STRATEGIC ISSUES IN SUPPLY CHAIN MANAGEMENT - AN INDIAN PERSPECTIVE
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By

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ABSTRACT

Supply Chain Management (SCM) is a methodology which presents an integrated approach to resolve issues in Sourcing, Customer-Service, Demand Flow and Distribution. This paper gives a conceptual framework for SCM, the Problems and Challenges in India and also looks into the issue as to how Strategy, Quality and Cost are affecting the Supply Chain Management concepts. This paper also touches upon the Major Strategies one should focus on, for making SCM effective in their organizations.

1.0 Introduction:-

Supply Chain Management is one such methodology which presents an integrated approach to resolve issues in Sourcing, Customer-Service, Demand Flow and Distribution.

The results derived by applying Supply Chain Management (SCM) are:

- Reduced Operational Costs
- Improved Flow of Supplies
- Reduction in Delays of Distribution and Increased Customer Satisfaction

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Because of Global competitiveness, the customer is considered supreme and India's competitiveness as a nation makes a sad reading (50 out of 53). Indian organizations will have to focus on Production and Delivery aspects of a Business Enterprise. The Supply Chain Management (SCM) will play a major role in the times to come.

1.1 Conceptual frame work for Supply Chain Management:

The Fig. 1 given below gives a conceptual frame work for supply chain management.

![Diagram of Supply Chain Management](image)

If the Supply Chain is not managed properly, the Delivery Chain is automatically bound to be affected resulting in Customer-dissatisfaction and finally loss of business. Supply chain management involves both the Hardware as well as Software aspects.

**Hardware:** Physical Elements of Logistics and Purchase

**Software:** Overall philosophy of the Business Enterprises' dealing with the Supplier or Vendor.
Supply chain management can also be looked at from another point of view:-

"The competition for an enterprise may come from its suppliers and customers apart from their existing and potential rivals as well as substitute product and services" – Michael Porter

Competitiveness of an organization can be related to in-house Manufacturing Vs Outsourcing; Core Competency of an organization and how effectively it is utilized. Competitiveness can be enhanced both in terms of **Quality, Price and Time**.

The ultimate requirement of successful Supply Chain Management is namely, creative or innovative approach to management. It is desirable for organizations to benchmark one’s activities with the best practice in the market and also encourage an atmosphere of culture of innovative thinking.

2.0 Supply Chain Management in India – Problems & Challenges:

The main objective of SCM is to fulfill the demand at the right place, at the right time with the right quality at the lowest possible cost. The science of movement of materials, intermediaries and final products from the producer to the consumer is called Logistics. Logistics is an integral part of Supply Chain Management.
The critical relationship between Supplier (Vendor) and Company (Producer) on the basis of Cost, Quality, Speed and Flexibility is given below:

**The Critical Relationships**

**Table 1**

<table>
<thead>
<tr>
<th>Supplier-Company Relationship</th>
<th>Cost</th>
<th>Quality</th>
<th>Speed</th>
<th>Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Suppliers, Single Company</td>
<td>Transaction-Based</td>
<td>Company-Dictated</td>
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<td>Company-Dictated</td>
</tr>
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<td>Supplier-Dictated</td>
<td>Supplier-Dictated</td>
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</tr>
<tr>
<td>Company-Joint Supplier, Venture</td>
<td>Company-Dictated</td>
<td>Supplier-Dictated</td>
<td>Supplier-Dictated</td>
<td>Supplier-Dictated</td>
</tr>
</tbody>
</table>

2.1 How Strategy is Changing the Chain:-

- If customization is the differentiator, Suppliers must be chosen for their versatility.
- When Customer tastes are fast changing, the Supply Chain has to be fast and flexible.
- Firms in mature markets are building long Supply Chains and only branding the product.
- Companies that compete on cost in the market place are picking suppliers on the basis of price.
2.2 How Quality is Changing the Chain:-

- Customers are defining quality standards that the entire supply chain must meet.
- Suppliers are confirming to their buyers' Just-in-Time (JIT) and Lean Manufacturing Systems are being adapted.
- Manufacturers are partnering their vendors in determining designs and product specifications.
- Companies are passing on the Costs of Poor Quality (COPQ) to their Suppliers (Vendors) instead of taking them on themselves.

2.3 How Cost Management is Changing the Chain:-

- Demand forecast tools are being used to micro-tailor orders for suppliers.
- Inventories are being decimated as companies are sourcing on a need based-system.
- Manufacturers are setting target costs to their suppliers instead of asking for prices.
- Companies are helping their vendors, lower their production costs so as to pay lower prices.

2.4 What Some of the Business Leaders have to say in the Context of SCM

1. “It was companies, who used to compare with each other earlier. Today, the competition is much broader – between Supply Chains. The one with the best Supply Chain will walk away with the customer, however competent individual pockets in the supply chain are”

   - Rohit Agarwal
   V.P (Strategic Marketing), Herndon, USA
2. “The idea is to focus on the tasks that add the real value – so that you can also capture the greatest profits – while leaving the rest to your suppliers”

   – Vijay Krishna
   CEO, Godrej – GE

3. “If I have to launch a product from scratch every 18 months, and continue modifying it every 3-months, it has to be a collaborative effort”

   – Adarsh Gupta
   Executive Director, Liberty Shoes

4. “The cost of every activity in the supply chain has to be lower than the value it adds, otherwise, it is of no use”

   – K Ramachandran,
   CEO, Philips India

3.0 The Critical parameters for Supply Chain Characteristics and Competitive Position

The Critical Parameters for Competitive Positions could be:

- Reliable Demand Estimation
- Unreliable Demand Estimation
- Start-up Stage
- Growth Stage
- Maturity Stage

The Supply Chain Characteristics could be:

- Flexibility
- Speed
- Cost
- Quality
- Responsiveness
- Single Piece Flow
4.0 Major Strategies in Supply Chain Management

4.1 Procurement Strategy
- Proper specifications-Quality of Input Materials and Designs
- Value Analysis and Bargaining Leverage/Market research
- Vendor Analysis and Broad based data bank
- Information System – Use for Cost Benefit
- Segmental and Geographical Scope of Procurement
- Long term Agreements and Technological Coalitions
- Global Sourcing

4.2 Inventory Strategy
- Service level Policy
- Replenishment Strategy
- Stock-turnover Target

4.3 Warehousing Strategy
- Number of Stock-holding Points
- Location of Depots
- Warehousing Design/Layout
- Material Handling Methods

4.4 Transport Strategy
- Fleet mix
- Lease/Buy Decisions
- Customer pick-up/Delivery etc.
- Vehicle utilization targets
- Routing Flexibility
- Modes of Transportation

4.5 Customer Satisfaction Strategy
- Order Status Policy
- Order Processing Systems
- Policy for Acceptance/claims for Defective Supplies
- Stock Availability Vs Ordering Convenience
- Frequency & Reliability of Delivery including Documentation
5.0 Conclusion:

With the advent of Networking and use of Information Technology (IT) as an enabler, pre-determined pricing is giving way to auction based bidding for the best price. Sourcing is becoming global as suppliers all over the world would be selling on the net. Long-term partnerships with vendors are making room for deal-to-deal relationship. Buyers are being forced to compete with one another to secure the best and cheapest suppliers thus Supply Chain Management in Indian Companies will pay a major role for their competitive advantage.

6.0 References:


MEASURING TECHNICAL EFFICIENCY IN DATA ENVIRONMENTAL ANALYSIS
MEASURING TECHNICAL EFFICIENCY IN DATA ENVELOPMENT ANALYSIS

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T. A. PAI MANAGEMENT INSTITUTE
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Measuring Technical Efficiency in Data Envelopment Analysis

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Abstract: In this study an attempt is made to examine, using data envelopment analysis, the productivity trends in the Indian Pig Iron and Sponge Iron industry for the period after economic liberalization. The methods of cross-efficiency matrix, distribution of virtual inputs and returns to scale are also used to get further insights into the performances of the individual units. The results show that there has been declining efficiency trend since 1996 which could be taken as the evidence of rapid capacity addition in the early 1990s coupled with the recession in the steel sector. Though our DEA results on peer group and target provide limited information as to how performance can be improved through on-site inspection of operations, these are not robust in the sense that some of the peers identified are not real peers. However, the results on cross efficiency matrix and the distribution of virtual inputs provide information concerning not only the real peers but also their truly efficient operating practices where there is high probability that both efficient as well as inefficient companies could possibly improve upon.

Key Words: DEA; Technical Efficiency; Peer Group; Cross-Efficiency Matrix; Distribution of Virtual Inputs.

1. Introduction

Industrial growth of a country results mainly from the interaction of two factors: investment in capabilities, and the productivity with which these capabilities are utilized (Majumdar, 1996). The productivity of investments generates surpluses, which, in turn, motivate the entrepreneurs towards undertaking further industrial activity. Harberger (1959) recognizes that inefficiency in resource usage leads to substantial welfare losses of a country where there is a multiplicity of socio-economic demands on scarce resources, such as capital. In the Indian economic literature it is well recognized that efficiency has a major role to play in ensuring industrial success. Nayyar (1994) maintains that success at industrialization is not only about resource allocation. It is as much, if not more, about resource utilization and resource creation. The mode of utilization of resources is a critical determinant of economic efficiency. The process of creation of resources is a crucial determinant of economic growth.

1. 1. Economic Liberalization in India

Prior to the onset of economic liberalization in 1991, the Indian Iron and Steel industry was regulated by the control mechanism of the Government. Competition in the industry was absent. The entire supply of pig iron mainly came from the integrated steel plants (ISPs). The control mechanisms and the negation of competitive forces led to inefficiencies, dwindling surpluses and flagging growth rates of the industry. With the advent of liberalization, the deregulation was felt necessary principally to tackle the problem of inadequate investible resources with adversely affected creation and upgrading of capacities in large-scale units. On the one hand, internal generation of resources by the existing producers has been facilitated by deregulation of prices and distribution. On the other hand, creation of new capacities has been given a boost through the removal of restrictions on participation of private capital. As a result, the Iron and Steel industry attracted large investments, both indigenous and foreign. Plants got modernized,
capacities were added, and the years 1994-95 and 1995-96 experienced the expected growth (Joint Plant Committee, 1996-97). But growth and consumption have slowed compared to earlier two years. Hence almost each unit in the industry now faces intense competition and excess capacity. There is now a structural shift of supply from ISPs to mini plants. The mini plants are preferred to large plants on technical as well as market considerations. The mini-blast furnaces, being dedicated to pig iron production, could actually vary the quality of output according to the need, which was not the case for the ISPs where the pig iron was mere an input for higher value added products. Smaller capacity costs tend to make mini-blast furnaces more competitive. The plants were located near their respective markets which gave them a tremendous edge -proximity to markets means low freight, which can be a big protection in the case of low-value product.

1.2. Size and Location Variation in Indian Pig Iron and Sponge Iron Industry

We find in this industry that there is a wide variation of size (in terms of capacity) among the companies, ranging from 20,000 to 5,40,000 tonnes per annum (Sastry, 1996). This wide variation in size is also reflected in the data on inputs and output, resulting in efficiency to vary substantially among the units. Most of the units started production from 1991-92 onwards and are therefore young. The units are geographically very highly dispersed. Therefore most of the units are generally not aware of how other units are performing and what their operating practices are. There is thus a need to measure the efficiency of these units, identify peers for each unit, and analyze their behaviors relating to returns to scale. Such a micro-level study has not been conducted so far for this industry.

The choice of this pig and sponge industry in our study is not only made for its importance but also is designed to be illustrative of the many potential applications elsewhere in the manufacturing sector. The sponge iron industry was identified by the Government as a thrust area and was completely delicensed in 1986, much before the era of economic liberalization was introduced in the country. This active support from the Government, coupled with abundant availability of indigenous raw material, encouraged many entrepreneurs to put-up sponge plants of different capacities. Due to the acute shortage and high price of good quality scrap, sponge iron, a substitute for scrap, was readily accepted as an ideal charge mix in India for steel making. It confirms a famous saying "Necessity is mother of invention but circumstances can be a great tutor". Circumstances of severe scrap shortage taught Indian steel producers to quickly learn to use sponge iron in the electric arc furnaces (EAF) and induction furnaces. Besides this, there are two more reasons for accelerating the demand for sponge iron. First, decreased generation of home scrap due to widespread adoption of continuous casting technology in steel plants. Hence, the generations of revert scrap decreased and consumption of scrap increased. Second, keeping in line with the international trend, Indian steel makers shifted their product mix to high value added steel. This necessitated purer form of charge material having low tramp elements. As the quality requirements of such finished steel are very stringent, sponge iron became a preferred choice in India with electric furnace steel makers. However, pig iron is mainly used for manufacturing iron castings, i.e., the foundry industry whose growth in turn is dependent on the automobile industry, the engineering industry, the railways and government spending on sewerage plants etc. Also, pig iron can partially replace scrap or sponge iron in the production of steel through EAF route. Many producers in India are using 10% pig iron in the charge mix.

In the present study we measure the technical efficiency, identify peer groups and truly efficient operating practices, and estimate returns to scale, using the DEA approach. We have considered panel data on inputs and output for the period spanning from 1991 to 1999 for the companies in the Indian Pig Iron and Sponge Iron industry. This paper finally examines the possible factors that influence efficiency variations in the companies.

The paper is organized as follows: Section 2 describes how the DEA approach can be utilized to measure efficiency. The empirical application to data from Indian Pig Iron and Sponge Iron industry is reported in Section 3. Section 4 gives a summary and conclusion of the work.

2. Technical Efficiency - Concepts & Measures

The concept of technical efficiency in production originated with the work of Koopmans (Koopmans, 1951). Koopmans defines a decision making unit (DMU) as technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or results in a reduction in at least one output. Thus a technically efficient DMU can produce the same output with less of at least one input, or can use the same inputs to produce more of at least one output. But this definition, by itself, is not sufficient to determine an absolute efficiency frontier. It is the path-
breaking work of Farrell (Farrell, 1957), largely inspired by Koopmans, which lays emphasis on the empirical necessity of treating Koopmans' definition of technical efficiency as a relative notion, relative to the best observed practice in the comparison group, leading to a way of differentiating an efficient DMU, from the inefficient ones. This way of differentiating an efficient DMU, however, offers no guidance in either measuring the degree of inefficiency of an inefficient DMU or identifying an efficient DMU with which to compare an inefficient DMU. This issue was addressed by Debreu (1951), who offers the first measure of technical efficiency (radial measure) with his 'coefficient of resource utilization'. Farrell and Debreu define technical efficiency as one minus maximum feasible equi-proportionate reduction in all inputs that still allows the continued production of given outputs. A score of unity indicates technical efficiency because no feasible equiproportionate reduction in all inputs is possible and a score of less than unity indicates technical inefficiency since it is possible to have feasible equiproportionate contraction of all inputs. The above measure, obviously, has an input orientation. Farrell's approach is based on the technology set consisting of convex hull of input-output vectors, which was reformulated as a mathematical programming problem by Charnes et al. (1978, 1979, 1981). This mathematical programming approach to efficiency measurement is known as data envelopment analysis (DEA).

From the above discussion it is clear that the radial measures are better in the sense that it is based on maximum feasible equiproportionate reduction/expansion in all inputs/outputs, and it is independent of the unit of measurement. But the problems with this measure are two folds. First, the conventional target-setting with this measure suggests that inputs/outputs of the inefficient DMUs are reduced/increased equiproportionately along a radial contraction/expansion path. This rules out the possibility of trade off between inputs/outputs and hence is counterintuitive. Second, technical efficiency is obtained through maximum feasible equiproportionate input reduction/output expansion even though some slacks remain in input/output vectors. This amounts to saying that a DMU labeled efficient on the basis of radial measure (Debreu-Farrell measure) may not be efficient on the basis of Koopmans definition. It may, thus, be concluded that Farrell's technical efficiency is weak in the sense that slacks remain in the input/output vectors whereas Koopmans' technical efficiency is strong in the sense that no slacks remain in the input/output vector, which yields itself to measurement by the non-radial measure of Russell (Fare et al., 1994, Fare and Lovell, 1978, Russell, 1985).

2.1. Efficiency Estimation Procedures

Following Farrell (1957), there are two quite different methodologies which are extensively used for determining efficiency frontiers and the nature, existence and magnitude of departure from them: (1) econometric estimation of production frontiers, and (2) data envelopment analysis (DEA). The econometric approach to estimating efficiency frontiers maintains the assumption of explicit functional form for the underlying production technology along with a two-part error term. One part is the noise that is generally assumed to follow a normal distribution and the other part represents inefficiency which is assumed to follow an one-sided distribution such as half-normal, exponential, truncated normal, or gamma distribution (Aigner et al., 1977, Aigner and Schmidt (ed.), 1980, Green, 1990, Green and Mayes, 1991, Stevenson, 1980). The parameters of the production frontier are estimated using regression techniques, and the residuals are decomposed into a random component and an inefficiency component. In contrast, DEA does not require any underlying assumptions for the functional form of the production technology but enables one to obtain extremal relations such as the production functions and/or efficient production possibility surfaces. The advantage of DEA lies in its approach. DEA optimizes for each individual observation whereas a single optimization is performed in statistical regressions for the whole observations. Instead of trying to fit a regression plane through the centre of the data, it floats piecewise linear/Cobb-Douglas (log-linear) surface to rest on the top of the observations due to which it is able to uncover such relationships (Seiford and Thrall, 1990). This linear surface is empirically driven by the data rather than by assumptions as to the functional forms. The only assumption made in DEA is that the production technology enveloped by the piecewise-linear surface is convex.

The most widely used methods for the estimation of technical efficiency are the Charnes et al. (CCR) and Banker et al. (BCC) models. Both the models are based on the assumption of strong (free) disposability, but the former is based on the assumption of constant returns to scale (CRS) whereas the latter is on variable returns to scale (VRS). The efficiency estimate of a target DMUj can be computed from the following BCC model.
\[ h^B_i (VRS, S) = \min_{\lambda, \theta} \theta \]

s.t. \[ u'_n \leq \sum_{j=1}^{J} \lambda_j u'_n, \quad n = 1, 2, \ldots, N, \]

\[ \sum_{j=1}^{J} \lambda_j x'^j_m \leq \theta x'^j_m, \quad m = 1, 2, \ldots, M, \]

\[ \sum_{j=1}^{J} \lambda_j = 1, \]

\[ \lambda_j \geq 0. \]

where,

- \( VRS \) = variable returns to scale,
- \( S \) = strong disposability,
- \( u'_n \) = amount of \( n^{th} \) output produced by \( j^{th} \) DMU,
- \( x'^j_m \) = amount of \( m^{th} \) input used by \( j^{th} \) DMU,
- \( \lambda_j \) = the intensity vector corresponding to \( j^{th} \) DMU (shadow price),
- \( J \) = the number of DMUs,
- \( N \) = the number of outputs,
- \( M \) = the number of inputs.

The dual of the above model can be written as:

\[ h^B_i (VRS, S) = \max \sum_{n=1}^{N} \mu_n u'_n + \omega \]

s.t. \[ \sum_{m=1}^{M} v'_m x'^j_m = 1, \]

\[ \sum_{n=1}^{N} \mu_n u'_n - \sum_{m=1}^{M} v'_m x'^j_m + \omega \leq 0, \quad j = 1, 2, \ldots, J, \]

\[ \mu_n, \ v'_m \geq 0, \text{ and } \omega \text{ is unconstrained in sign} \]

where,

- \( \omega \) = the variable representing returns to scale parameter,
- \( \mu_n \) = the weight attached to \( n^{th} \) output,
- \( v'_m \) = the weight attached to \( m^{th} \) input,

and, all other notations are same as before.

Using only the observed output and input data for each of the \( J \) units, this model estimates an ex post measure of how efficient each unit is in converting inputs into outputs, accomplished by constructing an empirically based production frontier, and evaluating each unit against all the other units included in the model. A score of unity for \( \theta \) and zero slack and surplus variables indicate that the unit \( j \) is technically efficient. It means that it is not possible to further reduce the inputs radially so far as the continued level of production is concerned. And any efficiency score of less than one indicates technical inefficiency.

It is noted here that the removal of the last constraint (\( \sum \lambda_j = 1 \)) in the BCC model (equation 1) (or equivalently removing \( \omega \) from objective function as well as constraints of dual representation of BCC model given in equation 2) converts it into a CCR model. Banker et al. (1984) show that the CCR efficiency score (also called Debreu-Farrell efficiency) confounds the effects of both technical and scale efficiency, and it can be decomposed into a pure technical efficiency component and a scale efficiency component whereas their model captures the resource conversion efficiencies (pure technical efficiency) feasible by units irrespective of returns to scale considerations. Dividing the CCR efficiency score by the BCC efficiency score yields a measure of scale efficiency, which reflects...
the ability of the unit to operate as close to its most productive scale size as possible (Banker et al., 1984). The deviations from scale efficiency of a unit is due to the fact that it is not operating at the scale operations consistent with long-run equilibrium, i.e. at a point consistent with constant returns to scale. Scale efficiency is thus a discrepancy between the true constant returns to scale technology and the estimate of the intermediate or short-run (VRS) technology.

3. The Empirical Application
3.1. The Data
This study uses panel data on output and inputs of the Indian Pig Iron and Sponge Iron industry covering the period 1991-1999 from the software PROWES prepared by Centre for Monitoring Indian Economy, and wholesale price index (WPI) data from Comprehensive Online Data Base on the Indian Economy. From the data set available, we have considered 15 companies whose input and output data are available from 1991 to 1999, though a slightly more number of companies is available in the current years. A single output - sales, and five inputs - raw materials, energy, labor, capital and selling expense - are considered. The WPI data include the wholesale price index of 'iron and steel', 'industrial machinery and equipment', 'power' and 'all commodities'.

Output and Input Definitions
- **Sales**: We have taken here 'net sales' which is defined as sales excluding indirect taxes and duties such as excise, sales tax, octroi.
- **Raw material**: It is the consumption of raw materials, stores as well as packing expenses and purchase of finished goods for resale. Expenses incurred on inward transportation of raw materials form a part of raw material expenses. Change in stock of semi-finished goods is netted off from the cost of raw material expenses.
- **Energy**: It is the total cost of energy like power, fuel, and coal.
- **Labor**: Since the data on number of workers are not available unit-wise, we have taken here total wages and salaries as proxy for labor.
- **Capital**: The capital input is approximated by depreciation plus profit relative to the total assets (i.e., fixed assets + working capital) employed. Thus, the capital input for any particular period is computed as the sum of depreciation for that period and current assets employed times the return on assets in the base period (Sumanth, 1985). Depreciation is here defined as net of lease equalization and also excludes depreciation on revalued assets. However, in finance literature capital is defined as the sum of total equity and debt.
- **Selling costs**: It includes advertising, marketing and outward distribution expenses. Besides advertising it includes rebates and discounts, selling commission. It also includes provision for doubtful debts during the year.

All these output and inputs are measured in rupees in crore. All these variables are deflated by the appropriate wholesale price indices.

We realize that there are considerable problems with the data. First, our study measures financial rather than operational efficiency of the companies since the data for inputs and output variables are in monetary units. So there is certainly a difference between the two and that difference, if not properly understood, may lead to erroneous inferences. A Company, for example, is rated here inefficient due to relatively high wages that it pays to its labor force. But, the high wages might be necessary due to local economic conditions and the inefficient company actually uses less manpower to produce the same or more outputs (e.g., tons of iron) than its peers that were ranked as efficient. Second, two types of technologies - Tata Korf and Mannesmann - are used in this industry. The problem arises when a peer is formed with a combination of units, each employing a distinct technology. These two exceptions to the data, and many more that could be made, fall under the general criticism of the conventional microeconomic assumptions of homogeneous labor, common production technologies and processes. Data permitting, we would like to take all these factors into account.

3.2. Discussion of Results
It is not uncommon in empirical work in the DEA literature to present descriptive statistics on the input-output data prior to formal modeling of the production process (Rangan et al., 1988, Fare et al., 1987, Grosskopf and Valdmanis, 1987). This serves to provide some intuition on the plausibility of the derivative DEA-efficiency coefficients. These coefficients lack a simple test statistic such as would be output from conventional parametric procedures like 'ordinary least squares'. In a similar context Besley (1989) and Hammond (1981) have proposed the evaluation of efficiency "ex ante" and "ex post". Thus the efficiency predictions in this section are termed "ex ante" in the sense.
that they are derived from descriptive statistics on the data prior to formal evaluation of performance with DEA. Analogously the DEA efficiency scores can be interpreted as "ex post" predictions of efficiency. Table 1 contains means, standard deviations, maxima and minima of the input-output data set based on the full panel data set comprising 15 companies for nine years.

From the extreme values in the data it is possible to make crude ex ante efficiency predictions. Since our efficiency estimates are based on inputs, these predictions are based on the extreme values of expenses on 'raw materials', 'energy', 'wages', 'capital', and 'advertising, distribution and selling'. From this table this would imply that Tata Sponge Iron Ltd. (1991, 1998) might be among best practice companies with minimal expenditures respectively on raw materials and energy. Similarly, other companies such as Bellary Steels & Alloys Ltd. (1991), Raipur Alloys & Steel (1991) are expected to be among others best practice companies with minimal expenditure on respectively wages and capital, whereas the companies Sponge Iron India Ltd. (1991, 1992, 1993, 1994, 1995, 1998, 1999) and Rashtriya Ispat Nigam Ltd. (1999) taken together would be the best with respect to minimal expenses on advertising, distribution and selling. Analogously the companies incurring maximal expenses on most of these inputs might be anticipated to be poor efficiency candidates. Example here among other poor performers is the Steel Authority of India Ltd. Our DEA results will of course throw some light on this, which will be discussed at the end.

The analysis of efficiency on the input-side rather than the output-side is becoming common in DEA applications for a variety of reasons. Profitability in any business hinges on the efficiency of operations. But if the business involves a commodity, then what depends on efficient operations is survival. When prices are beyond a company's control, what remains are costs on inputs. This reflects the companies' emphasis on the input dimensions of policies. On a tentative basis, it has been suggested in the literature that costs (or inputs) are generally more predictable than outputs, giving cost targets a greater credibility than those for outputs (Sengupta, 1987, Mellander and Ysander, 1987). Sengupta (1987, p. 2,290) has argued that: "..... data variations may arise in practical situations ..... when the output measures have large and uncertain measurement errors which are much more significant than in the input measures. For example in school efficiency studies, the input costs, such as teachers' salaries, administrative expenses, etc., may have low measurement errors whereas the performance test scores of students may contain large errors of measurement of true student quality". This argument is most compelling where measurement errors are large relative to true random fluctuations in the production process.

The efficiency estimates are calculated using the assumption of CRS for the reference technology. As pointed out by Fare et al. (1997), this technology has some useful feature in that it captures the notion of maximal average product (consistent with the minimum point on a long-run U-shaped average cost curve) which provides a very nice benchmark for identifying the optimal scale.

We have used the input oriented DEA model in a number of ways to elaborate in detail on the performance of individual companies and to ascertain how the units can become more efficient. These uses are the following:

- Identifying efficient and inefficient units
- Identifying peer groups
- Setting realistic targets
- Adopting efficient operating practices
- Monitoring efficiency change over time
- Determining returns to scale
3.2.1. Identifying efficient and inefficient units

Since we have panel data of 15 units over nine periods, each unit is treated as a different unit for each period of time. This will give us a total of 135 (15 x 9) units to be assessed. Of these units, 30 have a score of unity and thus are relatively efficient in their management of various input expenditures. The reminder, 105 in all, are relatively input inefficient to varying degrees attaining an efficiency score less than unity. In the literature it is a common practice to calculate the mean efficiency score as a representative level of performance. We have taken here the mean of non-unit efficiencies. The inclusion of best-practice tends to overstate levels of performance since the mean including best-practice is greater than that excluding it. Thus the mean efficiency score including all 135 units is 0.889; excluding best-practice it is 0.858, as shown in Table 2. This distinction is important from the point of view adjusting expenditures at inefficient companies. For if mean efficiency is calculated to include best-practice the representative target will suggest too small an adjustment in costs at the typical inefficient company. Only the mean inefficiency gives an accurate definition of a representative target. Nevertheless, it is acknowledged that to get the broadest possible view of efficiency of all companies, the mean efficiency based on the whole sample may remain appropriate - particularly in the calculation of total available savings, rather than those at inefficient companies alone.

The CRS efficiency scores in Table 2 are defined relative to the standards set by the best practice companies. These companies are not necessarily efficient in an absolute sense - rather no company belonging to this panel performs better.

3.2.2. The Peer Groups

Here we examine the question of using the best-practice results of peers for improving inefficient production. It is widely argued in the literature (Charnes et al., 1989, Thanassoulis et al., 1987, Bowlin, 1986) that an inefficient unit should draw upon the examples of relatively better managerial and productive procedures of its efficient peers to improve its own productive performance. From the results in Table 2 the inefficient company such as Bihar Sponge Iron Ltd. (1999), for example, would inspect the best practice companies such as its own unit in 1992, Essar Steel Ltd. (1992) and Tata Sponge Iron Ltd. (1992). This could take the form of on-site inspection of the peer unit procedures or greater disaggregation of costs at the modeling stage. Contrasting the input/output levels of the relatively inefficient unit with those of its peer units often helps to highlight inadequacies in the performance of the relatively inefficient unit.

Smith and Mayston (1987) suggest an important supplementary measure in assessing the robustness of this result is the number of inefficient units for which the best-practice unit forms the efficient frontier. They continue that if this number is high the unit is genuinely efficient with respect to large number of units. On this basis the most useful examples of best-practice are likely to be found in heavily cited instances of best practice. These can be extracted from Table 3. The company Jindal Strips Ltd. (1999), for example, would find that the company Tata Sponge Iron Ltd. (1992), Essar Steel (1994) and Bellary Steels and Alloys Ltd. (1999) in its peer group are respectively cited 34, 34, and 18 times. On the other hand companies such as Bellary Steels and Alloys Ltd. (1997) and Essar Steel Ltd. (1998) could be argued to be poorer peers in being cited respectively 5 and 8 times. Thus the informational contents of the peer group can be read in the light of what amounts to the number of citations for the best practice.

It should be noted here that each best practice unit does not have an equal probability of citation unless inefficient units are spread evenly through the feasible production space. This may not be the case. This possibility is clearly evident, for example, in the case of inefficient unit such as Bihar Sponge Iron Ltd. (1991) where its peers such as its own unit in 1992 and Essar Steel Ltd. (1998) are cited less frequently than others such as Tata Sponge Iron Ltd. (1992) and Ispat Industries Ltd. (1994). It follows that a high number of citations imply only comparability in terms of factor proportions with a larger number of inefficient units. In the study of DEA to financial statements, Smith (1990) has made an analogous point arguing that the comparability of an observation conveys nothing in and of itself on the underlying efficiency in a unit.

In general, it is true that the larger the number of citations for a unit, the larger the sample of observations in the neighbourhood of that unit. On the basis of traditional sampling theory, the larger is the sample in a particular neighbourhood, the closer is the sample frontier likely to approximate the true frontier. However, it is not at all clear a priori what would constitute an appropriately high number of citations and therefore at point a dominant observation accurately conveys the attainments and practices which are possible on the true but unknown frontier.
<table>
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101 Raipur Alloys & Steel Ltd. 0.849821 80,123
102 Rishi Steel Ltd. 0.901699 26,80,90,123
103 Tata Steel Ltd. 0.950406 80,123
104 Voltas Ltd. 0.913025 20,49,53
105 Wipro Ltd. 0.869005 80,123
106 Zee Telefilms Ltd. 0.937012 80,123

Average 0.86461 34.3721 0.80912 0.069028 0.757254 0.05954 1.305065 0.351947 0.846392 0.300523 0.228360 13.935225

Notes: (1) Only inefficient companies are included explicitly.
(2) Target performance is given by the efficiency score and (where applicable) adjustments in the input-slack variables.
Table 3: Citations of Best-Practice Companies

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<tr>
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</tbody>
</table>

Note: This table contains those efficient companies which appear in the peer groups (not including their own) of inefficient companies.

3.2.3. Target Setting

It is very often desired to set realistic targets for relatively inefficient companies. Such targets provide concrete benchmarks by which companies can monitor their performance. The adjustments to companies' expenditure implied by their efficiency score are summarized in Table 2. Bihar Sponge Iron Ltd. (1999), for example, has an efficiency score of 0.591261. This implies a lowest target level of raw material expense 0.16735 \(=0.591261 \times \text{efficiency} \times 0.283047\) (raw materials) is the target which would put this company on the best-practice isoquant. Essentially, DEA is predicting that this company can support existing levels of sales with a reduction of \((1-0.591) = 40.87\%\) in its current raw material expenses. The distribution of savings is not spread evenly through the panel. In both the years 1991 and 1992, Rashtriya Ispat Nigam Ltd., for example, is overspending more than by one-half, given the levels of its outcome variable. Of course, this company and some others may choose to argue that examination
results do not adequately reflect the range of output they seek to provide. Unlike Rashtriya Ispat Nigam Ltd., some companies such as HEG Ltd. (1991) and Electrosteel Castings Ltd. (1992) would have to improve performance only marginally to be ranked along with the best-practice companies. An average across all inefficient producers in the sample suggests a typical reduction in costs approaching 14%. It is worth noting in passing that the average target is consistent with the mean efficiency score of 0.860 in Table 2. This also implies a typical reduction in all costs of nearly 14%. However, the mean efficiency score including best practice, 0.891, suggests that costs might be adjusted by under 3.1% which is clearly an understatement of the average potential for savings at inefficient companies, but which is an accurate indicator of total available savings.

It is to be noted here that on a simple split between years the simple proportions of companies relatively efficient in each of these nine years are respectively 83%, 85%, 85%, 86%, 90%, 89%, 86%, 83% and 84%. This result could be taken as evidence of greater inefficiency after economic liberalization has been felt, particularly after 1995.

Following the study of Fare et al. (1987), an *ad hoc* procedure has been adopted here to limit the impact of noise on the estimated level of efficiency. Here a more stable picture of performance can be extracted by performing separate envelopments on the successive nine cross sections and derive the mean efficiency score of a company over time (See Table 4).

<table>
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<tr>
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<tr>
<td>11 Raipur Alloys &amp; Steel Ltd.</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>0.92404</td>
<td>1.00000</td>
<td>1.00000</td>
<td>0.97750</td>
</tr>
<tr>
<td>12 Rashtriya Ispat Nigam Ltd.</td>
<td>0.44627</td>
<td>0.45864</td>
<td>0.59315</td>
<td>0.90017</td>
<td>1.00000</td>
<td>0.94161</td>
<td>0.98992</td>
<td>0.98890</td>
<td>0.98376</td>
</tr>
<tr>
<td>13 Sponge Iron India Ltd.</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>0.98787</td>
<td>1.00000</td>
<td>1.00000</td>
<td>0.99376</td>
</tr>
<tr>
<td>14 Steel Authority Of India Ltd.</td>
<td>1.00000</td>
<td>0.88717</td>
<td>0.93190</td>
<td>0.94213</td>
<td>1.00000</td>
<td>0.94619</td>
<td>0.98375</td>
<td>0.98332</td>
<td>0.98189</td>
</tr>
<tr>
<td>15 Tata Sponge Iron Ltd.</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>1.00000</td>
<td>0.99156</td>
<td>1.00000</td>
<td>1.00000</td>
<td>0.94161</td>
</tr>
<tr>
<td>average (all units)</td>
<td>0.95622</td>
<td>0.94867</td>
<td>0.96834</td>
<td>0.98940</td>
<td>0.99399</td>
<td>0.97973</td>
<td>0.98139</td>
<td>0.98982</td>
<td>0.97764</td>
</tr>
<tr>
<td>average (inefficient units)</td>
<td>0.68867</td>
<td>0.64662</td>
<td>0.64168</td>
<td>0.94659</td>
<td>0.96604</td>
<td>0.94933</td>
<td>0.93022</td>
<td>0.94882</td>
<td>0.94449</td>
</tr>
</tbody>
</table>

Spearman's rank correlation coefficient was used to establish whether noise in outcomes made any unexpected or abrupt change in the efficiency ranking of the companies year-on-year *vis-à-vis* mean efficiencies of these units over nine years. High value of the rank correlation coefficient was taken to represent stable efficiency scores, which reflect underlying levels of performance. These rank correlation estimates are reported below.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank Correlation</td>
<td>0.512</td>
<td>0.646</td>
<td>0.639</td>
<td>0.538</td>
<td>0.116</td>
<td>0.516</td>
<td>0.754</td>
<td>0.523</td>
<td>0.255</td>
</tr>
<tr>
<td>Significance Level (p)</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
<td>0.04</td>
<td>0.06</td>
<td>0.05</td>
<td>0.00</td>
<td>0.04</td>
<td>0.36</td>
</tr>
</tbody>
</table>

The mean-year efficiency scores of these 15 companies are found to be significantly correlated with their year specific efficiency estimates excepting for the years 1995 and 1999. This finding of significant rank correlation suggests that these efficiency estimates are stable and can be taken as the basis of acceptable targets. The sample average efficiency estimates for the inefficient companies for each of these years are found to be respectively 69%, 85%, 85%, 95%, 97%, 95%, 93%, 95% and 94%, which could be seen as a *consistent declining performance since 1995*. This finding is in broad agreement with our earlier finding. And the grand average of all these inefficient producers is 89.6%, which indicates a typical reduction in costs of around 10%, our earlier result warrants a 14% reduction in all input costs. This result is not surprising because the creation of envelopes for successive cross sections limits the number of firms to 15 each, which increases the change of inefficient units to become efficient in our DEA evaluation procedures.
3.2.4. Identifying Efficient Operating Practices

Identification and dissemination of good operating practices could lead to improved efficiency not only for relatively inefficient DMUs but also for relatively efficient ones. The relatively efficient units are the obvious source of good operating practices. However, even amongst efficient units some exhibit better efficient practices than others. So there is a need to discriminate between relatively efficient units in seeking better operating practices. The DEA model allows a unit to choose weights for the inputs and outputs so as to secure a maximum efficiency rating for itself. While so doing, the weight structure may be such that certain important inputs and outputs of a unit may be completely ignored in favor of other, less important ones. Thus, even if a unit is efficient, its operating practices may not be efficient if the weight structure ignores some important inputs and outputs. A number of methods have been suggested in the literature (Dyson and Thanassoulis, 1988, Green et al., 1996, Oral et al., 1991, Sexton et al., 1986, Thanassoulis et al., 1987, Wrong and Beasley, 1990) to get over this problem. We have followed the Cross-Efficiency Matrix and Distribution of Virtual Inputs and Outputs methods.

Cross Efficiency Matrix
A Cross-Efficiency Matrix (Sexton et al., 1986) is a table conveying information on how a unit's relative efficiency is rated by others.

The entry in cell $ij$ of Table 5 represents the relative efficiency of company $i$ with DEA weights optimal for the target company $j$. The CCR dual model (where $\omega$ is taken as zero in equation 2) is used to calculate the efficiency scores given in each cell of this cross-efficiency matrix. As seen in this table, Bellary Steels and Alloys Ltd. (1991), for example, has a relative efficiency of 1 with its own optimal weights and attains a score of less than unity with other efficient units' optimal weights structure. The average efficiency score (0.5662) obtained for this company gives a measure of how other efficient companies in the years spanning from 1991 to 1999 rate this company. However, the average efficiency score (0.6175), given in the last column indicates how this company is rated by the other efficient companies in the same year 1991. Similarly, other efficient companies can be interpreted in an analogous way. We find here that Bellary Steels and Alloys Ltd. (1999) offers good operating practices as its average efficiency score is high in comparison to other efficient units. However, best efficient units, as is evident in the last column, change over years. We conclude from this observation that the units appearing in the peer group with low average efficiency scores are unlikely to offer truly efficient performance, for they are largely self-evaluators. The average efficiencies obtained for each of these efficient units provide further information on their efficiency rankings.