have ability to increase green leaf production by 12.64% through better utilization of available resources and technology.
10	35	2019	2017	241	SFA: Estimation of TE Regression Analysis: Determinants of TI	China 	TG	$P_{EDUCATION}$, $P_{MIGRATION\ STATUS}$ (rural–urban migration experience), N_{FAMILY}	Q_T, $F_{LOCATION}$ (farm – village committee distance to have access to new agricultural technologies and agricultural activities condu -cted by village committees and	TE_{mean} = 0.581 → TGs have ability to increase the green leaf production by 9 % by effectively utilizing the available resources (I/Ps) • N_{AGE} has an inverted U-shaped (non-linear)

									township location)	relationship with TE • N_{AGE} (turning point) = 42.813 years
11	18	2019	2018-19	40	SFA: Estimation of TE, CE, AE and EE MLE: Determinants of TE and CE	India 	STG	$P_{EXTENSION\ SERVICE}$ (Training), $P_{EDUCATION}$	N/A	TE_{mean} = 0.85 < CE_{mean} = 1.15 → Organic STGs have more ability to increase production (O/P) by 15 % by effectively utilizing the available resources (I/Ps) AE_{mean} = 88 % and EE_{mean} = 75 % →Scope to increase the extent of organic tea cultivation and production by the small tea growers by increasing the EE of the system with adaptation of appropriate strategies (allocation of available resources and effectively utilizing them) • 98 % variations in O/P were due to technical inefficiency (TI). • 20 % variations in O/P were due to cost inefficiency (CI). The variable taken into consideration proved to be statistically insignificant to CI.

12	36	2020	2014, 2015 2016, 2017	210	SFA: Estimation of TE OLS : Determinants of TI	India 	STG	P_{AGE}, $P_{ETHNICITY}$ (Assamese speaking farmers were more technically efficient than that of non-Assamese speaking farmers), $INFRA_{OWN\ TRANSPORT}$, $PREGD$	N/A	TE_{mean} = 0.503 → STGs have ability to increase the green leaf production by 49.7 % by effectively utilizing the available resources (I/Ps) • Q_T, $F_{LOCATION}$ (farm – located in highest concentration of STGs), $Q_{FERTILIZER}$, CapEx positively impacts Y
13	37	2020	2018	100	SFA: Estimation of TE OLS & MLE : Determinants of TI	Sri Lanka 	STG	$P_{OCCUPATION}$, $P_{EDUCATION}$ $P_{EXPERIENCE}$, $F_{TEA\ VARIETY}$, $P_{FAMILY\ SIZE}$, P_{GENDER}, t (duration of organic tea cultivation)	P_{AGE}, $P_{LIVESTOCK}$	TE_{mean} = 0.247
14	38	2021	May 2016 to June 2016	161	SFA: Estimation of TE_{oo} by two methods viz., (i) CD-SPF, and (ii) TLSPF OLS : Determinants of TE_{oo} Delta method: Assess I/P – O/P elasticity (ε) & Marginal Effect of all the exploratory components w.r.t Y	China 	STG	T_{STATUS} (secured through certification, land readjust -ment and registration) $P_{EXPERIENCE}$, $F_{LOCATION}$ (farm distance from house), E_{LAND} S_{LOPE}, Q_T	P_{AGE}, $Q_{FERTILIZER}$ (chemical fertilizer), $P_{EDUCATION}$	(i) (TE_{mean}) CD-SPF = 0.661856; (ii) (TE_{mean}) TLSPF = 0.674684 ε (T, Y) = 0.144, • ε (I, Y) = 0.105 & ε (N_{FAMILY}, Y) = 0.01 → T is the most crucial input • T and (T& N_{FAMILY}) $_{JOINTLY}$ have a positive impact on Y • I, N_{FAMILY} have no

15	39	2021	2020	120	SFA: Estimation of TE obit Regression Model: Determinants of TE	Sri Lanka 	STG	$P_{EDUCATION}$, P_{GENDER}, $P_{EXTENSION\ SERVICE}$, $F_{TEA\ VARIETY}$ (clone TRI-2026)	F_{AGE}	significant impact on Y TE_{mean} = 0.7844 → STGs have ability to increase the green leaf production by 21.56 % by effectively utilizing the available resources (I/Ps) • QLABOUR is the most significant factor in STG production system (β = + 0.843)

Table 2: Tabulation of Empirical Work on Estimation of Technical Efficiency of Tea Farming System Using Data Envelopment Analysis (DEA)

Sl. No.	Aut hor(s)	Year	Period	Sample Size	Methodology	Country	Sector	Remarks		
								Factors having positive impact on TE	Factors having negative impact on TE	Others
1	21	2014	November, 2013	50	**DEA:** Determination of TE and SE scores Probit Regression Model : Determinants of TE	Zimbabwe 	STG – Out grower (OG)	Q_T, $P_{EXTENSION\ SERVICE}$, Y	P_{AGE}, $Q_{FERTILIZER}$, $F_{COMMERCIALIZATION}$, Q_{LABOUR}	TE_{mean} = 0.79 < SE_{mean} = 0.89 → Inefficiency is mainly due to inefficient operation in implementing the production plan of the STG – OGs.

2	40	2015		78	DEA: Determination of TE scores Descriptive Statistics: Impact of various inputs on the TE	India 	STG	Q_T, $P_{EXTENSION\ SERVICE}$, $P_{EXPERIENCE}$	N/A	TE_{mean} = 0.845
3	22	2018	December 2015 to March 2016	525	DEA: Determination of TE and SE scores Fractional Regression Model (FRM): Determinants of TE	Kenya 	STG	$P_{EDUCATION}$, $P_{EXTENSION\ SERVICE}$, N_{FAMILY}, $P_{MARKETING\ CHANNEL}$, $F_{LOCATION}$	Q_T, F_{AGE}	TE_{mean} = 0.46 < SE_{mean} = 0.67 → Inefficiency is mainly due to inefficient operation in implementing the production plan of the STG
4	23	2019	2017	138	DEA: Determination of TE, SE, AE, EE and PTE scores Tobit Regression Model: Determinants of TE	Turkey 	TG	P_{AGE}, $P_{EDUCATION}$, $P_{FAMILY\ SIZE}$, Q_T, P_{GAP} (soil test performance, fertilizer application method, terrace cultivation), $P_{AFFILIATE}$, C_{MODE}, T_{STATUS}	F_{AGE}, $F_{LOCATION}$ ($E_{LAND\ SLOPE}$, $E_{ALTITUDE}$, $E_{EROSION\ RISK}$)	TE_{mean} = 0.645, AE_{mean} = 0.74, EE_{mean} = 0.48, PTE_{mean} = 0.575 & SE_{mean} = 0.885 TE_{mean} < SE_{mean} → Inefficiency is mainly due to inefficient operation in implementing the production plan of the TG.
5	41	2020	July 2014 to Septe mber 2014	40	DEA: Determination of TE Stochastic Frontier Regression Analysis: Determinants of TE	Kenya 	STG	N/A	P_{GENDER}, $P_{OCCUPATION}$, Q_T	TE_{mean} = 0.503

Table 3: Tabulation of Empirical Work on Calculation of Technical Efficiency of Tea Farming System Using Both Methodologies: Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA)

								Remarks	
Sl. No.	**Author(s)**	**Year**	**Period**	**Sample Size**	**Methodology**	**Country**	**Sector**	**Factors having impact on TE**	**Others**
1	42	2017	2007 to 2008	124	DEA: Determination of PTE, SE and TE SFA: Estimation of TE OLS & MLE : Determinants of yield of green leaf (Y) Descriptive Statistics : Factors influencing TE	India	STG	F_{AGE}, $P_{MARKETING\ CHANNEL}$, $P_{EXPERIENCE}$, Q_{LABOUR} (skilled labour) has positive impact on TE	**DEA** • PTE_{mean} = 0.9164 > SE_{mean} = 0.8913 → Improper utilization of resources contributes more to the overall inefficiency of the plantations than does supervisory underperformance. • $(TE_{mean})_{DEA}$ = 0.8167 **SFA** • (TEmean)SFA= 0.62 $(TE_{mean})_{DEA}$ > $(TE_{mean})_{SFA}$ → DEA incorporates random noises as a part of the efficiency score, whereas SFA separate random noise from efficiency score **OLE & MLE** • Q_T, $Q_{FERTILIZER}$ (Nitrogen & Potassium), Q_{FN}, Q_{PEST}, Q_{LABOUR} (hired) have a positive impact on Y **Descriptive Statistics** • QT has significant impact on TE with 12 acres or more as optimal size
			2010 to 2011 and 2011 to 2012	273	OLS & D escriptive Statistics: Analysis of the inter relationship between STG and		BTG		• Δ (share in the tea produced from out sourced -green leaf) = +8.31% • Δ (BTGs outsourced green leaf) = +0.74% • F_{AGE} and Q_{LABOUR} (permanent & causal), $F_{OPERATE}$,

BTG		Q_{GL-OUT}, $Q_{OUT-STG}$ have a negative and positive impact on Y respectively. • $(COP)_{STG} < (COP)_{BTG}$ Preference of out sourcing green leaf from STGs by BTGs.

Where, $(COP)_{STG}$ = COP in STGs, $(COP)_{BTG}$ = COP in BTGs

Major Findings and Discussion

The research work carried out on estimation of TE worldwide on different commodities is plentiful. However, the researches carried out on TE of tea farms are scarce. About 21 studies from all over the world were investigated by the researchers and the computed TE_{mean} of TGs is around 67.98%. This indicated that that there is considerable space to increase GTL yield in tea cultivation without additional inputs and given existing production technology The studies have been conducted in developed and developing countries with tea growing areas to determine or estimate the TE of the tea farms at plantation level. Sri Lanka accounts with highest number of studies (6 or 28.57%), followed by India (5 or 23.81%), Vietnam (3 or 14.29%), China & Kenya (each 2 or 9.52%), and Turkey, Zimbabwe & Malawi (each 1 or 4.76%). The TE_{mean} of the tea farms was found to be highest in Zimbabwe (0.79) followed by India (0.74), Vietnam (0.68), Malawi (0.67), Turkey (0.65), Sri Lanka & China (each 0.64) and Kenya (0.48). A study conducted in Sri Lanka by[28] highlighted that the TE_{mean} of migrant STG[9] ($TE_{mean-MIGRANT}$) (0.7767) is greater than that of non-migrant farms ($TE_{mean-NON-MIGRANT}$) (0.6269) were calculated as 0.7767 and 0.6269 respectively. Another study conducted in Sri Lanka by[29] revealed that TE_{mean} of UTZ certified STGs ($TE_{mean-UTZ}$) (0.517) is comparatively less than that of Non-UTZ STGs ($TE_{mean-NON-UTZ}$) (0.596). The major findings from the above research works have been tabulated in Table (1), (2) and (3) followed by an interpretation on the same.

Interpretation of the Studies Using SFA Technique

A major portion of the studies reviewed used the SFA technique to estimate the plantation level TE of TGs as stated in Table (1) above. The TE_{mean} of TGs from these 15 (71.43%) studies was 0.683064. The researchers used the production or cost model based either on a CD function or TL function in estimating the production and/or cost frontier. The use of various SFA models by the investigators in their studies is stated below.

Sl. No.	SFA Model	Studies
1	TL-SFA model	30, 31, 16, 29
2	CD-SFA model	17, 32, 34, 35, 18, 36, 37, 39
3	Both TL-SFA & CD-SFA models	28, 33, 38

Interestingly, to calculate the EE of TGs[17] and form[18] used CD-SFA production and cost models in their studies.[16] utilized the TL-SFA production model to estimate the TE_{io} and the TE_{oo} of a sample TGs in Vietnam. The value of TE_{io} (0.9229) was found to be greater than that of TE_{oo} (0.8221) which indicated that the sample has the capacity to decrease the observed level of all inputs by 17.79% without compromising the contemporary level of output. Interestingly, an investigation carried out by 38 in China revealed that the TE_{mean} of STGs estimated by considering production model in CD-SFA form (0.661856) and TL-SFA form (0.674684) gave almost same results. Moreover, it was observed that both these frontier models adapted in the studies can be applied to a single cross section as well as to panel data.

The various statistical techniques applied by the researchers in their studies to analyze the effect of various factors on the TE of TGs are stated below.

Sl. No.	Statistical Technique	Studies
1	Bootstrapping	30
2	OLS Estimates	36, 38
3	MLE Estimates	31, 17, 29, 34, 18
4	MLE & OLS Estimates	28, 37
5	Tobit Regression Model	16, 32, 39
6	Regression Analysis	33, 35

The significant contrasting outcomes from the studies using SFA technique is stated below, which opens up the door for future research:

Sl. No.	Factor	Studies revealing the positive impact of it on TE	Studies revealing the negative impact of it on TE
1	$P_{EXTENSION\ SERVICE}$	30, 33, 18, 39	31, 17, 32
2	$P_{EDUCATION}$	30, 31, 17, 32, 33, 34, 35, 18, 37, 39	28, 16, 38
3	$P_{ETHNICITY}$	16, 36	30
4	P_{AGE}	34, 36	28, 31, 16, 37, 38
5	$P_{AFFILIATE}$	31, 34	16
6	$P_{OCCUPATION}$	32, 34, 37	31, 16
7	F_{AGE}	16, 34	31, 33, 39
8	$F_{LOCATION}$	32, 38	35
9	QT	38	35

Interestingly, the study conducted by[35] revealed that it was revealed that there exists an inverted U-shaped (non-linear) relationship between the TE and P_{AGE}, and the turning point of age was found to be 42.813 years. In a recent study conducted in Sri Lanka by[37] found that the TE_{mean} of the organic STGs is 0.247, which is lowest among all the studies conducted in the country. Contrary to this, an investigation carried out by[18] found that the TE_{mean} of the STGs is 0.85, which is comparatively high than the TE_{mean} of the STGs calculated from other studies in the country. A similar study conducted by[33] in the Vi Xuyen district, Ha Giang province of Vietnam revealed that TE_{mean} for conventional tea production (CTP) cultivators $\{(TE_{mean})_{CTP}\}$ (0.701) higher than that of and organic tea production (OTP) cultivators $\{(TE_{mean})_{OTP}\}$ (0.652). it is noteworthy that,[33] adapted the Discrete Choice models in form of Binary Logit to determine the influencing factors of the tea farmer's choice (decision) on OTP. The ambiguous outcomes related to the impact of organic conversion of tea farms on its TE in different nations will thus create a dilemma on the farmer's decision to adopt organic tea farming.

Interpretation of the Studies Using Dea Technique

Out of 21 studies reviewed it was found that 5 (23.81%) studies used DEA to determine the TE of the TGs at plantation level as stated in Table (2) above. The plantation level TE_{mean} of TGs determined by this method is 0.676617. The studies reflected the use of both BCC and CCR models of DEA. The use of different models of DEA by researchers in carrying out their studies is stated below.

Sl. No.	DEA Model	Studies
1	CCR	21
2	BCC (output oriented)	40
3	Both CCR & BCC	22, 23, 41

The various statistical techniques applied by the researchers in their studies to analyze the effect of various factors on the TE of TGs are stated below.

Sl. No.	Statistical Technique	Studies
1	Probit Regression Analysis	[21]
2	Descriptive Statistics	[40]
3	Fractional Regression Analysis	[22]
4	Double Censored Tobit Regression Analysis	[23]
5	Stochastic Frontier Regression Analysis	[41]

It was notable that[23] conducted the VIF Diagnostic Test to check the multi-co linearity among the independent variables prior to the determination of the factors contributing to the efficiency of the TG farms.

The significant contrasting outcomes from the studies using DEA technique is stated below, which puts forth further avenues for research.

Sl. No.	Factor	Studies revealing the positive impact of it on TE	Studies revealing the negative impact of it on TE
1	Q_T	[21, 40, 23]	[22, 41]
2	$F_{LOCATION}$	22	[23]
3	P_{AGE}	23	[21]

Interpretation of the Studies using both SFA and DEA Technique

The only study carried out by[42] in India reflected that the TE_{mean} of the STGs determined by using DEA technique $\{(TE_{mean})_{DEA}\}$ is 0.8167 which was higher than that by using SFA $\{(TE_{mean})_{SFA}\}$in the same set of data (0.62), as it takes into account the data noise such as errors and omitted variables. The study also found that the means of procurement of leaf from STGs by the large tea estates (BTG) has been adopted on the ground of CE or cost of production (COP) of GTL.

Conclusion

It can be concluded that to raise the efficiency and productivity of the tea farms, it becomes imperative to quantitatively measure the existing level of TE and policy options available for raising the present level of efficiency, given the fact that efficiency of production is directly related to the overall productivity of the plantation sector. The empirical evidence is very important in identifying the factors that threaten the productivity of these units and in generating information for designing of support policies for the small tea gardens and institutional improvement.

Future Outlook

- The impact of various factors on their TE had contradictory outcomes in different studies. To validate such contradictions, a further investigation is required to be carried out to find the impact of such factors on the TE of the tea farms in different geographical locations.
- The quality parameters of the tea farms were not taken into consideration in any of the studies to benchmark the best practicing farm, which opened up the scope to carry out investigation incorporating the quality aspect of the tea farms to measure the performance of the farms.

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Conflict of Interest

All the authors declare that there is no conflict of interest with any authority.

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