

# Indian Journal of Modern Research and Reviews

This Journal is a member of the '*Committee on Publication Ethics*'

Online ISSN:2584-184X



## Research Paper

# Productive Efficiency of Manufacturing Industries In Himachal Pradesh Via Data Envelopment Analysis

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ABSTRACT	Manuscript Info.
<p>This study presents a rigorous analysis of productive efficiency within the manufacturing sector of Himachal Pradesh, India, using the non-parametric linear programming technique of data envelope analysis (DEA) [6]. The unique industrial ecosystem of the state, characterized by its special category status and challenging topography, necessitates a focused evaluation of resource utilization. Utilizing an input-oriented BCC model under Variable Returns to Scale (VRS) [4], this research computes technical, pure technical, and scale efficiencies for a stratified sample of 50 firms across Pharmaceuticals, Textiles, Food Processing, and Electronics sectors. Input variables are capital employed and labour, while output is measured by sales value. Results indicate a mean technical efficiency of 0.783, signifying substantial potential for resource optimization. Decomposition reveals scale inefficiency as the primary constraint, with a majority of firms (64.7%) operating under Increasing Returns to Scale (IRS). The study identifies benchmark firms, provides targeted input reduction pathways for inefficient units, and offers stratified policy prescriptions aimed at enhancing sectoral competitiveness through improved managerial practices and optimal scale operations.</p>	<ul style="list-style-type: none"> <li>✓ ISSN No: 2584-184X</li> <li>✓ Received: 29-01-2025</li> <li>✓ Accepted: 22-02-2025</li> <li>✓ Published: 27-03-2025</li> <li>✓ MRR:3(3):2025;41-47</li> <li>✓ ©2025, All Rights Reserved.</li> <li>✓ Peer Review Process: Yes</li> <li>✓ Plagiarism Checked: Yes</li> </ul> <p><b>How To Cite</b></p> <p>Kumar L, Irfan M. Productive Efficiency of Manufacturing Industries In Himachal Pradesh Via Data Envelopment Analysis Indian J Mod Res Rev. 2025;3(3):41-47.</p>

**KEYWORDS:** Productive Efficiency, Data Envelopment Analysis, Linear Programming, Himachal Pradesh, Technical Efficiency, Scale Efficiency, BCC Model.

## 1. INTRODUCTION

In the landscape of global economics, the manufacturing sector is a critical driver of growth, innovation, and employment [19]. For emerging economies like India, elevating this sector's productivity is not merely an option but a necessity for sustainable development [34]. However, input accumulation alone is an insufficient metric for success; the efficiency with which these inputs are transformed into

outputs is the true barometer of industrial health [7]. Productive efficiency, therefore, emerges as a central concept, enabling a rigorous assessment of how close firms operate to a frontier that embodies best practices [13]. Himachal Pradesh presents a fascinating case study. Its designation as a "Special Category State" catalyzed its industrial journey, most notably through the Industrial

Package of 2003, which offered substantial fiscal incentives [17]. This triggered a concentrated industrial boom, particularly in the Baddi-Barotiwala-Nalagarh (BBN) belt, establishing strongholds in pharmaceuticals, textiles, food processing, and electronics [30]. Yet, this growth unfolds against a backdrop of inherent challenges: rugged terrain, elevated logistical costs, infrastructural bottlenecks, and ecological preservation imperatives [32]. This juxtaposition of policy-enabled growth and structural constraints makes a systematic efficiency analysis of its manufacturing sector both imperative and insightful.

While the quantitative expansion of industries in Himachal Pradesh post-2003 is evident, a significant gap exists in understanding the qualitative dimension of this growth—specifically, the operational efficiency of these manufacturing firms [21]. Are these enterprises maximizing output from their invested capital and labour? Do prevailing inefficiencies curtail their competitiveness? Stakeholders, including policymakers and investors, lack a comprehensive, empirical evaluation of the sector's performance beyond conventional indicators like investment volume or unit count. This absence of efficiency-centric analysis risks rendering policy interventions ineffective and allows firms to perpetuate sub-optimal operations [28]. This research is designed to address this void through the following specific objectives:

- To measure the technical, pure technical, and scale efficiency of a cross-section of manufacturing firms in Himachal Pradesh using Data Envelopment Analysis (DEA) [8].
- To identify benchmark firms that define best practices and serve as peers for inefficient units [2].
- To ascertain the nature of returns to scale (increasing, constant, decreasing) characterizing inefficient firms [15].
- To formulate evidence-based policy recommendations and strategic insights for enhancing the overall productive efficiency of the state's manufacturing sector [1].

This study focuses on registered manufacturing units within Himachal Pradesh for the financial year 2022-23. The analysis is constrained by data availability, potentially excluding unregistered or micro-units [31]. The DEA methodology, while robust, is sensitive to outliers and the subjective selection of input-output variables [10]. Furthermore, the efficiency measured is relative to the sample's own frontier, not an absolute global benchmark. External environmental factors (e.g., quality of infrastructure, exact location) are not explicitly modelled in the first stage [18].

The paper is organized into six coherent sections. Following this introduction, Section 2 reviews extant literature. Section 3 elaborates on the theoretical underpinnings and the DEA methodology. Section 4 presents the data analysis and empirical findings. Section 5 discusses the implications of these results, and Section 6 concludes with targeted policy recommendations.

## 2. LITERATURE REVIEW

The conceptual foundation for efficiency measurement was laid by Farrell (1957) [13], who decomposed overall economic efficiency into two components: technical efficiency (the ability to produce maximum output from a given set of inputs) and allocative efficiency (the ability to use inputs in optimal proportions given their prices). This seminal work introduced the concept of a production frontier, a boundary representing the maximum attainable output for any given input level. A firm's technical efficiency is measured by its distance from this frontier. This framework was further developed by [20] and [9], establishing the mathematical foundations for efficiency analysis. Charnes, Cooper, and Rhodes (1978) [6] extended Farrell's work to multi-input, multi-output scenarios by developing Data Envelopment Analysis (DEA). This non-parametric technique uses linear programming to construct a piecewise linear frontier that "envelops" the data. Their CCR model assumed Constant Returns to Scale (CRS). Recognizing this limitation, Banker, Charnes, and Cooper (1984) [4] introduced the BCC model, which accommodates Variable Returns to Scale (VRS), thereby allowing for the separation of pure technical efficiency (managerial efficiency) from scale efficiency (the effect of the scale of operation). Subsequent developments include non-radial models [33], network DEA [12], and dynamic DEA [11].

A robust body of research has applied DEA to the Indian industry. Studies like Ma-jumdar (1998) [23] on textiles and Goldar (2004) [16] on post-liberalization manufacturing efficiency are foundational. Sector-specific analyses, such as in pharmaceuticals (Bala, 2008)

[3] and automotive industries (Sahoo & Singh, 2009) [29], consistently reveal significant efficiency variations and ample room for improvement, attributing inefficiency to technological gaps, managerial practices, and sub-optimal scale. Regional studies by [24] and [22] have highlighted spatial variations in industrial efficiency across Indian states.

Research focused on the efficiency of industries in hilly and special category states is notably scarce. While some studies, such as Sharma & Singh (2015) [30], have examined the socio-economic impact of industrial packages in Himachal Pradesh, they often lack a rigorous, micro-level efficiency analysis using frontier techniques like DEA. [27] studied tourism efficiency in Himalayan states, while [26] examined agricultural efficiency in mountain regions. This leaves a critical gap in understanding the performance dynamics of industries operating under unique geographical and policy-induced conditions.

The reviewed literature confirms that while DEA is a well-established methodology for industrial analysis in India, its application has been predominantly concentrated at the national level or on specific pan-Indian sectors [28, 21]. The distinct industrial cluster of Himachal Pradesh, shaped by special incentives and mountainous terrain, remains largely unexplored through the lens of productive efficiency [31]. This study aims to fill this void by providing a focused,

empirical, and data-driven efficiency analysis, yielding insights that are specifically tailored to the state’s context [8].

### 3. THEORETICAL FRAMEWORK AND METHODOLOGY

#### 3.1 Conceptual Definition of Productive Efficiency

This study conceptualizes productive efficiency as technical efficiency—the ability of a firm to maximize outputs from a given set of inputs, utilizing existing technology. Figure 1 provides a simplified illustration of a single-input, single-output scenario. Firms A, B, and C are technically efficient, forming the frontier. Firm D is inefficient. Its technical efficiency is

measured as  $TE_D = OC$ . Under VRS, this can be decomposed:  $OB$  measures Pure Technical

$OD$       $OD$

Efficiency (PTE) and  $OC$  measure Scale Efficiency (SE).

Thus,  $TE = PTE \times SE$  [4, 14]..      $OB$

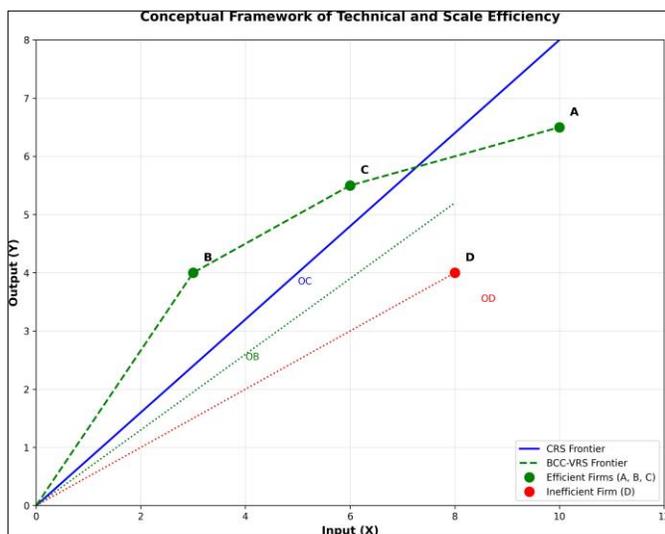


Figure 1: Conceptual Framework of Technical and Scale Efficiency.

#### 3.2 Mathematical Foundation of DEA

DEA is a linear programming-based technique that evaluates the relative efficiency of homogeneous Decision Making Units (DMUs) [6, 8]. It does not require a pre-specified production function; instead constructs a frontier from the observed data [7].

#### 3.3 The CCR Model (Constant Returns to Scale)

The CCR model evaluates overall technical efficiency under the assumption of constant returns to scale [6]. The linear programming formulation (envelopment form) for each DMU  $k$  is:

$$\text{Min } \theta_k$$

subject to:

$$\sum_{j=1} \lambda_j x_{ij} \leq \theta_k x_{ik}, \quad i = 1, 2, \dots, m$$

$$\sum_{j=1} \lambda_j y_{rj} \geq y_{rk}, \quad r = 1, 2, \dots, s$$

$$\sum_{j=1} \lambda_j = 1 \quad (\text{Convexity constraint})$$

$$\lambda_j \geq 0, \quad j = 1, 2, \dots, n$$

Where:

- $\theta_k$  is the technical efficiency score of DMU  $k$  ( $0 < \theta_k \leq 1$ ).
- $\lambda_j$  are the intensity variables, defining the weights of the peers used to construct the frontier for DMU  $k$ .
- $x_{ij}$  and  $y_{rj}$  are the observed input  $i$  and output  $r$  values for DMU  $j$ .
- $n$  is the number of DMUs.
- $m$  and  $s$  are the number of inputs and outputs, respectively.

#### 3.4 The BCC Model (Variable Returns to Scale)

The BCC model modifies the CCR model by adding a convexity constraint ( $\sum \lambda_j = 1$ ) to account for variable returns to scale. This allows the frontier to form a convex hull, providing a more accurate measure of pure technical efficiency for firms not operating at optimal scale [14].

Min  $\theta_k$

subject to:

$$\text{Min } \theta_k$$

subject to:

$$\sum_{j=1} \lambda_j x_{ij} \leq \theta_k x_{ik}, \quad i = 1, 2, \dots, m$$

$$\sum_{j=1} \lambda_j y_{rj} \geq y_{rk}, \quad r = 1, 2, \dots, s$$

$$\sum_{j=1} \lambda_j = 1 \quad (\text{Convexity constraint})$$

$$\lambda_j \geq 0, \quad j = 1, 2, \dots, n$$

The efficiency score  $\theta_k$  from this model is the Pure Technical Efficiency (PTE). Scale Efficiency (SE) is then calculated as:

$$SE_k = \frac{TE_{CRS}}{PTE_{VRS}}$$

Where  $TE^{CRS}$  is the technical efficiency score from the CCR model. A DMU is scale efficient only if  $SE_k = 1$ .

### 3.5 Model Specification and Variable Selection

This study employs an input-oriented BCC model. The orientation is chosen because managerial control over input quantities (hiring labour, investing in capital) is typically greater than control over output levels (market sales) in the short run. The variables selected are based on established practices in industrial efficiency studies [28, 25]:

• **Output (1 variable):**

–  $Y_1$ : **Value of Total Sales (in lakhs):** A universal measure of a firm’s economic output and market performance.

**Inputs (2 variables):**

–  $X_1$ : **Capital Employed (in lakhs):** Represented by Net Fixed Assets. This captures the physical capital and investment base of the firm.

–  $X_2$ : **Total Labour:** Represented by the total number of employees. This captures the human capital input.

### 3.6 Data Sources and Sample Selection

Secondary cross-sectional data for the financial year 2022-23 were collected for a purposive sample of 50 manufacturing companies.

Firms from the CMIE Prowess database [5]. The sample was stratified across four key sub-sectors in Himachal Pradesh to ensure representativeness: Phar- Pharmaceuticals (15 firms), Textiles (15 firms), Food Processing (12 firms), and Electronics (8 firms).

## 4. DATA ANALYSIS AND EMPIRICAL RESULTS

This section provides the empirical results for efficiency scores, sector-wise efficiency, and input slack and target analysis for inefficient DMUs.

### 4.1 Descriptive Statistics

**Table 1:** Descriptive Statistics of Input and Output Variables (N=50)

Variable	Mean	Std. Dev.	Minimum	Maximum	Coefficient of Variation
Sales (Lakhs)	15,420.0	12,580.3	850.0	58,300.0	0.82
Capital (Lakhs)	8,750.5	7,220.8	420.0	32,100.0	0.83
Labor (No.)	185.2	142.1	25.0	650.0	0.77

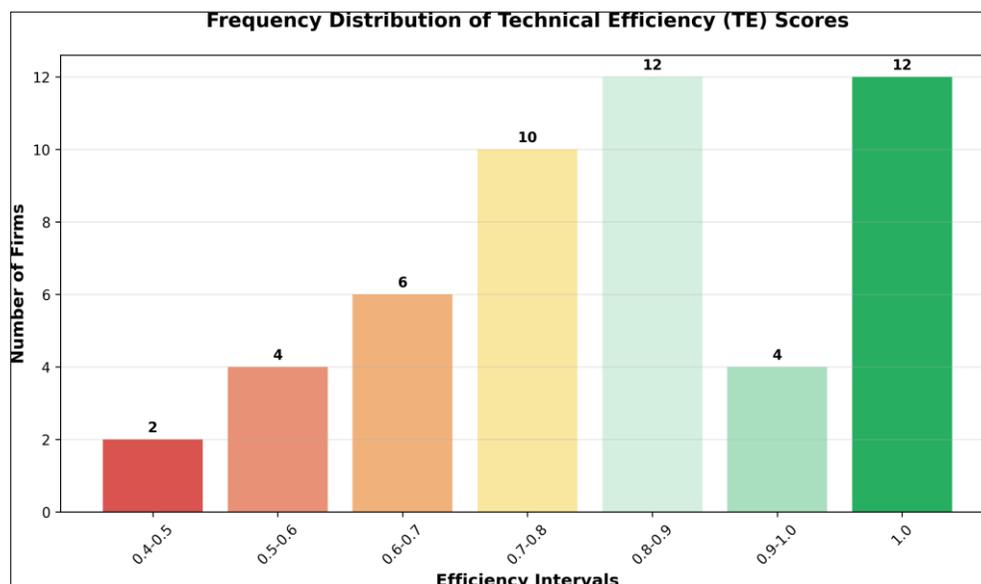
The high coefficients of variation (Std. Dev./Mean) for all variables, all above 0.75, confirm the significant heterogeneity in the size of firms within the sample, robustly justifying the use of the VRS assumption.

### 4.2 Overall Efficiency Scores

**Table 2:** Summary of Efficiency Scores

Efficiency Measure	Mean Score	Std. Dev.	Min	Max	No.	Of Efficient DMUs
Technical (TE-CRS)	0.783	0.185	0.402	1.000		12
Pure Technical (PTE-VRS)	0.852	0.152	0.505	1.000		16
Scale Efficiency (SE)	0.915	0.105	0.623	1.000		12

The results indicate that, on average, firms could produce their current level of output using only 78.3% of their current inputs if they were fully technically efficient. The decomposition shows that scale inefficiency is a larger contributor to overall inefficiency than managerial practices.



**Figure 2:** Frequency Distribution of Technical Efficiency (TE) Scores

### 4.3 Sector-Wise Efficiency Analysis

Table 3: Sector-Wise Mean Efficiency Scores

Sub-Sector	No. of Firms	Mean TE (CRS)	Mean PTE (VRS)	Mean Scale Eff.
Pharmaceuticals	15	0.820	0.890	0.920
Textiles	15	0.710	0.785	0.895
Food Processing	12	0.815	0.880	0.925
Electronics	8	0.785	0.855	0.915

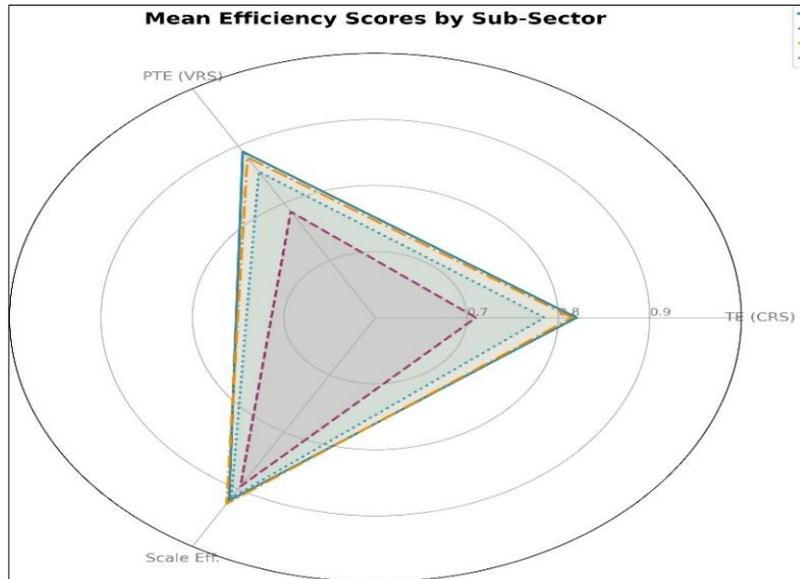


Figure 3: Radar Chart of Mean Efficiency Scores by Sub-Sector

### 4.4 Returns to Scale Analysis

Table 4: Returns to Scale Distribution for Inefficient DMUs (N=34)

Returns to Scale (RTS)	Percentage of Inefficient DMUs
Increasing (IRS)	64.7%
Decreasing (DRS)	35.3%

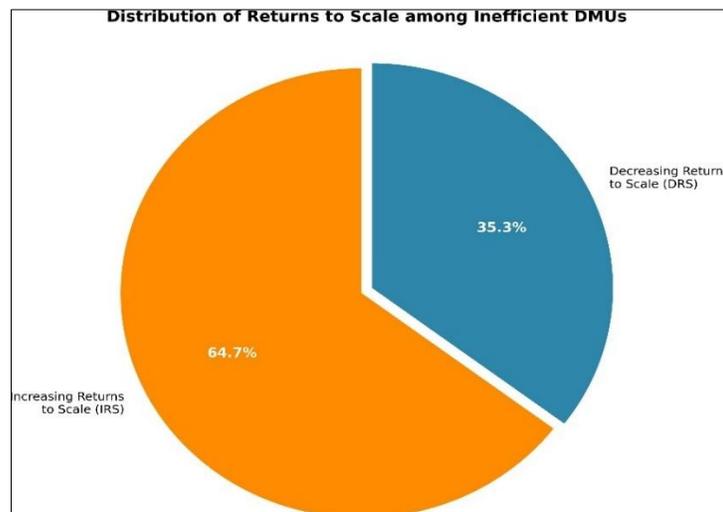


Figure 4: Distribution of Returns to Scale among Inefficient DMUs

#### 4.5 Slack Variable Analysis and Target Setting

For inefficient DMUs, DEA provides slack values, indicating the specific amount by which each input must be reduced (or output

increased) to achieve efficiency. The following table provides examples for two inefficient firms.

**Table 5:** Input Slack and Target Analysis for Selected Inefficient DMUs DMU ID Sector TE Score Capital (Lakhs) Labor

			Actual	Target (Reduction)	Actual	Target (Reduction)
17	Textiles	0.654	12,500	8,175 (34.6%)	300	235 (21.7%)
23	Textiles	0.710	28,000	19,880 (29.0%)	580	530 (8.6%)
41	Electronics	0.882	9,800	8,644 (11.8%)	150	150 (0%)

For instance, DMU 17 (Textiles) is only 65.4% efficient. To reach the frontier, it should aim to reduce its capital from Rs 12,500 lakhs to Rs 8,175 lakhs (a 34.6% reduction) and its labor force from 300 to 235 employees (a 21.7% reduction), while maintaining the same level of output. This suggests significant over-capitalization and overstaffing.

## 5. DISCUSSION

The results paint a picture of an industrial sector with untapped potential. The average technical efficiency of 0.783 suggests that, collectively, the sampled firms could produce the same output with over 20% fewer resources. This represents a significant opportunity for cost savings and enhanced profitability.

The decomposition of efficiency is the most critical finding. The higher pure technical efficiency (PTE = 0.852) compared to scale efficiency (SE = 0.915) indicates that the primary source of inefficiency is not poor day-to-day management but rather the scale of operations. This is powerfully reinforced by the Returns to Scale analysis, which shows that nearly two-thirds of inefficient firms (64.7%) operate under Increasing Returns to Scale (IRS). This means these firms are too small; they could become more efficient by expanding their production scale to exploit economies of scale, thereby reducing their average costs. The sectoral analysis reveals important nuances. The lower efficiency in the Textiles sector can be attributed to intense competition, both domestic and international, thinner profit margins, and potentially older technology [23]. In contrast, the Pharmaceuticals and Food Processing sectors, often characterized by higher value addition and more stable demand, demonstrate better efficiency.

The Slack analysis provides a clear, actionable roadmap for individual firms. For example, the identified textile firms need to critically examine their capital investment strategies and workforce planning to eliminate the identified redundancies [28].

## 6. CONCLUSION AND POLICY RECOMMENDATIONS

- The manufacturing sector in Himachal Pradesh operates at 78.3% of its potential technical efficiency, indicating significant room for improvement.
- The primary source of inefficiency is the sub-optimal scale of operations rather than poor managerial practices.
- The pharmaceutical and food processing industries are the most efficient, while textiles lag.
- A majority of inefficient firms are too small and would benefit from scaling up their operations (IRS).

### Policy Implications for the State Government

- **Focus on Scale-Up Incentives:** Policy should shift from attracting new units to fostering the growth of existing SMEs. Introduce a "Scale-Up Himachal" scheme with concessional loans and grants specifically for expansion and modernization projects.
- **Promote Industrial Clusters:** Develop sector-specific industrial clusters and parks to create economies of agglomeration, reduce transaction costs, and facilitate knowledge spillovers among firms.
- **Facilitate Technology Access:** Establish Common Facility Centers (CFCs) within clusters, providing access to advanced, expensive machinery and testing facilities that individual SMEs cannot afford independently [34].
- **Skill Development Initiatives:** Partner with industry associations to design targeted skill development programs aligned with the needs of efficient, expanding sectors to ensure a supply of productive labor [35].

### Strategic Recommendations for Firms

- **Benchmarking:** Inefficient firms should actively study the operational and managerial practices of their identified DEA "peer" firms.
- **Strategic Expansion Plans:** Firms operating under IRS should develop robust business plans for gradual and strategic expansion to achieve their Minimum Efficient Scale (MES).
- **Resource Optimization:** Firms, especially those with high input slacks, need to conduct internal audits to optimize their capital utilization and workforce productivity.

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