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Assessing Firm Level Efficiency in The Indian Tobacco Sector: A Non-Parametric Approach

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Abstract: This research examines how the Indian Tobacco industry has performed over the past ten years, with a focus on analysing productivity trends in some selected Tobacco manufacturing companies. Using input-oriented Data Envelopment Analysis (DEA), the study measures overall technical efficiency (OTE) and decomposes it into pure technical efficiency (PTE) and scale efficiency (SE). The results reveal an average OTE score of 0.876, suggesting that the typical Tobacco manufacturing company could reduce input usage by 12.4% without compromising output. Further analysis shows SE is higher at 0.878 compared to PTE at 0.756, indicating that most inefficiencies stem from resource mismanagement rather than suboptimal scale. In the second part of the study, a Tobit regression analysis was conducted to identify the factors affecting efficiency, using overall technical efficiency scores as the dependent variable. Results revealed that younger firms and those with higher Labour intensity tend to be more efficient. Conversely, older firms and those reliant on capital are less efficient, highlighting potential areas for improvement.

Key Words: Tobacco sector, Data Envelopment Analysis, Tobit regression, Technical Efficiency.

1. INTRODUCTION

India holds a significant position in the global tobacco market, ranking as the second-largest producer after China. The country dedicates approximately 0.45 million hectares to tobacco cultivation, representing about 10% of the world's total tobacco cultivation area. This contributes to roughly 9% of global tobacco production (Indian Brand Equity Foundation [IBEF], 2024). The average estimated annual production of tobacco crops in India hovers around 800 million kg (Reserve Bank of India [RBI], Handbook of Statistics on Indian

Economy, 2023). The diverse tobacco landscape of India includes varieties such as flue-cured Virginia, country tobacco, burley, bidi tobacco, cheroots, and chewing tobacco (Tobacco Board of India, 2022).

The Indian tobacco industry is a significant employer, providing livelihoods for approximately 45.7 million people across various stages, including farming, labour, manufacturing, processing, and export activities (Ministry of Agriculture & Farmers Welfare, Government of India, 2021). Compared to other tobacco manufacturing nations, India boasts relatively lower production, farming, and export costs, enhancing its competitive appeal. Furthermore, Indian manufactured tobacco is often perceived to have an advantage due to lower levels of heavy metals, Tobacco Specific Nitrosamines (TSNAs), and pesticide residues compared to tobacco from other producing countries (Central Tobacco Research Institute [CTRI], 2020).

Against this backdrop, the present study aims to evaluate the efficiency levels of the Tobacco sector in India using Data Envelopment Analysis model. The paper is organized as follows: Section 1 being Introduction, Section 2 presents a brief review of the literature related to the performance measurement of Tobacco manufacturing companies in India. Section 3 provides a discussion on the database, Section 4 provides details about methodology used for the efficiency measurement. Section 5 presents the empirical results. Section 6 concludes the paper.

2. REVIEW OF LITERATURE

This section delves into existing literature concerning the efficiency of the tobacco industry, particularly focusing on studies employing Data Envelopment Analysis (DEA). The study by Kumar and Sharma (2020) analysed productivity trends in India’s food, beverages, and tobacco industries from 1998-99 to 2017-18 using DEA and the Stochastic Frontier Approach (SFA). Their findings indicated a slowdown in total factor productivity growth (TFPG) in most of these industries post the global financial crisis (2008-09 to 2017-18), primarily driven by a decline in technological progress. This study sets a broader context for understanding productivity dynamics within the Indian tobacco sector and highlights the applicability of DEA in such analyses. Padmaja et al. (2006) investigated resource productivity and allocative efficiency of tobacco in the Prakasam District of Andhra Pradesh using a Cobb-Douglas production function. Their findings indicated increasing returns to scale and the overuse of inputs like human labour, fertilizers, and pesticides, suggesting potential for improved efficiency through resource reorganization at the farm level in a key tobacco-producing region of India. The study by Bhatnagar (2022) on India's food processing sector, which includes tobacco processing, estimated technical efficiency using a stochastic frontier production function. The findings revealed an average technical efficiency of 86.6% for the sector, indicating potential for improvement. Notably, the tobacco and beverages sub-sector showed a relatively high average technical efficiency of 87%. The study emphasized that growth in the food processing sector has been primarily driven by increased input use rather than efficiency gains, suggesting the need for technological upgrades and better resource management, which is also relevant for the tobacco processing segment. Salih (2016) examined the export performance of Indian tobacco companies and the role of the Tobacco Board, focusing on export procedures and documentation. While not employing DEA for efficiency assessment, the study provides crucial insights into the operational framework of tobacco exports in India, including the regulatory and logistical aspects that can influence overall export efficiency. Khamon (2015) investigated the improvement of efficiency and productivity in a cigarette production process in Thailand using Overall Equipment Effectiveness (OEE). The study identified key bottlenecks related to organization and labour, machinery, and raw materials, and proposed targeted improvement strategies. While focusing on cigarette manufacturing in Thailand, the methodological approach to identifying and addressing inefficiencies offers valuable insights for analysing the Indian tobacco manufacturing sector.

3. DATA AND SOURCES OF DATA

To assess efficiency, we analysed panel data (2013–2023) for 21 listed Indian Tobacco producing firms using input-oriented Data Envelopment Analysis Approach. Firms were chosen based on complete data for four inputs and one output from the CMIE database. Inputs selected were: real salaries/wages (CPI-adjusted), raw material costs, capital stock (PIM-based, WPI-adjusted), and fuel costs (WPI-adjusted). Output selected is: sales plus change in stock, deflated by Tobacco sector WPI.

4. METHODOLOGY

Data Envelopment Analysis (DEA) is a non-parametric linear programming method used to evaluate the efficiency of decision-making units (DMUs), such as firms, hospitals, schools, or bank branches, that convert multiple inputs into multiple outputs. DEA identifies efficient frontiers and compares each DMU against this benchmark to determine relative efficiency scores.

DEA models are typically categorized into:

1. CCR (Charnes, Cooper, and Rhodes) Model – assumes constant returns to scale (CRS).

2. BCC (Banker, Charnes, and Cooper) Model – assumes variable returns to scale (VRS).

DEA can be input-oriented (minimizing input while maintaining output) or output-oriented (maximizing output with given input).

A) Input oriented CCR Model (Constant Returns to Scale)

Let there be:

- n DMUs (indexed by $j = 1, \dots, n$),
- each DMU uses m inputs (indexed by $i = 1, \dots, m$) and produces s outputs (indexed by $r = 1, \dots, s$),
- inputs x_{ij} and outputs y_{rj},
- the DMU under evaluation is DMU_0 with inputs x_{i0} and outputs y_{r0}.

Primal Form (Envelopment Form)

$$
\begin{aligned}
\min_{\theta,\lambda} \quad & \theta && (1)\\
\text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{i0}, \quad \forall i = 1, \dots, m && (2)\\
& \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{r0}, \quad \forall r = 1, \dots, s && (3)\\
& \lambda_j \ge 0, \quad \forall j = 1, \dots, n && (4)
\end{aligned}
$$

Where:

- θ is the efficiency score ($0 < \theta \le 1$).
- λ_j are intensity variables forming a convex combination of DMUs.

B) Output oriented BCC Model

This model adds a convexity constraint to allow variable returns to scale.

Primal Form (Envelopment Form)

$$\min_{\theta,\lambda} \quad \theta \tag{5}$$

$$\text{s.t.} \quad \sum_{j=1}^{n} \lambda_j \, x_{ij} \leq \theta x_{i0}, \quad \forall i = 1, \dots, m \tag{6}$$

$$\sum_{j=1}^{n} \lambda_j \, y_{rj} \geq y_{r0}, \quad \forall r = 1, \dots, s \tag{7}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{8}$$

$$\lambda_j \geq 0, \quad \forall j = 1, \dots, n \tag{9}$$

The only difference from the CCR model is the convexity constraint:

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{10}$$

TOBIT ANALYSIS

To understand which factors influence the Overall Technical efficiency calculated in the first stage of Data Envelopment Analysis (DEA), we have utilized a Tobit regression model.

$$\begin{aligned} y_i^* = \beta_0 + \beta_1 \text{SIZE}_i + \beta_2 \text{ AGE}_i + \beta_3 \text{ LABOUR INTENSITY}_i + \beta_4 \text{ CAPITAL INTENSITY}_i \\ + \beta_5 \text{ CAPITAL-LABOUR RATIO}_i + \ \beta_6 \text{ MARKETING EXPENSES} \\ + \epsilon_i \qquad\qquad (11) \end{aligned}$$

In this equation, y_i^* is the latent variable representing the "efficiency score" for the firm I (selected decision-making unit). $\beta_1, \beta_2, \dots, \beta_6$: Coefficients of the independent variables. AGE_i is the age of the company. This is calculated by considering the years since the company was incorporated. SIZE_i is denoted as the size of the company. It is calculated by taking the logarithm of total assets. $\text{MARKETING EXPENSES}_i$ is the marketing expenses incurred by the company. CAPINT_i: is the capital intensity calculated as the ratio of the firm's capital value to its net sales revenue. This measure provides insights into the capital requirements for generating a unit of revenue, effectively capturing the firm's dependency on capital for its operational efficiency. (ie; capital per unit of output). LABINT_i: Here, labor intensity is calculated as the ratio of labor expenses to net sales revenue. This variable provides valuable insights into the firm's dependence on human capital for generating revenue and achieving operational efficiency. (labor costs per unit of output). Next variable is the CAPLAB_i. The capital-labor ratio is a significant variable that represents the proportion of capital resources employed relative to labor input in a firm's production process. In this study, the capital-labor ratio is computed as the ratio of the firm's capital value to its labor expenses. (capital divided by labor).

5. RESULTS AND DISCUSSIONS

Descriptive statistics of the entire dataset used in the study is given below. It helps the readers to understand the nature of variables in detail. All the figures in the analysis are depicted in Million.

Table 1: Descriptive Statistics of the variables

Variable	Mean	Std. Deviation	Minimum	Maximum
Net Sales	22062.11	7782.71	16.157	424992
Raw Material	5798	19602.9	1.34	12254
Labor	1234.27	3306.21	3.753	17982.9
Energy	335.891	1334.78	0.268	8372.92
Capital	7708.654	30670.96	2.192	186545.4

Source: Authors' own calculations

Table 1 shows the average sales of firms is 9,164.2 million. Average wages and salaries are 429.3 million, raw material costs 7,097.6 million, and power, fuel, and water expenses are 124.3 million.

5.1 Variation in Technical Efficiency of the Firms

For the purpose of present analysis, overall technical efficiency score, pure technical efficiency score and scale efficiency score of 21 Tobacco manufacturing firms were analysed using the above stated output and input variables in the DEAP software for the period of 2013-2023. Trends in overall technical efficiency is depicted in table 2

Table 2: Trends in overall technical efficiency

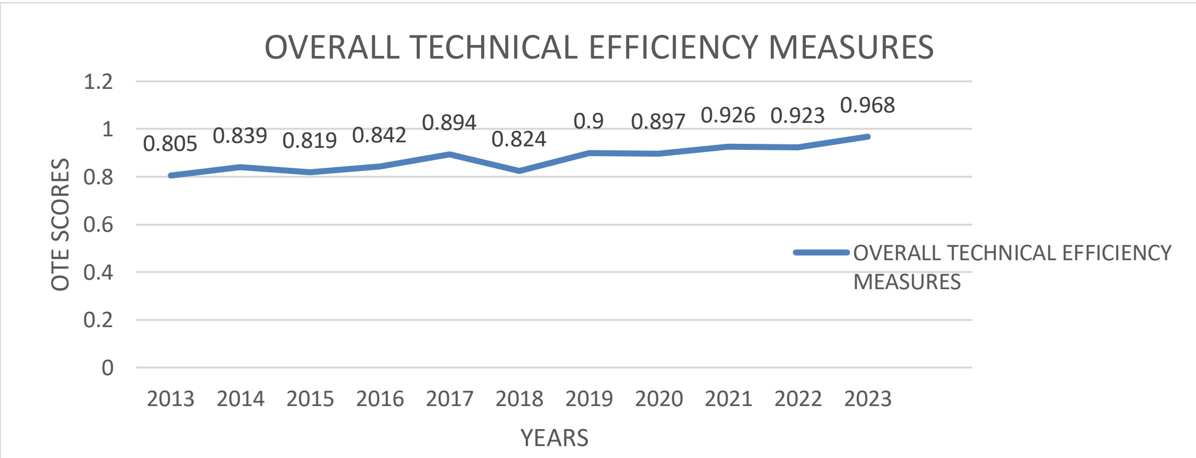
YEAR	MEAN	NO OF EFFICIENT FIRMS	MINIMUM SCORE
2013-2014	0.805	07	0.130
2014-2015	0.839	06	0.196
2015-2016	0.819	08	0.163
2016-2017	0.842	07	0.144
2017-2018	0.894	09	0.186
2018-2019	0.824	06	0.139

2019-2020	0.901	07	0.320
2020-2021	0.897	10	0.228
2021-2022	0.926	09	0.338
2022-2023	0.923	10	0.583
2023-2024	0.968	10	0.366

Source: Authors' own calculations

Table 2 provides an overview of the technical efficiency (OTE) statistics over the past decade. The mean values of the Overall Technical Efficiency ranges from 0.897 in 2020-2021 to 0.968 in 2023-2024. The average overall technical efficiency score of 0.876 implies that under constant return to scale (CRS) assumption, the typical tobacco manufacturing firm could reduce it's input usage by 12.4%. Out of the total of 21 firms, ten firms were efficient in the year- 2020-2021, 2022-2023 and 2023-2024. Apart from this, in the year 2018-2019, only six firms were purely efficient. Findings reveal that, a somewhat consistent trend is observed in the Overall Technical Efficiency measures. The plausible reason behind such trend is the habitual nature of the consumers, who buy tobacco products even after being aware of the ill effects of consuming it. Minimum scores achieved by the firms in particular years are also depicted in the third column of the table. Figure 1 provides a graphical representation of the trend observed while calculating the overall technical efficiency scores.

Figure 1: Graphical Representation of Overall Technical Efficiency Measures



Source: Authors' own Calculation

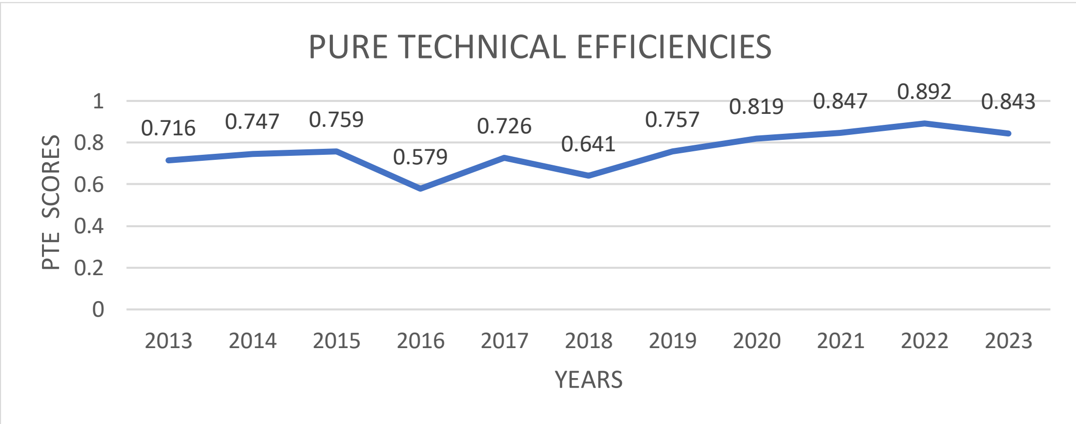
Pure Technical Efficiency scores were also calculated, as the part of the study. Results of the analysis are displayed in the table 3. Graphical representation of the same is depicted in Figure II.

Table 3: Trends in Pure Technical Efficiency scores of the Firms

YEAR	MEAN	NO OF EFFICIENT FIRMS	MINIMUM SCORE
2013-2014	0.716	13	0.195
2014-2015	0.747	13	0.258
2015-2016	0.759	13	0.285
2016-2017	0.579	10	0.213
2017-2018	0.726	12	0.320
2018-2019	0.641	11	0.517
2019-2020	0.757	08	0.403
2020-2021	0.819	15	0.623
2021-2022	0.847	11	0.481
2022-2023	0.892	15	0.421
2023-2024	0.843	16	0.732

Source: Authors' own calculations

Figure 2: Trends in Pure Technical Efficiency Scores of the Firms



Source: Authors' own Work

Scale Efficiency scores of the Tobacco manufacturing firms were also computed as the part of the study. Scale efficiency of a particular firm is measured by dividing the Overall Technical Efficiency scores with its Pure Technical efficiency score. This measure reveals about the size of the operation in the firm, suggesting whether a firm should increase or downsize its production capacity in order to operate on the efficiency frontier. Scale efficiency scores are depicted in the Table 4.

Table 4: Trends in Scale Efficiency of the Variables

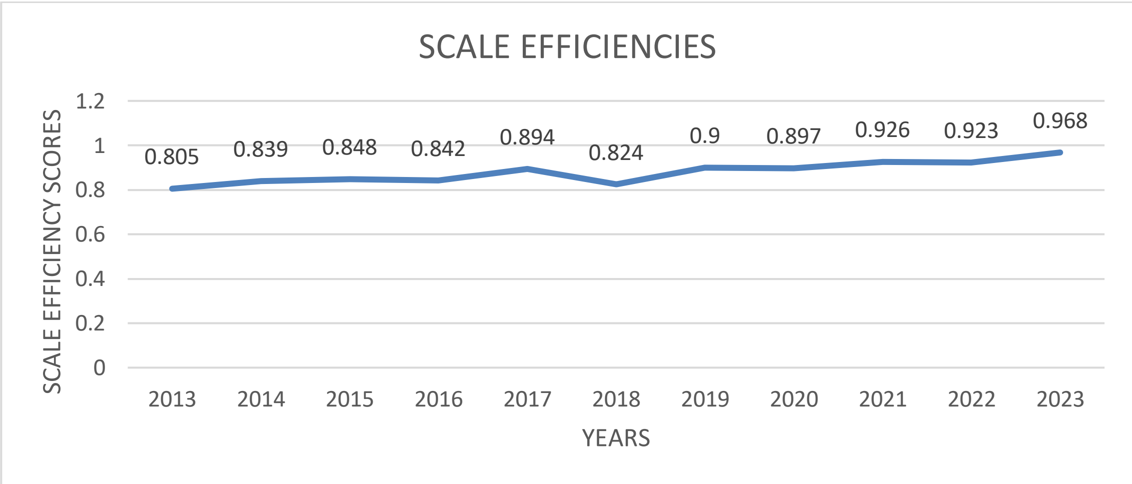
YEAR	MEAN	NO OF EFFICIENT FIRMS	MINIMUM SCORE
2013-2014	0.805	06	0.380
2014-2015	0.839	07	0.464
2015-2016	0.848	05	0.425

2016-2017	0.842	03	0.270
2017-2018	0.894	03	0.350
2018-2019	0.824	05	0.252
2019-2020	0.901	01	0.300
2020-2021	0.897	05	0.355
2021-2022	0.926	02	0.388
2022-2023	0.923	05	0.812
2023-2024	0.968	06	0.377

Source: Authors' own calculations

The average Scale efficiency value is 0.878. Minimum scores of the firms in each year is also presented in the third column of the table. 0.27 is among the lowest score observed in the year 2016-2017.

Figure 3 : Graphical Analysis of Scale efficiencies of the variables



Source: Authors' Own calculations

Table 4 reveals the average scale efficiency of the firms over the entire study period. The average Scale efficiency value is 0.878. Year wise average Scale Efficiencies presented in the table reveal that it is highest in the year 2021-2022 and lowest in the year 2013-2014. Table 5.2.2 revealed that the average pure technical efficiency value is 0.756. Hence, it can be computed that the average Pure Technical Inefficiency is 24.4%, and average scale inefficiency value is 12.2%. This result signifies that the inefficiency in Tobacco industry is mainly because of managerial inefficiency rather than disadvantageous scale size. Tobacco firms can become efficient through better conversion of inputs into outputs. Pure technical inefficiency dominates the scale inefficiency in Indian tobacco industry.

5.2 Tobit Analysis

Results of Tobit Regression Analysis is shown in Table 5. It is observed that the probability value is less than the chi-square value, implying that the set of independent variables considered together satisfactorily explain the variations in the dependent variable. Variations in the overall technical efficiency scores of the Tobacco manufacturing companies are explained significantly by the variables including age, labour intensity, capital intensity while variables such as Marketing Expenses and Capital-Labour ratio is not significantly impacting the efficiency.

Table 5: Results of Tobit Regression Analysis

VARIABLES	COEFFICIENTS	Z-VALUE	P-VALUE
Labor Intensity	0.25*	7.36	0.000
Capital Intensity	-0.47*	-10.77	0.000
Capital Labor Ratio	0.005	1.83	0.061
Marketing Expenses	1.2	0.59	0.552
Age	-0.01*	-3.06	0.000
Size	0.09*	1.76	0.078
Sigma_u	0.07*	4.25	0.000
Sigma_e	0.10*	20.97	0.000
Prob >Chi2		0.000*	
Wald Chi2 (6)		280.19*	

Source: Authors' own Calculation (* indicates significance at 5% level)

Findings reveals that labour intensity and capital intensity variables are highly significant at 5% degree of freedom. However, the coefficient values suggest that the labour intensity has a positive relation with the efficiency levels of the firm. Capital Intensity has a negative value of the coefficient, suggesting that most of the Tobacco manufacturing firms in India are labour intensive and not capital intensive. Selling expenditure has a negative impact on the efficiency levels of the firms, but the coefficient is statistically insignificant. It is also observed that the new and young firms have a positive impact on the efficiency levels of the firms as compared to the old and earlier established firms. Size of the firms have no significant impact on the efficiency levels of the firms in India. The probability value of the model being less than the chi-square indicates that the model is significant and robust.

6. CONCLUSION

This study provides valuable insights into the operational performance of the Indian tobacco manufacturing industry over the past decade. The DEA results indicate that while the industry is generally operating efficiently, there remains significant potential for input savings, particularly through better resource management. The decomposition of efficiency scores underscores that inefficiencies are largely due to managerial practices rather than scale limitations. Furthermore, the Tobit regression analysis highlights critical firm-specific characteristics influencing efficiency, suggesting that strategies focused on enhancing labour utilization and revitalizing older firms could lead to substantial performance gains. These findings offer both policymakers and industry leaders a data-driven foundation for improving productivity and competitiveness in the tobacco sector.

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