Chapter IV

Empirical Investigations
EMPIRICAL INVESTIGATIONS

4.0 INTRODUCTION

Managers of Decision Making Units (DMUs) have to control resources, some conventional and some other non-conventional type. In a relatively simple decision making problem the decision maker can visualise best possible course of action leading to the most effective utilization of resources. However, if the problem is complex the decision maker can not look into the future as clearly as he intends only by using intuition or common sense.

Operations Research is a methodology that identifies the best course of action from among a variation of courses of action available to the decision maker.

The present study aims at estimation of input losses of decision making units where a DMU is total manufacturing sector of an Indian State. An Operations Research approach, popularly known as Data Envelopment Analysis (DEA) is employed.

➢ The basic tool of DEA is linear programming.
➢ It identifies best practice production units. Such DMUs support the DEA frontier.
➢ Input and output losses can be effectively estimated due to productive inefficiency.
> The policy maker can identify inefficient DMUs and provide an environment that these DMUs can quickly adopt innovatively improved technology and train the human capital in tune with the changing technology.

INPUT PURE TECHNICAL EFFICIENCY:

> The total manufacturing sectors of Bihar, Maharastra and Punjab being pure technical efficient, support the variable returns to scale frontier.

> Inputs are freely disposed at an alarming rate by the total manufacturing sectors of West Bengal, Andhra Pradesh and Karnataka due to pure technical inefficiency. (wide (4.2.1))

INPUT OVERALL TECHNICAL EFFICIENCY:

> The total manufacturing sectors of Bihar and Maharastra support the constant returns to scale production frontier.

> Nearly 50 percent input losses are experienced by the total manufacturing sectors of West Bengal and Andhra Pradesh. (wide (4.3.1)).

INPUT SCALE EFFICIENCY:

> The structural scale efficiency is unity, implying that the total manufacturing sector of All India enjoys constant returns to scale.

> Being scale efficient the total manufacturing sectors of Bihar and Maharastra do not suffer from input losses. (wide (4.4.1)).
INPUT OVERALL PRODUCIVE EFFICIENCY:

▶ Factor minimal cost equals observed cost for the total manufacturing sector of Bihar.

▶ The total manufacturing sector of Bihar alone is input overall productive efficient.

▶ Sixty percent of inputs are freely disposed of by West Bengal due to input overall productive inefficiency. (wide (4.5.1)).

INPUT ALLOCATIVE EFFICIENCY:

▶ The total manufacturing sector of Bihar alone is allocatively efficient.

▶ Failure to operate at cost efficient inputs leads to considerable input losses by the total manufacturing sectors of Rajasthan and Gujarat. (wide (4.6.1)).

4.1:

For a long time, applied researchers in the field of Production Economics have estimated the average production function for a given set of observations on inputs and output. The production process is such that ‘n’ inputs are combined to produce an output, and all the firms which constitute an industry could be found technically the most efficient.
M.J. Farrell's (1957) simple, but path breaking article has examined the production of Decision Making Units (DMUs) under the hypothesis that not all of these DMUs have employed best practice techniques. Consequent to this assumption, inefficiency in the production has been introduced. Farrell's efficiency measurement approach is called non-parametric, since it is a basic tool of measurement and it is a linear homogeneous production frontier whose explicit specification is unnecessary to measure productive efficiency.

The present attempt is to measure productive efficiency which is also non-parametric, but the production frontiers used as reference sets are piecewise linear. The basic aim of this present chapter is to measure various technical efficiencies such as (i) Input pure technical efficiency, (ii) Input overall technical efficiency, (iii) Input scale efficiency, (iv) Cost efficiency or overall productive efficiency and (v) Input allocative efficiency for the data collected on selected variables of decision making units of total manufacturing sectors of Indian States. The empirical results obtained from the analysis relating to the above five technical efficiencies are respectively given in the sections 4.2 to 4.6.

These empirically determined frontier production functions may be viewed as inner approximations to smoothly continuous production frontiers as shown in the following figures.

To measure input oriented productive efficiency, the input sets \( L(u) \) provide reference sets. The various notions of inefficiency in the input orientation context are (i) Pure technical, (ii) Overall technical, (iii) Scale, (iv) Allocative and (v) Overall productive efficiencies.

The fundamental assumption in measuring input cost efficiency is for a cost minimization. Among the five input technical efficiencies, three are
obtained by solving the appropriate optimization problems. But, the input scale and allocative efficiencies are derived measures from the other efficiencies.

4.2 INPUT PURE TECHNICAL EFFICIENCY (IPTE) - OPTIMIZATION PROBLEM:

\[ \text{IPTE} = \min \lambda \]

subject to \( \lambda x_0 \in L'(u_0) \).

If the production possibility set is consistent with the axioms of convexity, inefficiency and minimal extrapolation, we have,

\[ \text{IPTE} = \min \lambda \]

subject to

\[ \sum_{i=1}^{k} \lambda_i x_i \leq \lambda x_0 \]

\[ \sum_{i=1}^{h} \lambda_i u_i \geq u_0 \]

\[ \lambda_i \geq 0 \]

\[ \sum_{i=1}^{h} \lambda_i = 1 \]

Here, \( L'(u_0) = \left\{ x : \sum_{i=1}^{h} \lambda_i x_i \leq x, \sum_{i=1}^{h} \lambda_i u_i \geq u_0, \lambda_i \geq 0, \sum_{i=1}^{h} \lambda_i = 1 \right\} \)
The production unit whose efficiency is under evaluation employs the input vector \( x_0 \in \mathbb{R}^2 \) and produces the output \( u_0 \). Then it is said to be input technical efficient. By reducing its inputs \( x_0 \) radially in the direction of origin, it achieves the technical efficiency.

It's input pure technical efficiency is \( \lambda \). Input wastage due to pure technical efficiency is \( \dot{\lambda}x_0 \).

In empirical investigation, the total industrial manufacturing sectors of 15 states which account for over 85 percent of the country's total manufacturing sector, the total manufacturing sector of All India is also
included as a Decision Making Unit (DMU), to measure the structural efficiency. Thus, the various DMUs are the total manufacturing sectors of (1) All India, (2) Andhra Pradesh (A.P), (3) Bihar, (4) Gujarat, (5) Haryana, (6) Karnataka, (7) Kerala, (8) Madhya Pradesh (M.P), (9) Maharashtra, (10) Orissa, (11) Punjab, (12) Rajasthan, (13) Tamil Nadu (T.N), (14) Uttar Pradesh (U.P) and (15) West Bengal (W.B).

To measure input pure technical efficiency of the total manufacturing sectors of All India, the relevant optimization problem is,

\[ \text{IPTE} = \text{Min } \lambda \]

subject to

\[ 8172836 \lambda_1 + 910356 \lambda_2 + 67750 \lambda_3 + 822884 \lambda_4 + 298501 \lambda_5 + 491789 \lambda_6 + 303286 \lambda_7 + 267685 \lambda_8 + 1217260 \lambda_9 + 132058 \lambda_{10} + 338647 \lambda_{11} + 234651 \lambda_{12} + 1103970 \lambda_{13} + 571719 \lambda_{14} + 588968 \lambda_{15} - 8172836 \lambda \leq 0 \]

\[ 40186473 \lambda_1 + 2712037 \lambda_2 + 141648 \lambda_3 + 6660127 \lambda_4 + 1316705 \lambda_5 + 2706031 \lambda_6 + 631256 \lambda_7 + 1673054 \lambda_8 + 7041233 \lambda_9 + 956551 \lambda_{10} + 1007595 \lambda_{11} + 1994473 \lambda_{12} + 3750517 \lambda_{13} + 3772531 \lambda_{14} + 1740738 \lambda_{15} - 40186473 \lambda \leq 0 \]

\[ 15497442 \lambda_1 + 911042 \lambda_2 + 108745 \lambda_3 + 1927579 \lambda_4 + 650151 \lambda_5 + 834737 \lambda_6 + 362980 \lambda_7 + 563712 \lambda_8 + 3458772 \lambda_9 + 267446 \lambda_{10} + 559388 \lambda_{11} + 531474 \lambda_{12} + 1479535 \lambda_{13} + 1022958 \lambda_{14} + 573679 \lambda_{15} \geq 15497442 \]

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\[ \lambda_1, \lambda_2, \ldots, \lambda_{15} \geq 0 \]

\[ \sum_{i=1}^{15} \lambda_i = 1 \]

This is a linear programming problem in as many constraints as there are inputs and outputs, apart from,

\[ \sum_{i=1}^{15} \lambda_i = 1 \]

Input pure technical efficiency of the total manufacturing sector of All India is,

\[ \text{IPTE} = 0.9910 \]

Although the input pure technical efficiency of the total manufacturing sectors of the Indian states varied, the structural efficiency of All India is about 99 percent. Less than 1 percent of the inputs has been wasted due to the input pure technical inefficiency.

Replacing 8172836, 40186473, 15497442 by the labour (910356), fixed capital (2712037) the above linear programming problem has to be solved yet again. Consequently, the estimated pure technical efficiency of the total manufacturing sector of Andhra Pradesh is,

\[ \hat{\lambda} = 0.6414 \]

About 36 percent of inputs are freely disposed due to pure technical inefficiency.
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Total manufacturing sector</th>
<th>Pure technical efficiency $\lambda$</th>
<th>Loss of labour input $(1-\lambda)L$</th>
<th>Loss of capital input $(1-\lambda)K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>All India</td>
<td>0.7215</td>
<td>2276134.8260</td>
<td>11191932.7300</td>
</tr>
<tr>
<td>2.</td>
<td>Andhra Pradesh</td>
<td>0.6414</td>
<td>326453.6616</td>
<td>972536.4682</td>
</tr>
<tr>
<td>3.</td>
<td>Bihar</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4.</td>
<td>Gujarat</td>
<td>0.8408</td>
<td>131003.1328</td>
<td>1062956.2690</td>
</tr>
<tr>
<td>5.</td>
<td>Haryana</td>
<td>0.9431</td>
<td>16984.7069</td>
<td>74920.5145</td>
</tr>
<tr>
<td>6.</td>
<td>Karnataka</td>
<td>0.6443</td>
<td>174929.3473</td>
<td>962535.2267</td>
</tr>
<tr>
<td>7.</td>
<td>Kerala</td>
<td>0.9983</td>
<td>515.5862</td>
<td>1073.1352</td>
</tr>
<tr>
<td>8.</td>
<td>Madhya Pradesh</td>
<td>0.8363</td>
<td>43820.0345</td>
<td>273878.9398</td>
</tr>
<tr>
<td>9.</td>
<td>Maharashtra</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10.</td>
<td>Orissa</td>
<td>0.9254</td>
<td>9851.5268</td>
<td>71358.7046</td>
</tr>
<tr>
<td>11.</td>
<td>Punjab</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12.</td>
<td>Rajasthan</td>
<td>0.9069</td>
<td>21846.0081</td>
<td>185685.4363</td>
</tr>
<tr>
<td>13.</td>
<td>Tamil Nadu</td>
<td>0.7792</td>
<td>243756.5760</td>
<td>828114.1536</td>
</tr>
<tr>
<td>14.</td>
<td>Uttar Pradesh</td>
<td>0.6672</td>
<td>190268.0832</td>
<td>1255498.3170</td>
</tr>
<tr>
<td>15.</td>
<td>West Bengal</td>
<td>0.5959</td>
<td>238001.9688</td>
<td>703432.2258</td>
</tr>
</tbody>
</table>
The underlying empirical production frontier and hence the production possibility set admits variable returns to scale.

The empirical frontier constituted by the line segments AB, BC and CD stands for variable returns to scale production frontier. Returns to scale is a property that refers to the surface of the underlying frontier production function. The segment AB displays increasing returns to scale. The production unit that operates at B enjoys constant returns to scale. The segments BC and CD refer to decreasing returns to scale.

The total manufacturing sectors of Bihar, Maharastra and Punjab are input pure technical efficient, consequently their free disposal of inputs is zero.

The total manufacturing sector of Kerala is nearly a pure technical efficient. West Bengal and Andhra Pradesh are worst hit by input pure technical inefficiency. The total manufacturing sector of West Bengal
suffers from an input loss of about 40 percent, whereas that of Andhra Pradesh suffers from free disposal of inputs by 36 percent.

For all the 15 decision making units we have,

\[ 0.5959 \leq IPTE \leq 1.00 \]

The largest of all the manufacturing sectors is that of Maharashtra which is input pure technical efficient.

Second to Maharashtra, is the total manufacturing sector of Gujarat. The estimated input losses of the total manufacturing sector of this state is about 16 percent, and its input pure technical efficiency is 84 percent approximately.

The total manufacturing sector of Orrissa disposed 7.5 percent of its inputs freely. The input losses are about 9.3 percent for the state Rajasthan. Heavy input losses are also observed for the total manufacturing sectors of Uttar Pradesh (33%), Karnataka (36%) and Tamil Nadu (22%) along with West Bengal and Gujarat due to input pure technical efficiency. About 16 percent of inputs are freely disposed by the total manufacturing sector of Madhya Pradesh.

**RETURNS TO SCALE – EMPIRICAL PRODUCTION FRONTIERS:**

Returns to scale are characterized for a homogenous production function as follows:
Let $\hat{z} = f(x)$ be homogenous production frontier, further suppose that $\lambda \geq 1$ then

$$f(\lambda x) = \lambda^\theta f(x) \quad \ldots (4.2.1)$$

$\theta > 1 \Rightarrow$ Returns to scale are increasing

$\theta = 1 \Rightarrow$ Returns to scale are constant

$\theta < 1 \Rightarrow$ Returns to scale are decreasing

For piece-wise linear empirical frontiers satisfying the axioms of convexity, inefficiency, minimum extrapolation and/or ray unboundedness, returns to scale are imposed by suitably placing or not placing the constraints,

$$\sum_{i=1}^{t} \lambda_i = 1, \sum_{i=1}^{t} \lambda_i \leq 1$$

The frontier production function admits variable returns to scale. The corresponding production possibility set may be expressed as,
The line segments OA, AB and BC constitute the frontier production function. The line segment OA stands for constant returns to scale. The line segments AB and BC constitute the part of the frontier which admit decreasing returns to scale. Thus, the frontier may be called as non-increasing returns to scale frontier.

The production possibility set that admits non-increasing returns to scale is,

\[ \text{PP Set} = \left\{ (x,u): \sum_{i=1}^{k} \lambda_i x_i \leq x, \sum_{i=1}^{k} \lambda_i u_i \geq u, \lambda_i \geq 0, \sum_{i=1}^{k} \lambda_i = 1 \right\} \]  \hspace{1cm} (4.2.3)
The ray that passes through the origin as shown above is the empirical constant returns to scale frontier that satisfies the axioms of inefficiency, ray unboundedness and minimum extrapolation. The corresponding production possibility set is,

$$\text{PP Set} = \left\{ (x, u): \sum_{i=1}^{k} \lambda_i x_i \leq x, \sum_{i=1}^{k} \lambda_i u_i \geq u, \lambda_i \geq 0 \right\} \quad \ldots \quad (4.2.4)$$

4.3 INPUT OVERALL TECHNICAL EFFICIENCY (IOTE) – OPTIMIZATION PROBLEMS:

Let $L^U(u_0)$ be the input level set that admits constant returns to scale. To estimate input overall technical efficiency we solve the following linear programming problem:

$$\text{IOTE} = \text{Min } \lambda$$

subject to $\lambda x_0 \in L^U(u_0)$

In terms of the piece-wise linear input level sets, the equivalent optimization problem is,
\( \text{IOTE} = \text{Min} \, \lambda \)

subject to \[ \sum_{i=1}^{I} \lambda_i x_i \leq \lambda x_0 \]
\[ \sum_{i=1}^{I} \lambda_i u_i \geq u_0 \]
\[ \lambda_i \geq 0 \]

\( \text{RELATIONSHIP BETWEEN IPTE AND IOTE:} \)

\( L^e(u_0) = \{ x : \sum \lambda_i x_i \leq x, \sum \lambda_i u_i \geq u \} \)

\( L^r(u_0) = \{ x : \sum \lambda_i x_i \leq x, \sum \lambda_i u_i \geq u, \lambda_i \geq 0, \sum \lambda_i = 1 \} \)

\( x \in L^r(u_0) \Rightarrow \sum \lambda_i x_i \leq x, \sum \lambda_i u_i \geq u, \lambda_i \geq 0, \sum \lambda_i = 1 \)

\( \Rightarrow x \in L^e(u_0) \)

\( L^r(u_0) \subseteq L^e(u_0) \)

\( \text{Min} \{ \lambda : \lambda x_0 \in L^r(u_0) \} \leq \text{Min} \{ \lambda : \lambda x_0 \in L^e(u_0) \} \)

\( \text{IOTE} \leq \text{IPTE} \)

\( \text{...... (4.3.2)} \)

To measure input overall efficiency, for example, for the total manufacturing sector of Bihar, imposing constant returns to scale, we have the following linear programming problem:

\[ \]
\[
\text{IOTE} = \text{Min } \lambda
\]

subject to
\[
8172836 \lambda_1 + 910356 \lambda_2 + 67750 \lambda_3 + 822884 \lambda_4 \\
+ 298501 \lambda_5 + 491789 \lambda_6 + 303286 \lambda_7 + 267685 \lambda_8 \\
+ 1217260 \lambda_9 + 132058 \lambda_{10} + 338647 \lambda_{11} + 234651 \lambda_{12} \\
+ 1103970 \lambda_{13} + 571719 \lambda_{14} + 588968 \lambda_{15} - 67750 \lambda \leq 0
\]

\[
40186473 \lambda_1 + 2712037 \lambda_2 + 141648 \lambda_3 + 6660127 \lambda_4 \\
+ 1316705 \lambda_5 + 2706031 \lambda_6 + 631256 \lambda_7 + 1673054 \lambda_8 \\
+ 7041233 \lambda_9 + 956551 \lambda_{10} + 1007595 \lambda_{11} + 1994473 \lambda_{12} \\
+ 3750517 \lambda_{13} + 3772531 \lambda_{14} + 1740738 \lambda_{15} - 141648 \lambda \leq 0
\]

\[
15497442 \lambda_1 + 911042 \lambda_2 + 108745 \lambda_3 + 1927579 \lambda_4 \\
+ 650151 \lambda_5 + 834737 \lambda_6 + 362980 \lambda_7 + 563712 \lambda_8 \\
+ 3458772 \lambda_9 + 267446 \lambda_{10} + 559388 \lambda_{11} + 531474 \lambda_{12} \\
+ 1479535 \lambda_{13} + 1022958 \lambda_{14} + 573679 \lambda_{15} \geq 108745
\]

\[
\lambda_1 \ldots \lambda_{15} \geq 0
\]

\[
\sum_{i=1}^{15} \lambda_i = 1
\]
\[ \lambda^k \leq \lambda^r \]

where \( \lambda^k \) and \( \lambda^r \) represent the input overall and pure technical efficiencies.

\[ u^\uparrow \]

\[ \lambda^k \leq \lambda^r \]

where \( \lambda^k \) and \( \lambda^r \) are respectively the input overall and pure technical efficiencies.

The following table, displays overall technical efficiency of 15 decision making units of which the total manufacturing sector is one, which is introduced to measure structural efficiency:
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Total Manufacturing sector</th>
<th>Overall technical efficiency ((\theta))</th>
<th>Loss of labour input ((1 - \theta) L)</th>
<th>Loss of capital input ((1 - \theta) K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All India</td>
<td>0.7215</td>
<td>2276134.8260</td>
<td>11191932.73</td>
</tr>
<tr>
<td>2</td>
<td>Andhra Pradesh</td>
<td>0.5260</td>
<td>431508.7440</td>
<td>1285505.5380</td>
</tr>
<tr>
<td>3</td>
<td>Bihar</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Gujarat</td>
<td>0.8243</td>
<td>144580.7188</td>
<td>1170184.3140</td>
</tr>
<tr>
<td>5</td>
<td>Haryana</td>
<td>0.9145</td>
<td>25521.8355</td>
<td>112578.2775</td>
</tr>
<tr>
<td>6</td>
<td>Karnataka</td>
<td>0.6179</td>
<td>187912.5769</td>
<td>1033974.4450</td>
</tr>
<tr>
<td>7</td>
<td>Kerala</td>
<td>0.7489</td>
<td>76155.1146</td>
<td>158508.3816</td>
</tr>
<tr>
<td>8</td>
<td>Madhya Pradesh</td>
<td>0.7411</td>
<td>69303.6465</td>
<td>433153.6806</td>
</tr>
<tr>
<td>9</td>
<td>Maharashtra</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Orissa</td>
<td>0.7127</td>
<td>37940.2634</td>
<td>274817.1023</td>
</tr>
<tr>
<td>11</td>
<td>Punjab</td>
<td>0.8688</td>
<td>44430.4864</td>
<td>132196.4640</td>
</tr>
<tr>
<td>12</td>
<td>Rajasthan</td>
<td>0.7971</td>
<td>47610.6879</td>
<td>404678.5717</td>
</tr>
<tr>
<td>13</td>
<td>Tamil Nadu</td>
<td>0.6562</td>
<td>379544.8860</td>
<td>1289427.7450</td>
</tr>
<tr>
<td>14</td>
<td>Uttar Pradesh</td>
<td>0.6297</td>
<td>211707.5457</td>
<td>1396968.2290</td>
</tr>
<tr>
<td>15</td>
<td>West Bengal</td>
<td>0.5141</td>
<td>286179.5512</td>
<td>845824.5942</td>
</tr>
</tbody>
</table>
The ray that passes through the origin as shown above represents the empirical frontier that admits constant returns to scale.

\[ f(x) = ax \]

\[ f(\lambda x) = a(\lambda x) = \lambda ax = \lambda f(x) \]

The frontier admits only constant returns to scale.

Overall input technical efficiency implies pure technical efficiency. But, the converse is not true. The total manufacturing sectors of Bihar and Maharashtra alone are overall technical efficient. The CRS frontier is determined by these two industrial manufacturing sectors. No input loss is experienced by these DMU’s.

West Bengal and Andhra Pradesh are the bottom most DMU’s and incur a significant free disposal of inputs due to overall technical inefficiency. These DMUs experience as much as 48 percent input losses.
The total manufacturing sectors of Karnataka, Uttar Pradesh and Tamil Nadu are nearer to each other in terms of their overall technical efficiency. The input losses of these total manufacturing sectors are respectively 38, 37 and 34 percents.

The total manufacturing sector of Haryana is the most input overall technical efficient among the other remaining states, except Bihar and Maharashtra. Its input overall technical efficiency is 92 percent approximately.

Thirteen percent of inputs of Punjab are freely disposed. For the total manufacturing sectors of Gujarat and Rajasthan the estimated input losses due to overall technical inefficiency, respectively are 18 and 20 percent.

The overall technical efficiency of the total manufacturing sectors of Kerala and Madhya Pradesh are about 74 percent.

In the table (4.3.1), input losses for labour and capital inputs are tabulated.

The input losses at aggregate level are about 38 percent. But, aggregate data is comprised not only the total manufacturing sectors of the 14 states listed above, but also the union territories and some other smaller states.

Thus, if the structural overall technical efficiency of the manufacturing sector of the country 0.7215 is chosen as some kind of average, the input OTEs of Andhra Pradesh, Karnataka, Orissa, Tamil Nadu,
Uttar Pradesh and West Bengal fall below the average and the rest of the 8 states fall above the average.

IDENTIFICATION OF RETURNS TO SCALE:

The concept of returns to scale is not only associated with production frontiers, but it has relevance with cost functions also. In the latter case we may call this as elasticity of scale*.

Let, Factor minimal cost function : \( Q(u, p) \)

Elasticity of scale : \( \varepsilon = \frac{\partial \ln Q(u, p)}{\partial \ln u} = \theta^{-1} \)

where \( u \) is the average output given, \( p \) is the vector of input prices, \( \theta \) is the degree of returns to scale.

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* Cobb-Douglas production frontier : \( u = A \prod_{i=1}^{n} x_i^\alpha \)

Returns to scale = \( \theta = \sum_{i=1}^{n} \alpha_i \)

The factor minimal dual cost function :

\( Q(u, p) = \ln \bar{A} + \frac{1}{\theta} \ln u + \sum_{i=1}^{n} \alpha_i \ln p_i \)

\( \ln Q(u, p) = \ln \bar{A} + \frac{1}{\theta} \ln u + \sum_{i=1}^{n} \alpha_i \ln p_i \)

\( \frac{\partial \ln Q(u, p)}{\partial \ln u} = \frac{1}{\theta} \Rightarrow \theta = \left[ \frac{\partial \ln Q(u, p)}{\partial \ln u} \right]^{-1} \)

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INCREASING RETURNS TO SCALE:

The producer who operates at A is input technical efficient. The horizontal line at A meets the VRTS frontier first, consequently, the returns to scale are increasing. A further projection takes this point onto the non-increasing returns and constant returns to scale frontier implying further possible reduction of inputs to gain overall technical efficiency.

\[ \lambda^* > \lambda^{NI} = \lambda^k \]

Where \( \lambda^*, \lambda^{NI} \) and \( \lambda^k \) respectively stand for variable, non-increasing and constant returns to scale concerned technical efficiencies.

Thus, to determine what returns to scale a particular DMU enjoys we solve two LP problems:

(1) \( \lambda^* = \text{Min } \lambda \)

subject to

\[ \sum \lambda_i x_i \leq \lambda x_0 \]
\[ \sum \lambda_i u_i \geq u_0 \]
\[ \lambda_i \geq 0 \]
\[ \sum \lambda_i = 1 \]

(2) \[ \lambda^M = \text{Min} \ \lambda \]

such that
\[ \sum \lambda_i x_i \leq \lambda x_0 \]
\[ \sum \lambda_i u_i \geq u_0 \]
\[ \lambda_i \geq 0 \]
\[ \sum \lambda_i \leq 1 \]

(3) \[ \lambda^k = \text{Min} \ \lambda \]

such that
\[ \sum \lambda_i x_i \leq \lambda x_0 \]
\[ \sum \lambda_i u_i \geq u_0 \]
\[ \lambda_i \geq 0 \]

\( \lambda^* > \lambda^M = \lambda^k \Rightarrow \) Returns to scale are increasing

For the total manufacturing sector of Gujarat,

\[ \lambda^* = 0.8408 \]
\[ \lambda^M = 0.8243 \]
\[ \lambda^k = 0.8243 \]

so that returns to scale are increasing.
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Total Manufacturing sector</th>
<th>$\lambda^N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All India</td>
<td>0.7215</td>
</tr>
<tr>
<td>2</td>
<td>Andhra Pradesh</td>
<td>0.6414</td>
</tr>
<tr>
<td>3</td>
<td>Bihar</td>
<td>1.0000</td>
</tr>
<tr>
<td>4</td>
<td>Gujarat</td>
<td>0.8243</td>
</tr>
<tr>
<td>5</td>
<td>Haryana</td>
<td>0.9431</td>
</tr>
<tr>
<td>6</td>
<td>Karnataka</td>
<td>0.6179</td>
</tr>
<tr>
<td>7</td>
<td>Kerala</td>
<td>0.9983</td>
</tr>
<tr>
<td>8</td>
<td>Madhya Pradesh</td>
<td>0.7411</td>
</tr>
<tr>
<td>9</td>
<td>Maharashtra</td>
<td>1.0000</td>
</tr>
<tr>
<td>10</td>
<td>Orissa</td>
<td>0.7127</td>
</tr>
<tr>
<td>11</td>
<td>Punjab</td>
<td>1.0000</td>
</tr>
<tr>
<td>12</td>
<td>Rajasthan</td>
<td>0.7971</td>
</tr>
<tr>
<td>13</td>
<td>Tamil Nadu</td>
<td>0.7792</td>
</tr>
<tr>
<td>14</td>
<td>Uttar Pradesh</td>
<td>0.6297</td>
</tr>
<tr>
<td>15</td>
<td>West Bengal</td>
<td>0.5959</td>
</tr>
</tbody>
</table>
Other total manufacturing sectors which enjoy increasing returns to scale are Karnataka, Madhya Pradesh, Orissa, Rajasthan and Uttar Pradesh.

DECREASING RETURNS TO SCALE:

The producer who operates at A are input technical inefficient. To gain technical efficiency A is first projected onto VRTS frontier and the point reached is a common point for both the VRTS and NIRS frontier. Further projection onto CRTS frontier reduces inputs so that overall technical efficiency is achieved.

\[ \lambda^c < \lambda^{NI} = \lambda^* \] implies that returns to scale are decreasing.

For the total manufacturing sectors of Andhra Padesh,

\[ \lambda^{k} = 0.5260 \]

\[ \lambda^{NI} = 0.6414 \]

\[ \lambda^* = 0.6414 \]

implying that the returns to scale are decreasing.

Returns to scale are decreasing for the total manufacturing sectors of Haryana, Kerala, Punjab, Tamil Nadu and West Bengal.
CONSTANT RETURNS TO SCALE:

\[ \lambda^r = \lambda^N = \lambda^k \]

For the total manufacturing sector of all India,

\[ \lambda^r = \lambda^N = \lambda^k = 0.7215 \]

Therefore, returns to scale are constant.

Returns to scale are constant for the total manufacturing sectors of the states Bihar and Maharashtra.

4.4 SCALE EFFICIENCY:

A production unit that achieves input overall technical efficiency is a scale efficient. Failure to operate on CRTS frontier, therefore, leads to the scale inefficiency. Interns of input level sets scale efficiency is measured as follows:
\[ L'(u_0) \subseteq L^t(u_0) \]

The producer who operates at \( P \) is not only a pure technical inefficient, but also a scale inefficient.

\[
\text{IPTE} = \frac{OQ}{OP}
\]

\[
\text{IOTE} = \frac{OR}{OP}
\]

Clearly, \( \text{IOTE} \leq \text{IPTE} \)

Input scale efficiency is defined as,

\[
\text{ISE} = \frac{OR}{OQ}
\]

\[
= \frac{OP}{OQ} \cdot \frac{OR}{OP}
\]

\[
= \frac{\text{IOTE}}{\text{IPTE}}
\]

Consequently, input overall technical efficiency is decomposed into the product of input pure technical and scale efficiencies.

\[
\text{IOTE} = \text{IPTE} \times \text{ISE}
\]
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Total Manufacturing sector</th>
<th>Overall technical efficiency (η)</th>
<th>Loss of labour input (1 - η) L</th>
<th>Loss of capital input (1 - η) k</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All India</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Andhra Pradesh</td>
<td>0.8200</td>
<td>163864.0800</td>
<td>488166.6600</td>
</tr>
<tr>
<td>3</td>
<td>Bihar</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Gujarat</td>
<td>0.9804</td>
<td>16128.5264</td>
<td>130538.4892</td>
</tr>
<tr>
<td>5</td>
<td>Haryana</td>
<td>0.9697</td>
<td>9044.5803</td>
<td>39896.1615</td>
</tr>
<tr>
<td>6</td>
<td>Karnataka</td>
<td>0.9590</td>
<td>20163.3490</td>
<td>110947.2710</td>
</tr>
<tr>
<td>7</td>
<td>Kerala</td>
<td>0.7502</td>
<td>75760.8428</td>
<td>157687.74880</td>
</tr>
<tr>
<td>8</td>
<td>Madhya Pradesh</td>
<td>0.8862</td>
<td>30462.5530</td>
<td>190393.5452</td>
</tr>
<tr>
<td>9</td>
<td>Maharashtra</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Orissa</td>
<td>0.7701</td>
<td>30360.1342</td>
<td>219911.0749</td>
</tr>
<tr>
<td>11</td>
<td>Punjab</td>
<td>0.8688</td>
<td>44430.4864</td>
<td>132196.4640</td>
</tr>
<tr>
<td>12</td>
<td>Rajasthan</td>
<td>0.8789</td>
<td>28416.2361</td>
<td>241530.6803</td>
</tr>
<tr>
<td>13</td>
<td>Tamil Nadu</td>
<td>0.8421</td>
<td>174316.8630</td>
<td>592206.6343</td>
</tr>
<tr>
<td>14</td>
<td>Uttar Pradesh</td>
<td>0.9408</td>
<td>33845.7648</td>
<td>223333.8352</td>
</tr>
<tr>
<td>15</td>
<td>West Bengal</td>
<td>0.9634</td>
<td>21556.2288</td>
<td>63711.0108</td>
</tr>
</tbody>
</table>
The total manufacturing sectors of All India, Bihar and Maharashtra are scale efficient, therefore, no input losses occur due to input scale inefficiency. Gujarat, Karnataka, Haryana, Uttar Pradesh and West Bengal are nearly scale efficient, for which the estimated scale efficiencies are respectively 98, 96, 97, 94 and 96.

Due to scale inefficiency significant input losses have occurred for the total manufacturing sectors of the states Kerala and Orissa. For these states inputs are freely disposed by 25 and 23 percents respectively, due to input scale inefficiency. The total manufacturing sectors of Andhra Pradesh, Madhya Pradesh, Punjab, Rajasthan and Tamil Nadu fall in one group and input losses for these states due to scale inefficiency are respectively 18, 11, 13 and 16 percent. In the table (4.4.1) input losses of each input employed in production are tabulated against the respective total manufacturing sector.

**FACTOR MINIMAL COST:**

For a pre-determined output level $u_0$ and exogeneously given input prices, $P \in R^n$, the factor minimal cost is given by,

$$Q^*(u_0, P) = \min \{ px : x \in L^k(u_0) \} \quad .... (4.4.1)$$

where k refers to the constant returns to scale.
The factor minimal cost is the outcome of an appropriate optimization problem. In terms of piece-wise linear production frontier, we solve the following linear programming problem:

\[ Q^{*}(u_0, p) = \text{Min } px \]

subject to \[ \sum_{i=1}^{k} \lambda_i x_i \leq x \]

\[ \sum_{i=1}^{k} \lambda_i u_i \geq u_0 \]

\[ \lambda_i \geq 0 \]

\[ \ldots \text{(4.4.2)} \]

From the above input sets diagram we have,

\[ L^V(x_0) \subseteq L^*(u_0) \]

The producer who operates at \( P \) is an overall technical inefficient. If there is reduction in inputs radially in the direction of origin to \( Q \) overall input technical efficiency can therefore be achieved. The iso-cost line,

\[ px = Q(u_0, p) \]
is tangent to the isoquant of $L^*(u_0)$. The cost that occurs at any input point
on the isoquant of $L^*(u_0)$ results in a cost larger than the cost at S. Thus, cost
at S is the factor minimal cost.

The producer who operates at Q is an overall technical efficient. But
the cost at Q is more than the factor minimal cost. Thus, by re-allocating
these inputs at Q in favour of S the producer achieves input allocative
efficiency (IAE). Therefore, the input allocative efficiency is defined as,

$$IAE = \frac{\text{Cost at Q}}{\text{Cost at S}} = \frac{p_1x_1^Q + p_2x_2^Q}{Q(u_0, p)}$$

But, the cost at S is same as cost at R.

$$x_1^R = \delta x_1^Q$$

$$x_2^R = \delta x_2^Q$$

Cost at R:

$$Q(u_0, p) = p_1x_1^R + p_2x_2^R = \delta(p_1x_1^Q + p_2x_2^Q)$$

$$IAE = \frac{p_1x_1^Q + p_2x_2^Q}{\delta(p_1x_1^Q + p_2x_2^Q)}$$

$$IAE = \delta^{-1}$$

$$IAE = \frac{Q_R}{Q_Q} = \delta^{-1}$$

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<table>
<thead>
<tr>
<th>S.No.</th>
<th>Total Manufacturing Sector</th>
<th>Factor minimal Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All India</td>
<td>10929180</td>
</tr>
<tr>
<td>2</td>
<td>Andhra Pradesh</td>
<td>451925</td>
</tr>
<tr>
<td>3</td>
<td>Bihar</td>
<td>108747</td>
</tr>
<tr>
<td>4</td>
<td>Gujarat</td>
<td>125084</td>
</tr>
<tr>
<td>5</td>
<td>Haryana</td>
<td>557790</td>
</tr>
<tr>
<td>6</td>
<td>Karnataka</td>
<td>510034</td>
</tr>
<tr>
<td>7</td>
<td>Kerala</td>
<td>268714</td>
</tr>
<tr>
<td>8</td>
<td>Madhya Pradesh</td>
<td>383801</td>
</tr>
<tr>
<td>9</td>
<td>Maharastra</td>
<td>3351773</td>
</tr>
<tr>
<td>10</td>
<td>Orissa</td>
<td>167052</td>
</tr>
<tr>
<td>11</td>
<td>Punjab</td>
<td>460393</td>
</tr>
<tr>
<td>12</td>
<td>Rajasthan</td>
<td>317667</td>
</tr>
<tr>
<td>13</td>
<td>Tamil Nadu</td>
<td>911666</td>
</tr>
<tr>
<td>14</td>
<td>Uttar Pradesh</td>
<td>587215</td>
</tr>
<tr>
<td>15</td>
<td>West Bengal</td>
<td>235242</td>
</tr>
</tbody>
</table>
For example, the factor minimal cost of Haryana is estimated by solving the following problem:

Minimize \[ \prod = 0.8206x_1 + 0.3077x_2 \]

subject to

\[
\begin{align*}
8172836 \lambda_1 + 910356 \lambda_2 + 67750 \lambda_3 + 822884 \lambda_4 \\
+ 298501 \lambda_5 + 491789 \lambda_6 + 303286 \lambda_7 + 267685 \lambda_8 \\
+ 1217260 \lambda_9 + 132058 \lambda_{10} + 338647 \lambda_{11} + 234651 \lambda_{12} \\
+ 1103970 \lambda_{13} + 571719 \lambda_{14} + 588968 \lambda_{15} - x_1 & \leq 0 \\
40186473 \lambda_1 + 2712037 \lambda_2 + 141648 \lambda_3 + 6660127 \lambda_4 \\
+ 1316705 \lambda_5 + 2706031 \lambda_6 + 631256 \lambda_7 + 1673054 \lambda_8 \\
+ 7041233 \lambda_9 + 956551 \lambda_{10} + 1007595 \lambda_{11} + 1994473 \lambda_{12} \\
+ 3750517 \lambda_{13} + 3772531 \lambda_{14} + 1740738 \lambda_{15} - x_2 & \leq 0 \\
15497442 \lambda_1 + 911042 \lambda_2 + 108745 \lambda_3 + 1927579 \lambda_4 \\
+ 650151 \lambda_5 + 834737 \lambda_6 + 362980 \lambda_7 + 563712 \lambda_8 \\
+ 3458772 \lambda_9 + 267446 \lambda_{10} + 559388 \lambda_{11} + 531474 \lambda_{12} \\
+ 1479535 \lambda_{13} + 1022958 \lambda_{14} + 573679 \lambda_{15} \geq 650151 \\
\lambda_i \geq 0, i = 1, 2...15 \\
x_1 \geq 0 \\
x_2 \geq 0
\end{align*}
\]
Some of the important properties that the factor minimal cost to satisfy are that it should be *(i)* monotone in output, *(ii)* linear homogeneous in input prices.

4.5 COST EFFICIENCY (OR) OVERALL PRODUCTIVE EFFICIENCY**:

Input overall productive efficiency (IOPE) is defined as the ratio of least cost to observed cost.

\[
\text{IOPE} = \frac{Q(u,p)}{px_0}
\]

*(i)* Let \( u_0 \leq u_1 \Rightarrow \left[ \begin{array}{c} L^k \ u_1 \\ u_0 \end{array} \right]

\[
Q(u_1, p) = \text{Min} px \text{, such that } x \in \left[ \begin{array}{c} L^k \ u_1 \\ u_0 \end{array} \right]
\]

\[
Q(u_0, p) : \text{Min} px \text{, such that } x \in \left[ \begin{array}{c} L^k \ u_0 \end{array} \right]
\]

Minimum over a subset is larger than or equal to minimum over a superset.

\[
Q(u_0, p) \leq Q(u_1, p)
\]

*(ii)* \(Q(u, \lambda p) = \text{Min} \{ \lambda px : x \in L(u) \} = \lambda \text{Min} \{ px : x \in L(u) \} = \lambda Q(u, p)\)

** For a parametric frontier to measure cost efficiency, the knowledge of its dual frontier cost function is necessary. For example, for Cobb–Douglas frontier the input overall productive efficiency is,

\[
\text{IOPE} = \frac{\theta}{px_0}
\]

where \( \theta = \sum_{i=1}^{a} \alpha_i \)

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Where $x_0$ is the input employed by the production unit whose efficiency is under evaluation.

In terms of input sets diagram we observe that,

$$ IOPE = \frac{Q(u_0, P)}{P x_0} = \frac{\text{cost at } R}{\text{cost at } P} = \frac{OR}{OP} $$

$$ = \frac{OR \cdot QQ}{QQ \cdot OP} $$

$$ = \text{IAE} \times \text{IOTE} $$

Input overall productive efficiency is the product of input allocative and overall technical efficiencies. Consequently,

$$ \text{IAE} = \frac{IOPE}{IOTE} $$
<table>
<thead>
<tr>
<th>S.No.</th>
<th>Total Manufacturing sector</th>
<th>Overall Productive efficiency</th>
<th>Loss of labour input</th>
<th>Loss of capital input</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All India</td>
<td>0.7052</td>
<td>2409352.0530</td>
<td>11846972.2400</td>
</tr>
<tr>
<td>2</td>
<td>Andhra Pradesh</td>
<td>0.4960</td>
<td>458819.4240</td>
<td>1366866.6480</td>
</tr>
<tr>
<td>3</td>
<td>Bihar</td>
<td>1.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Gujarat</td>
<td>0.6489</td>
<td>288914.5724</td>
<td>2338370.5900</td>
</tr>
<tr>
<td>5</td>
<td>Haryana</td>
<td>0.8579</td>
<td>42416.9921</td>
<td>187103.7805</td>
</tr>
<tr>
<td>6</td>
<td>Karnataka</td>
<td>0.6110</td>
<td>191305.9210</td>
<td>1052646.0590</td>
</tr>
<tr>
<td>7</td>
<td>Kerala</td>
<td>0.7403</td>
<td>78763.3742</td>
<td>163937.1832</td>
</tr>
<tr>
<td>8</td>
<td>Madhya Pradesh</td>
<td>0.6808</td>
<td>85445.0520</td>
<td>534038.8368</td>
</tr>
<tr>
<td>9</td>
<td>Maharashtra</td>
<td>0.9691</td>
<td>37613.3340</td>
<td>217574.0997</td>
</tr>
<tr>
<td>10</td>
<td>Orissa</td>
<td>0.6246</td>
<td>49574.5732</td>
<td>359089.2454</td>
</tr>
<tr>
<td>11</td>
<td>Punjab</td>
<td>0.8229</td>
<td>59974.3837</td>
<td>178445.0745</td>
</tr>
<tr>
<td>12</td>
<td>Rajasthan</td>
<td>0.5977</td>
<td>94400.0973</td>
<td>802376.4879</td>
</tr>
<tr>
<td>13</td>
<td>Tamil Nadu</td>
<td>0.6162</td>
<td>423703.6860</td>
<td>1439448.4250</td>
</tr>
<tr>
<td>14</td>
<td>Uttar Pradesh</td>
<td>0.5740</td>
<td>243552.2940</td>
<td>1607098.2060</td>
</tr>
<tr>
<td>15</td>
<td>West Bengal</td>
<td>0.4100</td>
<td>347491.1200</td>
<td>1027035.4200</td>
</tr>
</tbody>
</table>
Among all the total manufacturing sectors of different states along with All India as a DMU Bihar is the only state that is overall productive efficient. Maharashtra which is an overall technical efficient and is nearly a cost efficient. Only 3 percent of its inputs are freely disposed.

Due to input overall productive inefficiency the worst hit states are Andhra Pradesh and West Bengal. The input cost inefficiencies of these states are respectively 50 and 41 percent. For all the 15 decision making units we have,

\[ 0.41 \leq \text{IOPE} \leq 1 \]

Around 60 percent input OPE is experienced by Karnataka (61%), Orissa (62%), Rajasthan (60%), Tamil Nadu (62%) and Uttar Pradesh (57%).

35 percent of input losses are experienced by the total manufacturing sector of Gujarat. Above 80 percent cost efficiency is experienced by the total manufacturing sectors of the states Haryana and Punjab, apart from Bihar and Maharashtra. The input losses experienced by these states are respectively 86 and 82 percent.

The total manufacturing sectors of Kerala and Madhya Pradesh freely disposed inputs by 26 and 32 percent respectively.

The structural cost efficiency estimated is 71 percent.
4.6 INPUT ALLOCATIVE EFFICIENCY (IAE):

Input allocative efficiency as explained above is a derived measure. It is a ratio whose denominator is the cost that occurs if input overall technical efficient input vector is employed and numerator is a factor minimal cost. Allocative inefficiency occurs due to failure to operate cost minimizing input vector on the relevant isoquant of the production frontier.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Total Manufacturing sector</th>
<th>IAE</th>
<th>Loss of labour input</th>
<th>Loss of capital input</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All India</td>
<td>0.98</td>
<td>163456.72</td>
<td>803729.46</td>
</tr>
<tr>
<td>2</td>
<td>Andhra Pradesh</td>
<td>0.94</td>
<td>54621.36</td>
<td>162722.22</td>
</tr>
<tr>
<td>3</td>
<td>Bihar</td>
<td>1.00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Gujarat</td>
<td>0.79</td>
<td>172805.64</td>
<td>1398626.67</td>
</tr>
<tr>
<td>5</td>
<td>Haryana</td>
<td>0.94</td>
<td>17910.06</td>
<td>79002.30</td>
</tr>
<tr>
<td>6</td>
<td>Karnataka</td>
<td>0.99</td>
<td>4917.89</td>
<td>27060.31</td>
</tr>
<tr>
<td>7</td>
<td>Kerala</td>
<td>0.99</td>
<td>3032.86</td>
<td>6312.56</td>
</tr>
<tr>
<td>8</td>
<td>Madhya Pradesh</td>
<td>0.92</td>
<td>21414.80</td>
<td>133844.32</td>
</tr>
<tr>
<td>9</td>
<td>Maharashtra</td>
<td>0.97</td>
<td>36517.80</td>
<td>211236.99</td>
</tr>
<tr>
<td>10</td>
<td>Orissa</td>
<td>0.88</td>
<td>15846.96</td>
<td>114786.12</td>
</tr>
<tr>
<td>11</td>
<td>Punjab</td>
<td>0.95</td>
<td>16932.35</td>
<td>50379.75</td>
</tr>
<tr>
<td>12</td>
<td>Rajasthan</td>
<td>0.75</td>
<td>58662.75</td>
<td>498618.25</td>
</tr>
<tr>
<td>13</td>
<td>Tamil Nadu</td>
<td>0.94</td>
<td>66238.20</td>
<td>225031.02</td>
</tr>
<tr>
<td>14</td>
<td>Uttar Pradesh</td>
<td>0.91</td>
<td>51454.71</td>
<td>339527.79</td>
</tr>
<tr>
<td>15</td>
<td>West Bengal</td>
<td>0.80</td>
<td>117793.6</td>
<td>348147.60</td>
</tr>
</tbody>
</table>
The total manufacturing sectors of Gujarat, Orissa, Rajasthan and West Bengal allocated their inputs significantly away from the inputs those could minimize the cost of production. The input losses due to input allocative inefficiency by these decision making units are 21, 22, 25 and 20 percent respectively. Bihar is perfectly an allocative efficient. The total manufacturing sectors of Karnataka and Kerala are nearly allocatively efficient. About 1 percent of their inputs is freely disposed due to the allocative inefficiency. In addition to these, there are 7 DMUs whose input allocative efficiency exceeded 90 percent. These are the total manufacturing sectors of Andhra Pradesh (94%), Haryana (94%), Madhya Pradesh (92%), Maharashtra (97%), Punjab (95%), Tamil Nadu (94%) and Uttar Pradesh (%).

The structural input allocative efficiency is about 98 percent.