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MEASURING SUPPLY CHAIN EFFICIENCY: A DEA APPROACH

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ABSTRACT: Supply chain performance depends on the efficiency of supply chain. The efficiency depends on the utilized inputs and the outcome. In this paper an attempt has been taken to measure the efficiency of supply chain. We have taken the case of pharmaceutical industry of India. Efficiency of supply chain has been measured by taking inputs and outputs. The average technical efficiency score obtained through CRS model is 0.868, indicating scope for lots of improvement for the Pharmaceutical companies

k ey words: Supply Chain, Efficiency, Data Envelopment Analysis, Efficiency

1. INTRODUCTION

In a business environment supply chain efficiency measurement is an important factor to know the supply chain better, and hence helpful for the company to take corrective measures to check the problem. Supply Chain Management has become one of the most frequently discussed topics in the business literature. According to Simchi-Levi et al. (2000), supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements. Supply chain is defined as a combinatorial system consisting of four processes namely plan, source, make and deliver, whose constituent parts include material suppliers, production facilities, distribution services and customers linked together. Effective management of an organization's supply chains has proven to be a very effective mechanism for providing prompt and reliable delivery of high-quality products and services at the least cost. This is an essential cornerstone for the organizations to develop a sustainable competitive advantage and to remain at the fore front of excellence in a level playing market field.

In order to achieve an efficient supply chain, performance evaluation of the entire supply chain is extremely important. This means utilizing the combined resources of the supply chain members in the most efficient way possible to provide competitive and cost-effective products and services. Hence, "overall supply chain efficiency" is defined as the efficiency which takes into account the multiple performance measures related to the supply chain members, as well as the integration and coordination of the performances of those members. As such, managing this entire/overall supply chain efficiency is indeed a very difficult and challenging task. Ross (1998) had even mentioned that, even within large corporations such as Sears and General Motors which had large supply chain systems, the entire supply chain performance measurement systems were not in existence. It is important to emphasize that the primary objective of this paper is to provide a realistic framework within which to study supply chain performances. An illustrative example with managerial implications is discussed. Hence, incomplete and unavailability of data at present in many organizations may render the model inoperable if a full scale of supply chain efficiency measurement is considered. As such, this paper limits the context of supply chain efficiency within the direct suppliers and the customer relationships. In other words, only two tiers of the supply chain are considered. This paper aims to measure supply chain performance within the manufacturing firm by incorporating all of its value chain activities. It is essential to note that the intention is not purely focusing on the manufacturing processes, but rather the supply chain activities within the manufacturing organization. Although, the study does not incorporate the full length of the value chain which is from the suppliers' suppliers to ultimate customer, the measure could still be addressed as the supply chain efficiency within the internal organization context. This study will develop a tool to measure internal supply chain efficiency by using Data Envelopment Analysis (DEA).

DEA is a nonparametric method based on linear programming technique to evaluate the efficiencies of the analyzed units. DEA can measure multiple inputs and outputs, as well as evaluate the measures quantitatively and qualitatively, hence enabling managers to make reasonable judgment on the efficiency of the analyzed units. In this paper, we propose a DEA model to evaluate the supply chain efficiency in different companies. This model helps management identify the inefficient operations and provide remedies on how to improve its supply chain efficiency. In general, the paper is organized as follows. Firstly, we give a brief description on some of the traditional ways of measuring supply chain performance and problems associated with them, followed by a review on DEA and its application in supply chain. Then, we explain the methodology and DEA models developed to measure supply chain efficiency.

2. LITERATURE REVIEW

The traditional supply chain was normally driven by manufacturers who managed and controlled the pace at which products were developed, manufactured and distributed (Stewart, 1997). Generally, the efficiency is measured by taking the ratio of revenue over the total supply chain operational costs. However, in recent years, new trends have emerged in the efficiency measurement, where, customers have increasing demands on manufacturers for quick order fulfillment and fast delivery. This has made the supply chain efficiency difficult to be measured (Stewart, 1997). In addition to the usual financial measures, the supply chain performance needs to take into consideration other specific indicators such as the delivery rate and percentage of order fulfillment. This measurement is further complicated by the influence of manufacturing capacity and other influential operational constraints. In view of the increasing performance measures in supply chain, not many companies will know how to gauge the performance of their supply chain.

The rise of multiple performance measures has rendered the efficiency measurement task difficult and unchallenging. Hence, a tool to effectively measure the supply chain efficiency is greatly needed. Yee and Tan (2004), Rao (2005) further supported that in view of the current level of complexity to address the performance measurement problem. Traditional measures have certain disadvantages that will not be optimum while measuring supply chain efficiency, Hence a robust method is required to measure the efficiency. The "spider" or "radar" diagram and the "Z" chart are some of the popular tools used to measure supply chain efficiency. These tools are based on gap analysis techniques and they are very graphical in nature. It is not feasible to measure the efficiency using these tools when there are multiple inputs or outputs. However, a problem with comparison via ratios is that when there are multiple inputs and outputs to be considered, many different ratios would be obtained and it is difficult to combine the entire set of ratios into a single judgment. The evaluation of supply chain efficiency needs to look into multidimensional construct.

Mentzer et. al. (2001) developed criteria to assist with understanding the supply chain. It helps classify the concept and interpret the phenomenon. They suggest three levels of supply chain consideration including basic supply chain, extended supply chain and the ultimate supply chain. Mentzer et al. (2001) and Bowersox et al. (2002) suggest about the requirement of coordination between the parties. Supply management refers to a broder concept than purchasing, procurement and logistics that are functionally oriented and more specifically defined (Harland, et al., 2006). Chen and Paulraj (2004) suggest that environment is the external factor for the development of supply chain management. In the uncertain surrounding supply chain can be attributed to three sources like supply uncertainty, demand uncertainty and technology uncertainty.

There is an opportunity to explore the relationship between the environment and logistics and that environmental supply chain performance measurement (SCPM) should enable organizations to more effectively benchmark their supply chain environmental performance. A framework incorporating these notions and a research agenda for empirical study are also presented (Sarah, et al.,2010).

In today's world, supply chain management (SCM) is a key strategic factor for increasing organizational effectiveness and for better realization of organizational goals such as enhanced competitiveness, better customer care and increased profitability. The era of both globalization of markets and outsourcing has begun, and many companies select supply chain and logistics to manage their operations. Most of these companies realize that, in order to evolve an efficient and effective supply chain, SCM needs to be assessed for its performance. Based on a literature survey, an attempt has been made in this paper to develop a framework for measuring the strategic, tactical and operational level performance in a supply chain. In addition, a list of key performance metrics is presented. The emphasis is on performance measures dealing with suppliers, delivery performance, customer-service, and inventory and logistics costs in a SCM. In developing the metrics, an effort has been made to align and relate them to customer satisfaction.(Gunasekaran, et al., 2001)

The results of the evaluation are important for fine-tuning of an organization's current operations and creating new strategies. The single output to input financial ratios such as Return on Sales and Return on Investment may not be adequate for use as indices to characterize the overall supply chain efficiency. Hence, the traditional tools discussed earlier, which do not take into account multiple constructs, would not be able to provide a good measure of supply chain efficiency. Since, a company's supply chain efficiency is a complex phenomenon requiring more than a single criterion to be characterized.

Internal integration is the degree to which firms are able to integrate and collaborate across functional boundaries to provide better customer service (Kahn and Mentzer, 1996).Min and Mentzer (2000) exclusively studied the role of the marketing in effective supply chain management, marketing concept, marketing orientation, relationship marketing and its impact on supply chain implementation. They hypothesized that marketing function promote individual firms' coordinated activities inside and outside the firm to achieve customer satisfaction. Effective supply chain management requires partners to build and maintain close long term relationship. Ellram and Cooper (1990) asserted that a successful business rely on farming strategic partnership a long lasting inter firm relationship with trading partner. Better relationship helps in inventory and cost reduction and joint planning to impart agility and success to the supply as a whole. Marketing plays an important role in implementation and success of supply chain at strategic and tactical level. It provides valuable market information and success of supply chain at strategic and tactical level. It provides valuable market information about customers, competitors, potential channel partners, and emerging business avenues and information is the key in managing supply chain agent. As the origin of supply chain management is not specific, but its development starts along the line of physical distribution and transport (Croom et al. 2000). Both approaches emphasizes on focusing the single element in the chain that cannot assure the effectiveness of whole system (Croom et al. 2000). Supply chain management is originally introduced by consultants in 1980s and has gained tremendous attention (La Londe, 1998). A typical supply chain is generally a network of materials, information and services that linked with the characteristics of supply, transformation and demand. The term SCM has not only used to explain the logistic activities and the planning and control of materials and information flow but also used to describe strategic inter-organizational issues (Harland et al., 1999; Thorelli, 1986). Many a subject area such as purchasing and supply, logistics and transportation, marketing, organizational behaviour, network management, strategic management, management information system and operation management has contributed to the explosion of SCM literature. In this paper we examine and consolidate over various articles. This study may be the most comprehensive analysis of the multidisciplinary, wide ranging research on SCM. Supplier selection is complex problem due to number of criteria and their interdependence. In general the supplier selection problem in supply chain system is a group decision making under multiple criteria (Chen et al., 2006). The group decision making process involves human judgment; crisp data are not adequate to model these judgments as it involves human preferences. The more pragmatic approach is to use linguistic values for assessment. So the ratings and weights of the criteria in the problem are assessed by means of linguistic variables (Bellman and Zadeh, 1970; Herrara et al., 1996; Herrara , 2000).

Supply Chain Management (SCM) is a concept that integrates all parties over the value chain into one whole system and manages them as the assets of an extended enterprise (Simchi-Levi et al., 2000). It involves the removal of barriers between trading partners to facilitate the synchronization of information. It involves not only logistics activities like inventory management, transportation, warehousing and order processing but also other business processes like customer relationship management, demand management, order fulfillment, procurement, and product development and commercialization etc. SCM adopts a systematic and integrative approach to manage the operations and relationships among the different parties in supply chains. It is aimed at building trust, exchanging information on market needs, developing new products, and reducing the supplier base to release management resources for developing long term, mutual benefited relationships. The high quality of products and services from each level of the supplier network is an essential part of successful SCM (Choi and Rungtusanatham, 1999). An improved SCM process leads to cost reductions, optimum resource utilization and improved process efficiency (Beamon and Ware, 1998). Foker et al. (1997) demonstrate that Total Quality Management (TQM) can influence the quality performance in the supply chain. Wong & Fung (1999) present an indepth case study of the TQM system of Construction Company in Hong Kong. They examined the strategy, structure, and tasks for managing the supplier-subcontractor relationships that form an integral part of TQM system. Matthews et al. (2000) showed that the concepts of quality management systems and partnering could be effectively incorporated into the construction supply chain. This is because the closer working relationships and the increased technology transfers provide organizations with the opportunity to obtain expert skills from their partners with limited resources. Houshmand and Rakotobe (2001) developed an integrated supply chain structural analysis method to identify the priorities for a blood processing centre operations improvement. In this model, all channel members appeared to be in cohesion with their next line in the process. Romano and Vinelli (2001) discussed how quality can be managed in supply chain. Their case study indicated that the whorl supply network could improve its ability to meet the expectations in quality of the final customer through the joint definition and co-management of quality practices and procedures.

A number of studies have suggested that a multi-factor performance measurement model may be applied for the evaluation of supply chain efficiency (Zhu, 2000). A comparison analysis of DEA as a discrete alternate MCDM (Multi Criteria Decision Making) tool has been suggested by Sarkis (2001) and Seydel (2006). Past literature has shown that DEA has been widely applied in measuring efficiency particularly in external benchmarking issues. DEA has been utilized for selection of partners for benchmarking in telecommunications industry (Collier and Storbeck, 1993) and in travel management (Bell and Morey, 1995). Collier and Storbeck (1993) used standard DEA approach, which calculate "technical" efficiencies for determining benchmarking partners. Bell and Morey (1995) used DEA to identify appropriate benchmarking partners that use a different mix of resources that are more cost effective as compared to that used by the firm. Other areas on external benchmarking using DEA are the Banking and Finance Industry and Grocery Industry. DEA has also been applied in addressing internal benchmarking issues (Schefcyzk, 1993; Sherman and Ladino, 1995; Sarkis and Talluri, 1999; Humphreys et al., 2005).In addition, Rickards (2003) also showed the importance of using DEA in evaluating balanced scorecards and the dependency on this tool is increasing in order to maintain its position as a strategic management tool. Although DEA models have been vastly applied in various applications based on the past literature, no study investigating their applicability in supply chain performance measurement has so far been reported. It is, therefore, worthwhile to extend the traditional DEA models into the supply chain management.

This study aims to develop a DEA model to measure internal supply chain efficiency and present a case study of supply chain performance measurement using the proposed DEA approach. Wong and Wong (2007) explained the motivation of using DEA as a supply chain performance measurement tool, by giving ample evidences, literature supports and reasons on the suitability of DEA as a decision-making tool in supply chain management.

2.1. UNDERSTANDING EFFICIENCY

The efficiency can be defined as the ratio of output to the input i.e.

$$Efficiency = \frac{Output}{Input} \tag{4.1}$$

The efficiency evaluation of a unit in presence of multiple inputs and outputs becomes difficult using the above model. The problem becomes more difficult if there is complex relationship between the inputs and outputs and unknown tradeoff between them. In real life problem such situations are common. The efficiency score in presence of multiple input and output can be calculated using the "weighted cost approach" given by

$$Efficiency = \frac{weighted\ sum\ of\ \ outputs}{weighted\ sum\ of\ \ inputs} \qquad (4.2)$$

The problem with this is that it assumes that all the weights are uniform. Mathematically equation (3.2) can be expressed as

$$Efficiency = \frac{\sum_{r=1}^{n} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \qquad (4.3)$$

$Where;$ $y_r = quantity\ of\ \ output\ r;$

$u_r = weight\ attached\ to\ \ output\ \ r;$

$x_i = quantity\ of\ \ input\ i;$

$v_i = weight\ attached\ to\ \ input\ \ i;$

A value equal to unity implies complete efficiency. The weights are specific to each unit so that: 0 <Efficiency ≤ 1.

2.2. TECHNICAL EFFICIENCY USING THE PRODUCTION FUNCTION

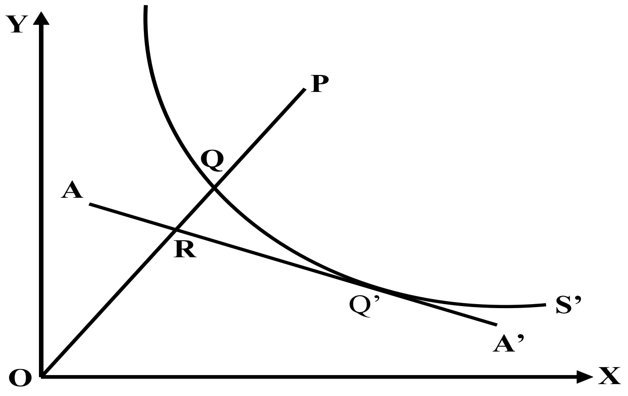
Farrell1(1957) introduced a new measure of (technical) efficiency, which employs the concept of the efficient production function. This method of measuring technical efficiency of a firm consists in comparing it with a hypothetical perfectly efficient firm represented by the production function. The efficient production function is some postulated standard of perfect efficiency and is defined as the output that a perfectly efficient firm could obtain from any given combination of inputs.

The first step in calculating the technical efficiency by this method is determining the efficient production function. There are two ways in which the production function can be determined. It could either be a theoretical function or an empirical one. The problem with using a theoretical function is that it is very difficult to define a realistic theoretical function for a complex process. The empirical efficient production function, on the other hand, is estimated from observations of inputs and outputs of a number of firms. Therefore, it is easier to compare performances with the best actually achieved (the empirical production function) than to compare with some unattainable ideal (the theoretical function).

To understand the concept of an efficient production function, we take the example of a set of firms employing two factors of production (inputs) to produce a single product (output) under conditions of constant returns to scale (Kabnurkar, 2001; Forsund et.al., 2000*).* Constant returns to scale mean that increase in the inputs by a certain proportion results in a proportional increase in the output. An isoquant diagram is the one in which all firms producing the same output lie in the same plane. Each firm in an isoquant diagram is represented by a point so that a set of firms yields a scatter of points. An efficient production function is a curve, which joins all the firms in an isoquant diagram utilizing the inputs most efficiently.

While drawing the isoquant from the scatter plot, two more assumptions, in addition to constant returns to scale are made. Firstly, the isoquant is convex to the origin. This means that if two points are attainable in practice then so is their convex combination. Secondly, the slope of the isoquant is nowhere positive which ensures that an increase in both inputs does not result in a decrease in the output.

Figure – 1: Representation of the Production Function (Isoquant) SS′



In Figure 1, isoquant SS′ represents a production function. Point P represents an inefficient firm, which uses the two inputs per unit of output in a certain proportion. Point Q represents an efficient firm, which produces the same output as P, uses the two inputs in the same proportion as P but uses only a fraction OQ/OP as much of each input. Point Q could also be thought of as producing OP/OQ times as much output from the same inputs.

Therefore, the ratio OQ/OP is defined as the technical efficiencyof firm P. This measure of efficiency ignores the information about the prices of the factors. To incorporate the price information, use is made of the other type of efficiency measure called price (or allocative) efficiency. Price efficiency is a measure of the extent to which a firm uses the various factors of production in the best proportions, in view of their prices.

In Figure 1, if AA′ has a slope equal to the ratio of the prices of the two input factors, then Q′ and not Q is an optimal method of production. Although both Q and Q′ represent 100 percent technical efficiency, the costs of production at Q′ will only be a fraction OR/OQ of those at Q. Therefore, the ratio OR/OQ is called the price efficiencyof both firms P and Q. The product of technical efficiency and price efficiency is called overall efficiency. In Figure 1, the ratio OR/OP represents the overall efficiency of firm P. We see that an important feature of Farrell's (Farrell, 1957) method outlined above is the distinction between price and technical efficiency. While the price efficiency measures a firm's success in choosing an optimal set of inputs, which minimize the cost of production, the technical efficiency measures its success in producing maximum output from a given set of inputs.

2.3. THE CCR MODEL

This model is an extension of the ratio technique used in traditional efficiency measurement approaches. The measure of efficiency of any DMU (Decision Making Unit) is obtained as the maximum of a ratio of weighted output to weighted input subject to the condition that similar ratios for every DMU be less than or equal to unity.

To develop the DEA model mathematically, we define the following notations.

Notations

To develop the DEA model, we use the following parameters and variables:

n = Number of DMU $\{j = 1,2,..., n\}$

s = Number of outputs $\{r = 1,2,..., s\}$

m = Number of inputs $\{i = 1,2,..., m\}$

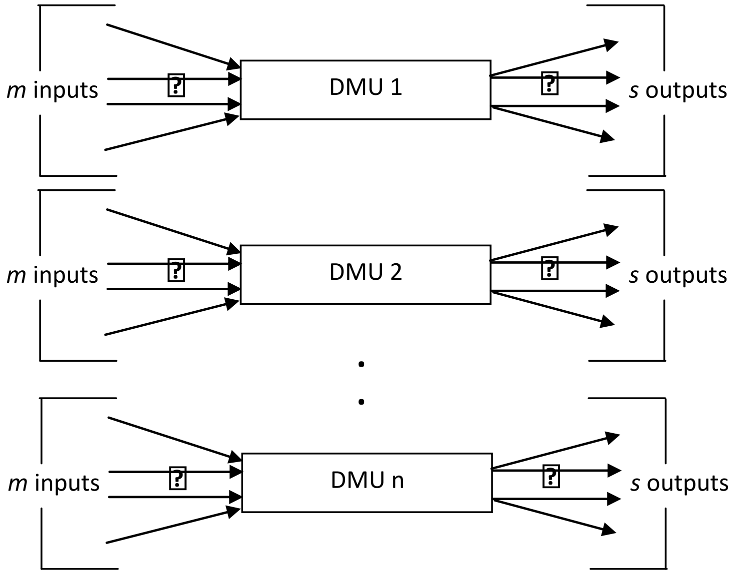
y_{rj} = Quantity of r^{th} output of j^{th} DMU

x_{ij} = Quantity of i^{th} input of j^{th} DMU

u_r = weight of r^{th} output

v_i = weight of i^{th} input

Figure 2: DMU and Homogeneous Units



2.4. DATA ENVELOPMENT ANALYSIS MODEL

The relative efficiency score of j_0 DMU is given by

Maximize the efficiency of unit j_0 , Subject to the efficiency (output / input) of all units being ≤ 1.

Or, output - input ≤ 0 Algebraically the model can be written as

$$\max h_{j_0}(u,v) = \frac{\sum_{r=1}^{s} u_r y_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij_0}}$$

$$subject \quad to \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j = 1,2,\ldots,n$$

$$u_r, v_i \geq 0 \ \forall \ r, i$$

The variables of the above problem are the weights and the solution produces the weights most favourable to unit j_0 and also produces a measure of efficiency. The decision variables and $u = (u_1, u_2, \ldots, u_r, \ldots, u_s)$ are respectively the weights given to $v = (v_1, v_2, \ldots, v_i, \ldots, v_m)$ the s outputs and to the m inputs. The numerator of the objective function in (3.4) is the weighted sum of the output and the denominator is the weighted sum of input for j_0 DMU respectively. In the constraint part we write the difference of weighted sum of output and weighted sum of input one by one for all the n DMUs. To obtain the relative efficiencies of all the units, the model is solved n times, for one unit at a time. The fractional program (4.4) can be reduced to Linear Programming Problem (LPP) as follows:

$$\max h_{j_0} = \sum_{r=1}^{s} u_r y_{rj_0}$$

$$subject \quad to \quad \sum_{i=1}^{m} v_i x_{ij_0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \qquad j = 1,2,\ldots,n$$

$$u_r, v_i \geq 0 \ \forall \ r, i \qquad (4.5)$$

This model is called CCR output maximization DEA model.

2.5. *THE BCC MODEL*

The CRS assumption is only appropriate when all the DMUs are operating at an optimal scale. Imperfect competition, constraints on finance etc. may cause a DMU to be not operating at optimal scale. Banker, Charnes and Cooper (1984) suggested an extension of the CRS DEA model to account of Variable Return to Scale (VRS) situations. The use of the CRS specification when not all DMUs are operating at optimal scale will result in measure of Technical Efficiency (TE), which is confounded by scale efficiencies (SE). The use of VRS specifications will permit the calculation of TE devoid of these SE effects . The primary difference between this model and the CCR model is the treatment of returns to scale. The CCR version bases the evaluation on constant returns to scale. The BCC version is more flexible and allows variable returns to scale. The model can be shown as below.

$$\min \theta$$

$$Subject \quad to \quad \sum_{i=1}^{n} \lambda_i x_j - \theta x_{j_0} \leq 0 \quad \forall \ j$$

$$\sum_{i=1}^{n} \lambda_i y_j - y_{j_0} \quad \geq 0 \quad \forall \ k$$

$$\lambda_i \geq 0 \qquad \forall i$$

$$\sum \lambda_i = 1$$

$$where \qquad \theta = Efficiency \quad Score$$

$$\lambda_s = Dual \quad Variable \qquad (4.14)$$

The difference between the CCR model (model 4.13) and the BCC model (model 3.14) the λ_j's are now restricted to summing to one. This has the effect of removing the constraint in the CCR model that DMUs must be scale efficient. Consequently, the BCC model allows variable returns to scale and measures only technical efficiency for each DMU. That is, for a DMU to be considered as CCR efficient, it must be both scale and technical efficient. For a DMU to be considered BCC efficient, it only need be technically efficient.

3. A CASE ON PHARMACEUTICAL INDUSTRY

The pharmaceutical Industry in India has been going through a major shift in its business model to get ready for the product patent regime from 2005 onwards, in order to comply with the Trade Related Intellectual Property Rights Agreement (TRIPS). The belief that stronger patent laws would protect an innovator's interests in turn encouraging more innovation. To optimize the sales from limited patent periods and recover R&D investments expended to innovate and develop products, firms in advanced countries need strategic sourcing alliances, which enables rapid introduction and quick and effective marketing of products. Bulk drugs and intermediates make up 40%, a fairly high share of pharmaceutical trade, but the ratio of imported to domestic sourcing is still lower than many industries in the developed countries, leaving significant cost savings (Tarabusi and Vickery, 1998). For example the cost of setting up a plant in India is 40% lower and the cost of producing a bulk drug is 60% lesser than that of developed countries (www.ciionline.org).

The long established processing capabilities of the Indian Pharmaceutical Sector, low cost of manpower and protection for their patented products through strong Intellectual Property Protection laws make it an attractive destination for developed countries to outsource their production which until recently did not venture into outsourcing to India due to reverse engineering practices of Indian firms.

The reservation of certain bulk drugs to small-scale units by the Indian government during the past 40 years ensured the establishment of thriving drug industry dominated by many small scale units with low capital budget, focused on the production of bulk drugs, which later forayed into formulation of business as well. The Indian Pharmaceutical Industry is the fourth largest pharmaceutical producer in the world, after US, Japan and Germany. Most of the drugs produced in India until recently were either off patented generics or reverse-engineered patented drugs, which were allowed to be produced in India as long as a different process is used. The change of patent regime that was implemented in a phased manner from 1995 onwards from process patenting to product patenting forced some of the larger and mid-size drug companies to invest in the R&D of new drug development. Most of them also began exploring contract manufacturing possibilities of patented and off-patented drugs. The impact of globalization coupled with the increasing costs of production and R&D expenditure are driving the global drug majors to outsource their R&D and production requirements to lower cost destinations like India. Trade liberalization of 1991, which relaxed various licensing requirements, import, export tariffs, restrictions on FDI, etc. in the Indian Pharmaceutical Industries, opened up various avenues for joint ventures, R&D collaborations and contract manufacturing opportunities between the domestic companies as well as multinationals. Overseas generic players are exploring India for collaborations with domestic firms and setting up low-cost manufacturing facilities, which will mainly act as sourcing centers and their international operations. Some of the leading multinational firms such as Eli Lilly, Merck, Bristol, Myers Squib, Cynamid, Baxter International and BYK Gulden have already signed manufacturing contracts with Indian firms, while other global pharmaceutical major like Pfizer and Glaxo Smith Kline (GSK) and conducting clinical trial.

Here we have taken the data of 29 Indian industries manufacturing drugs and medicines as mentioned in Table 1 (indiastat.com as well as annual reports of companies). We have taken eight inputs like Internal Manufacturing capacity, Supply chain cost, working capital, invested capital, number of employees, wages to workers, material consumed and fuels consumed. Similarly two outputs like net value added and net income has taken for analysis.

3.1. EXPLANATION OF INPUTS AND OUTPUTS:

Each year is considered as a Decision Making Unit (DMU).The data used here is from the year 1974-75 to 2004-05). The general output maximization CCR-DEA (Charnes, Cooper and Rhodes-Data Envelopment Analysis) model is used to solve the problem to get the efficiency score. We have used the DEA solver pro 5.0 version to solve the model. The result of DEA analysis is displayed in Table 2. Other measures are listed in the Table 13 in the Appendix A.

Table 2 shows the descriptive statistics for the sample used. The maximum, minimum, mean, median, standard deviation and range of the data are calculated. The mean of NF is 2120. The Maximum Working capital is 600909 lakhs, as the business of the company expands the working capital increases. The mean of wages to worker is 20668.65 lakhs. The maximum is 140109 lakhs and the minimum is 1536 lakhs. It is due to the size of the firm. It depends upon the span of operation of pharmaceutical company. They are small players and also large players; hence they have variation in manpower as per their operation. The Table 3 indicates that there is a high degree of significant positive correlation between IMC and NI, FuC, IC. Similarly there is high degree correlation between SC and IC, NE, FuC, NVA and NI. It is observed that all factors have significant positive correlation between them. The degree of correlation is less between WW and MC, NVA. It is .551 and .563.

UNDERSTANDING SLACKS

Suppose the DMU A is the most efficient, we can set Performance Targets for the inefficient firms to enable them to reach 100 % relative efficiency. Since the DMU A has operated under similar environment and hence using its performance as benchmark is realistic. We are not assigning unrealistic targets.

Input Target: The input target for an inefficient unit say DMU B is the amount of input which shall be used by the inefficient DMU to produce the same level of output so as to make the DMU efficient one.

$$\text{Input Target} = \text{Actual Input} * \text{Efficiency}$$

Input Slack: For inefficient firms, Input target will be smaller than actual input. The difference between actual input and input target is usually called the Input Slack.

Input Slack for an inefficient DMU = Actual Input – Input Target

Input Slack can also be expressed in percentage.

$$\text{Input Target} = \frac{\text{Input Slack}}{\text{Actual Input}} * 100$$

Using a similar logic, we can compute *Output Targets* and *Output Slacks*.

$$\text{Output Target} = \frac{\text{Actual Output}}{\text{Efficiency}}$$

$$\text{Output Slack} = \text{Output Target} - \text{Actual Output}$$

$$\text{Output Target Percentage} = \frac{\text{Output Slack}}{\text{Actual Output}} * 100$$

ANALYSIS AND INTERPRETATION

The input target and the output target of all the 29 DMUs are calculated and shown in Table 5 and Table 6 respectively. It is observed from Table 5, the target of inputs like IMC, SC, WC, IC, NE, WW, FuC, MC are 574.55, 12462.71, 14483.75, 30154.1, 56170.21, 3046, 1819, and 26658.6 respectively. Similarly for other DMUs are also calculated. Table 6 shows the targets of outputs, i.e. NVA and NI as 15925.96 and 13484.56 respectively. Similarly for other DMUs are calculated.

Table 4 represents efficiency and weights of DMUs. Out of 29 DMUs 11 DMUs are relatively efficient and rest are inefficient. The DMU-1, DMU-5, DMU-11, DMU-12, DMU-25 are having efficiency more than 0.9. The efficiency of DMU-6, DMU-8, and DMU-24 are having efficiency more than 0.8. DMU-7, DMU-10, DMU-16, DMU-17, DMU-18, DMU-19 are having more than 0.7. The mean efficiency score is 0.869. The weights of inputs and outputs of each DMU are also given in Table 4. The summary of input and output targets has been shown in Table 5 and Table 6.

Table 7 represents efficiency and weights of DMUs. Out of 29 DMUs 16 DMUs are relatively efficient and rest are inefficient. The DMU-5, DMU-11, DMU-16, are having efficiency more than 0.9. The efficiency of DMU-6, DMU-8, and DMU-17 are having efficiency more than 0.8. DMU-7, DMU-10, DMU-15, DMU-18, DMU-19 are having more than 0.7. The mean efficiency score is 0.914. The weights of inputs and outputs of each DMU are given below.

A regression based approach is employed here to study the effect on the DEA scores of that factor which are beyond managerial control but are likely to affect the performance of Decision Making Units (DMU). Internal Manufacturing capacity, Supply chain cost, number of employees, wages to workers, fuel consumed, materials consumed and net value added have the negative values, which signifies that the efficiency score would decrease if these above mentioned variables will increase. Similarly working capital, invested capital and net income has positive values which indicate the increase in efficiency for the increase in invested capital, working capital and net income.

The scale efficiency is the ratio of technical efficiency of CRS model to the technical efficiency of VRS model. The average technical efficiency of DMUs calculated using output oriented CRS model is 0.868The average technical efficiency of DMUs calculated using output oriented VRS model is 0.914. Next the correlation coefficient is calculated among all the rankings. The correlation coefficient between the two DEA rankings using CRS and VRS model is 0.799. All these correlations are statistically significant.

To test the difference between the ranks obtained through various models, we use “Paired-Sample t test”.

The hypotheses set being:

$$H_0 : Efficiency\ score\ of\ \ DEA-CRS = Efficiency\ \ score\ of\ \ DEA-VRS$$

$$H_1 : Efficiency\ score\ of\ \ DEA-CRS \neq Efficiency\ score\ of\ \ DEA-VRS$$

The results of paired sample t test are as follows:

Pair 1: CRS-VRS	t	Sig. (two tailed)
	-1	0.012

When paired sample t test is applied to the efficiency score obtained by DEA-CRS and DEA-VRS model. We obtain a p value of 0.012 which is very low. This means we reject the null hypothesis (Type-I error). This allows us to accept the alternative hypothesis, that there is significant difference between the ranks assigned by DEA-CRS and DEA-VRS model.

CONCLUSION

In this study supply chain efficiency is measured by the application of Data Envelopment Analysis. DEA solver pro 5.0 is used for the calculation. The technical efficiency score has been calculated by Constant Return to Scale (CRS) assumption as well as Variable Return to Scale (VRS) assumption. The average technical efficiency score obtained through CRS model is 0.868, indicating scope for lots of improvement for the Pharmaceutical companies through collaboration, strategic alliance with other companies or they have to develop in line with their core competency. The average efficiency score obtained through VRS model is found to be comparatively higher with the average score being 0.914. The result of Sensitivity Analysis shows that when dropping the input X1 (IMC) and X2 (SC) one by one, there is no significant change in technical efficiency score of DMUs. The efficient units remain efficient. The deviation in efficiency score observed when the output Net Income is dropped from the analysis. DMU_{11}, $DMU_{12,}$ DMU_{14} is becoming inefficient when Net Income is not considered. Hence Net Income is an important output for the company. Sensitivity analysis gives the robustness of the model. The sensitivity of DEA model can be verified by checking whether the efficiency of DMU is affected appreciably if only one input or output is omitted from DEA analysis or dropping one efficient DMU at a time from DEA analysis. For our study the robustness test of the DEA results obtained is done is two ways. Initially the input “IMC” is dropped from the analysis and technical efficiency of DMUs is calculated. Then input MC is dropped and similarly the output NI is dropped and technical efficiency of DMUs will be calculated. The supply chain efficiency measurement will help the company to address different related issues where the company is facing problem and it helps for improvement. This study is useful for continuous performance improvement for a company to understand in each point of time so that they can be stand as a competitive firm in near future. Here only eight inputs and two outputs have been taken. More inputs can also be taken to make the study more exhaustive. Future research can also possible by taking customer satisfaction, the delivery efficiency as outputs.

REFERENCES

Beamon, B.M. and Ware, T.M. (1998), “A process quality model for the analysis, improvement and control of supply chain systems”, International Journal of Physical Distribution and Logistics Management, Vol.28, No.9/10, pp.704-715.

Bellman, B.E and Zadeh, L.A. (1970), “Decision-making in a fuzzy environment”, Management Science, Vol.17, No.4, pp.141-164

Chen, C.T., Lin, Ching-Tong and Huang, Sue-Fn. (2006), “A fuzzy approach for supplier evaluation and selection in supply chain management”, International Journal of Production Economics, Vol.102, No.6, pp.141-164.

Chen, I. J., & Paulraj, A. (2004). “Towards a theory of supply chain management: the constructs and measurements”, Journal of Operations Management, Vol.22, pp 119-126.

Choi, T.Y. and Rungtusanatham, M. (1999), “Comparison of quality management practices: across the supply chain and industries”, The Journal of Supply Chain Management, Vol. 35, No.1, pp. 20 – 27.

Collier, D. and Storbeck, J. (1993), “A data envelopment approach to benchmarking in the telecommunications industry”, Technical report, Ohio State Faculty of Management Sciences, Ohio University, Columbus.

Croom, S.R., Romano, P. and Giannakis, M. (2000), “Supply Chain Management: An analytical framework for critical literature review”, European Journal of Purchasing and Supply Management, Vol.6, No.1, pp.67-83.

Ellram, L.M. and Cooper, M.C. (1990) “Supply Chain Management, partnership and the supplier, third party relationship”, International Journal of Physical Distribution & Logistics Management, Vol.21, No.1, pp.13-22.

Farrell, M.J. (1957), “The measurement of productive efficiency”, Journal of Royal Statistical Society, Vol.120, No.3, pp.254 - 290.

Foker, L.B., Mendez, D. andHershauer, J.C. (1997), “Total Quality Management in Supply Chain: what is its impact on performance?”,International Journal of Production Research, Vol.35, No.6, pp.1681-1701.

Forsund, F.R., Lovell, C.A.K. and Schmidt, P. (1980), “A Survey of Frontier Production Functions and of their relationship to Efficiency Measurement, Journal of Econometrics, Vol.13, No.1, pp.5–25.

Gunasekaran, A, Patel, C, Tirtiroglu, E. (2001) “Performance measures and metrics in a supply chain environment”, International Journal of Operations & Production Management, Vol. 21, pp.71 - 87

Harland, C. M., Lamming, R. C. and Cousins, P. D. (1999), “Developing the concept of supply strategy”, International Journal of Operations and Production Management, Vol. 19, No.7, pp.650-673.

Harland, C.M., R.C. Lamming, H. W., Phillips, W.E., Caldwell, N.D., Johnsen, T.E., Knight, L.A., & Zheng, J. (2006). Supply management: is it a discipline? International Journal of Operations & Production Management, Vol.26, pp.730-753

Herrera, F. and Herrera-Viedma, E. (2000), “Linguistic decision analysis: Steps for solving decision problems under linguistic information”, Fuzzy Sets and Systems, Vol.115, No.1, pp. 67–82.

Herrera, F., Herrera-Viedma, E. and Verdegay, J.L. (1996), “A model of consensus in group decision making under linguistic assessments”, Fuzzy Sets and Systems, Vol.78, No.1, pp. 73–87.

Houshmand, A. and Rakotobe-Joel, T. (2001), “Integrating the Supply Chain Management and continuous quality improvement approaches by use of the integrated supply chain structural analysis method”, Quality Engineering, Vol. 13, No.1, pp.201-213.

Humphreys, P., Huang, G. and Cadden, T. (2005), “A web-based supplier evaluation tool for the product development process”, Industrial management and data systems, Vol.105, No.2, pp.147–163.

Kabnurkar, A. (2001), “Mathematical modeling for Data Envelopment Analysis with fuzzy restrictions on weights”, Master’s Thesis.Virginia Polytechnic Institute and StateUniversity, Department of Industrial and Systems Engineering, Blacksburg, Virginia.

Khan, K.B.and Mentzer, J.T. (1996), “Logistics and interdepartmental integration, International Journal of Physical Distribution and logistics Management”, Vol. 26, No.8, pp.6-14.

La Londe, B.J. (1998). “Supply chain evolution by the numbers”, Supply Chain Management Review, Vol.2, No.1, pp.7-8.

Matthews, J., Pellew, L., Phua, F., and Rowlinson, S. (2000). “Quality relationships: partnering in the construction supply chain”. International Journal of Quality and Reliability Management, Vol. 17, No.4/5, pp.493-510.

Mentzer, J.T., Dewitt, W., Keebler, J.S., Min, S., Nix, N.W., Smith, C.D. andZacharia, Z.G. (2001). “Defining supply chain management, Journal of Business Logistics”, Vol. 22, No.2, pp. 1–25.

Min, S. and Mentzer, J. (2000), “The role of marketing in supply chain management”, International Journal of Physical Distribution and Logistics Management”, Vol.30, No.9, pp.766-787.

Rao, P. and Holt, D. (2005), “Do green supply chains lead to competitiveness and economic performance? International Journal of Production Management, Vol. 25,No.9, pp. 898-916.

Rickard, J. (2003), “A logistician’s plea”, Forced Migration Review, Vol.18,No.9, p.9.

Romano, P. and Vinelli, A. (2001), “Quality management in a supply chain perspective: strategic and operative choices in a textile apparel network”. International Journal of Operations and Production Management, Vol.21, No.4, pp.446-460.

Ross, D.F. (1998), “Competing Through Supply Chain Management: Creating Market-Winning Strategies through Supply Chain Partnership”, New York, Chapman and Hall.

Sarah Shaw, David B. Grant, John Mangan, (2010) “Developing environmental supply chain performance measures”, Benchmarking: An International Journal, Vol. 17 Iss: 3, pp.320 – 339

Sarkis, J. (2000). “A strategic decision framework for green supply chain management”, Journal of Clean Production, Vol.11, No.4, pp.397-409.

Sarkis, J. and Talluri, S. (1999), “A decision model for evaluation of flexible manufacturing systems in the presence of both cardinal and ordinal factors”, International Journal of Production Research, Vol.37, No.13, pp.2927- 2938.

Schefczyk, M. (1993), “Operational performance of airlines: an extension of traditional measurement paradigms”, Strategic Management Journal, Vol.14, No.4, pp.301-317.

Seydel, J. (2006) “Data envelopment analysis for decision support”, Industrial Management and Data Systems, Vol.106, No.1, pp.81-95.

Sherman, H. D. and Ladino, G. (1995), “Managing bank productivity using Data Envelopment Analysis,” Interfaces, Vol. 25, No.2, pp.60-73.

Simchi-Levi, D., Kaminsky, P. and Simchi-Levie, E. (2000),“Designing and managing the supply chain- concepts, strategies and case studies”, McGraw Hill, New Delhi.

Stewart, G. (1997) “Supply-chain operations reference model (SCOR): the first cross industry framework for integrated supply-chain management”, Logistics Information System, Vol.10, No.2, pp.62-67.

Tarabusi, C.C. and Vickery, G. (1998), “Globalisation in the pharmaceutical Industry”, International Journal of Health Services, Vol.28, No.2, pp.281-303.

Thorelli, H. (1986), “Networks between markets and hierarchies", Strategic Management Journal, Vol.7, No.1, pp.37-51.

Wong, A and Fung, P. (1999) "Total quality management in the construction industry in Hong Kong: A supply chain management perspective," Total Quality Management, Vol.10, No.2, pp.199-208.

Wong, P.W. and Wong, K.Y. (2007), "Supply chain performance measurement system using DEA modeling" International Journal of Management and Data System, Vol.107, No.2, PP.361-381.

Yee, C.L. and Tan, K.H. (2004), "A process and tool for supply network analysis", IndustrialManagement and Data Systems, Vol.104, No.4, pp.355-363.

Zhu, J. (2000), "Multi-factor performance measure model with an application to fortune 500 companies", European Journal of Operation Research, Vol.123, No.1, pp. 105–124.

http://ciionline.org, accessed on 23rd December 2010.

APPENDIX A - Tables

Table 1: Classification of Inputs & Output

Inputs	Outputs
X1: Internal Manufacturing Capacity (IMC) X2: Supply chain cost (SC)[Rs. in lakhs] X3: Working Capital (WC) [Rs. in lakhs] X4: Invested Capital (IC) [Rs. in lakhs] X5: Number of Employees (NE) X6: Wages to Workers (WW) [Rs. in lakhs] X7: Materials Consumed (MC) [Rs. in lakhs] X8: Fuels Consumed (FC) [Rs. in lakhs]	Y1: Net Value Added due to supply chain (NVA) [Rs. in lakhs] Y2: Net Income (NI) [Rs. in lakhs]

Table 2: Descriptive Statistics on Inputs/Outputs Data

	IMC	SC	WC	IC	NE	WW	FuC	MC	NVA	NI
Mean	2119.8	278400	107534.7	391633.48	108433	20668.655	49821.069	290978.55	125406.9	70296
Median	1358	76576	54170	155980	103738	12778	10303	155209	61638	35883
SD	2315.62	623330	120560.5	755634.3	76723	33093.3	188648.1	350768	214860.9	156947.1
Max	12656	3303003	600909	4055974	472330	140109	1028465	1716212	1062762	868909
Min	587	591	14629	34049	25592	1536	777	4116	6600	598
Range	12069	3302412	586280	4021925	446738	138573	1027688	1712096	1056162	868381

Table 3: Correlation Matrix of Inputs and Outputs

	IMC	**SC**	**WC**	**IC**	**NE**	**WW**	**FuC**	**MC**	**NVA**	**NI**
IMC	1	0.921207	0.787309	0.921253	0.887695	0.77092	0.888619	0.775141	0.725297	0.912402
FC		1	0.884535	0.99939	0.870118	0.805016	0.947037	0.874631	0.82712	0.972032
WC			1	0.895916	0.648959	0.769899	0.800362	0.796981	0.914068	0.819574
IC				1	0.865491	0.808309	0.94639	0.87968	0.835407	0.97057
NE					1	0.718657	0.910248	0.633753	0.663831	0.927017
WW						1	0.695721	0.551026	0.563915	0.722913
FuC							1	0.811435	0.84279	0.985985
MC								1	0.732485	0.838002
NVA									1	0.836383
NI										1

Table 4: Efficiency and weight of inputs and outputs of each DMU (Output oriented DEA, Scale Assumption: CRS)

DMU	Eff.	W_{x1}	W_{x2}	W_{x3}	W_{x4}	W_{x5}	W_{x6}	W_{x7}	W_{x8}	W_{y1}	W_{y2}
1	0.985	0	0	0	0	0	1.37E-05	5.35E-04	0	0	7.45E-05
2	1	0	0	5.81E-05	0	0	0	0	0	0	4.02E-05
3	1	0	0	3.05E-05	0	0	0	1.33E-04	0	0	4.62E-05
4	1	2.55E-04	4.27E-05	0	0	0	0	0	0	0	4.18E-05
5	0.913	2.80E-04	0	0	0	0	0	1.89E-04	0	0	3.64E-05
6	0.808	0	0	2.21E-05	0	0	0	1.15E-04	0	1.03E-05	2.41E-05
7	0.720	0	0	1.91E-05	0	0	8.40E-05	0	0	0	2.28E-05
8	0.860	0	0	3.01E-05	0	0	0	0	0	1.39E-05	0
9	1	1.16E-04	0	0	0	0	6.64E-05	0	0	0	1.82E-05
10	0.776	0	0	0	0	0	0	0	0	0	2.09E-05
11	0.926	0	0	0	0	0	0	6.47E-05	0	0	1.90E-05
12	0.989	0	0	0	0	0	0	0	8.47E-05	0	7.42E-05
13	1	0	0	0	0	0	0	3.89E-04	0	0	5.68E-05
14	1	2.42E-04	0	0	0	0	0	0	0	0	0
15	0.498	0	0	4.90E-05	0	0	0	0	0	2.27E-05	1.33E-05
16	0.762	0	0	2.27E-05	0	0	0	0	0	1.07E-05	1.40E-05
17	0.716	0	0	1.74E-05	0	0	0	0	0	0	1.38E-05
18	0.728	0	0	0	0	0	4.48E-05	0	0	0	2.19E-05
19	0.729	0	0	0	0	0	3.65E-05	0	0	0	1.78E-05
20	0.601	0	0	0	0	0	3.98E-05	0	0	0	1.94E-05
21	0.692	0	0	0	0	0	2.65E-05	0	0	0	1.29E-05
22	1	0	0	0	0	0	2.45E-05	0	0	0	0
23	1	0	0	0	0	0	0	4.05E-05	0	0	1.53E-05
24	0.861	1.21E-03	0	0	0	0	0	0	0	0	1.64E-05
25	0.997	1.65E-03	0	0	0	0	0	0	0	0	1.60E-05
26	1	0	0	0	0	1.35E-05	0	2.69E-05	0	0	1.71E-05
27	0.630	1.32E-03	0	0	0	0	0	0	0	0	2.73E-05
28	1	1.61E-03	0	0	0	0	0	0	0	0	0
29	1	0	0	0	0	0	0	0	0	0	0
Mean	0.869	0.0002302	1.471E-06	8.584E-06	0	4.651E-07	1.16E-05	5.152E-05	2.919E-06	1.986E-06	2.346E-05

Note: Wxi represents the weight of inputs (i = 1,2,…) Wyi represents the weight of outputs (i = 1,2,..

Table 5: SAMPLE OF INPUT TARGETS (Output oriented DEA, Scale Assumption: CRS)

DMU	IMC	SC	WC	IC	NE	WW	FuC	MC
1	574.558	12462.71	14483.75	30154.1	56170.21	3046	1819	26658.6
2	800	14602	16654	36425	85559	7850	39386	49408
3	866	15791	19878	39528	85603	3798	2948	44231
4	918	17485	22865	45312	103468	4356	3286	52416
5	1070	22239.43	26609.9	54641.03	106115.7	5378.715	4197	61481.33
6	1067.35	26295.67	29905	63355.27	106343.2	6400.554	5023	71620.97
7	1090.01	35202	35426	79628.84	108417	7942	7007	87579.88
8	1017.94	38324	37016	87642.65	103056.9	9316.565	7537.757	100391.8
9	1187	44194	42639	101515	120396	10867	8619	117083
10	1251.39	50800.23	49325.51	117569	123394	12328.05	9716.904	136714.4
11	1222.21	53646.85	48542.43	119885	118468	12773.95	9522	134581.9
12	1157.68	56789.21	42691.28	120625.1	104229.6	14487.69	1535.074	11938
13	1497	73434	55204	155980	134779	18734	1985	15437
14	1554	87577	72869	201616	135384	20356	15752	246382
15	739.217	40348.55	39759	80794.02	69223.61	6689.736	9786	72500.79
16	892.811	55185.76	41301	102715.5	82698	8365.884	13740	91930.98
17	1059.30	89364.05	54170	151662.3	88553	10299	14516	131242.7
18	1258.14	138060	68260.52	217700.2	93741	12733	19338	178121.9
19	1570.77	235980	87765.25	330114.9	99731	13955	25807	231147.6
20	1717.35	271538	98790.33	378397.6	103738	15737	30374	263695.9
21	2253.94	414359	129978.6	552699.7	119302	19502	38881	366441.7
22	3855	982507	206070	1186858	132180	24320	51959	690302
23	4046	719461	255442	937341	134861	136618	9292	63597
24	587	127348.9	177104	233136	28870.15	9129.357	13925.68	279947.9
25	608	207064.5	149170.7	325860.7	33940.47	14676.82	17281.66	494567.6
26	640	228821	150160	354173	36194	16142	19060	546393
27	642	104675.2	89306	172801	38303.3	8314.409	22097	158057.2
28	621	591	285636	116035	25592	1536	777	4116
29	12656	3303003	600909	4055974	472330	140109	1028465	1716212
Mean	**1669.64**	**257487.9**	**101652.**	**360349.6**	**105194.5**	**19853.85**	**49435.6**	**222213.7**

**Table 6: Summary of Output Targets
(Output Oriented DEA, Scale Assumption: CRS)**

DMU	NVA	NI
1	15925.967	13484.56
2	18557	21653
3	24808	21653
4	27041	23753
5	34608.485	29582.64
6	41085.244	33768.17
7	51570.494	40455.06
8	55297.964	45524.87
9	63307	53079
10	73613.32	57400.9
11	69958.54	55832.55
12	8258.4636	13617.69
13	10679	17609
14	69011.961	33253.63
15	68177.461	41706.68
16	85985.206	50056.9
17	132741.86	75175.15
18	105353.15	61356.96
19	132741.86	75175.15
20	149147.18	83638.39
21	189253.78	109162.6
22	257688	176840
23	57905	65168
24	273739.42	30954.73
25	125881.21	49573.74
26	107364	54759
27	143906.42	35537.91
28	616915	598
29	1062762	868909

DATA ENVELOPMENT ANALYSIS WITH VARIABLE RETURN TO SCALE (VRS) ASSUMPTION

The third analysis is made with variable return to scale assumption, the efficiency of all the DMUs are calculated using output oriented model. The efficiency score of each DMU is calculated using output oriented model. The result is tabulated in Table 7. [Results from DEA solver LV (V5)]

Table 7: Efficiency and Weight of each DMU (Output oriented DEA: Scale Assumption: VRS)

DMU	Eff.	W_{x1}	W_{x2}	W_{x3}	W_{x4}	W_{x5}	W_{x6}	W_{x7}	W_{x8}	W_{y1}	W_{y2}
1	1	0	0	0	0	0	1.45E-05	5.47E-04	0	0	7.46E-05
2	1	0	0	5.81E-05	0	0	0	0	0	0	4.02E-05
3	1	0	0	3.05E-05	0	0	0	1.33E-04	0	0	4.62E-05
4	1	2.55E-04	4.27E-05	0	0	0	0	0	0	0	4.18E-05
5	0.938	0	0	0	0	0	0	2.01E-04	0	0	3.63E-05
6	0.821	0	0	0	0	0	0	1.77E-04	0	0	3.54E-05
7	0.724	0	0	0	0	0	1.41E-04	0	0	0	3.35E-05
8	0.879	0	0	3.50E-05	0	0	0	0	0	1.59E-05	0
9	1	1.16E-04	0	0	0	0	6.64E-05	0	0	0	1.82E-05
10	0.780	0	0	0	0	0	0	0	0	0	1.98E-05
11	0.934	0	0	0	0	0	0	5.69E-05	0	0	1.93E-05
12	1	0	0	0	0	0	0	0	8.77E-05	0	7.42E-05
13	1	0	0	0	0	0	0	3.89E-04	0	0	5.68E-05
14	1	2.42E-04	0	0	0	0	0	0	0	0	0
15	0.734	0	0	2.95E-05	0	4.55E-05	0	0	0	0	3.97E-05
16	0.993	0	0	1.56E-05	0	2.13E-05	0	0	0	0	2.23E-05
17	0.872	0	0	1.15E-05	0	1.58E-05	0	0	0	0	2.06E-05
18	0.766	0	0	0	0	0	4.90E-05	0	0	0	2.24E-05
19	0.755	0	0	0	0	0	4.00E-05	0	0	0	1.82E-05
20	0.616	0	0	0	0	0	3.65E-05	0	0	0	1.99E-05
21	0.697	0	0	0	0	0	2.46E-05	0	0	0	1.32E-05
22	1	0	0	0	0	0	2.45E-05	0	0	0	0
23	1	0	0	0	0	0	0	4.05E-05	0	0	1.53E-05
24	1	2.63E-03	0	0	0	0	0	0	0	0	1.20E-05
25	1	1.72E-03	0	0	0	0	0	0	0	0	1.60E-05
26	1	0	0	0	0	1.35E-05	0	2.69E-05	0	0	1.71E-05
27	1	4.67E-04	0	1.42E-05	0	1.30E-05	0	0	0	0	2.19E-05
28	1	1.61E-03	0	0	0	0	0	0	0	0	0
29	1	0	0	0	0	0	0	0	0	0	0
Mean	**0.914**	**0.000242**	**1.47E-06**	**6.69E-06**	**0**	**3.7E-06**	**1.36E-05**	**5.42E-05**	**3.02E-06**	**5.4E-07**	**2.53E-05**

Table 8: Sample of Input Targets (Output Oriented DEA, Scale Assumption: VRS)

DMU	IMC	SC	WC	IC	NE	WW	FuC	MC
1	682	13370	14629	34049	80384	3046	1819	31941
2	800	14602	16654	36425	85559	7850	39386	49408
3	866	15791	19878	39528	85603	3798	2948	44231
4	918	17485	22865	45312	103468	4356	3286	52416
5	978.8401	24319	27462.48	58489.55	106828	5954	4197	63015.12
6	1001.175	26999.63	29905	64595.36	104094.4	6621	5023	72027
7	1059.234	35202	35050.94	79364.05	105445.9	7942	7007	87374
8	1101.754	38324	37016	86643.81	110490.7	8946.126	7976	97185.85
9	1187	44194	42639	101515	120396	10867	8619	117083
10	1241.56	50805.31	49143.64	117569	122126.5	12314.5	9701.356	136905.3
11	1209.104	52081.67	54044	119079.1	118468	11930.02	9522	138685.9
12	1374	62117	46735	130898	120174	15160	1921	11938
13	1497	73434	55204	155980	134779	18734	1985	15437
14	1554	87577	72869	201616	135384	20356	15752	246382
15	811.7946	76576	39759	123958.2	74844	6834.303	9786	169071.2
16	1000.249	105497	41301	154481.3	82698	7045.197	13740	154511.1
17	1100.015	101415	54170	156387.7	88553	7996.295	14516	141411.3
18	1146.15	138060	92419	224271.1	93741	12733	19338	249245.3
19	1486.466	235980	104604	334747.5	99731	13955	25807	286961.1
20	1752.992	271538	150290	397567.1	103738	15737	30374	280197.4
21	2295.604	414359	158936.7	563914.5	119302	19502	38881	365612.3
22	3855	982507	206070	1186858	132180	24320	51959	690302
23	4046	719461	255442	937341	134861	136618	9292	63597
24	587	230394.9	177104	342808.2	47972.94	17528.92	18909.9	496375.5
25	608	398729.6	170768.6	574175.9	44295.87	17207.48	22063.02	615935
26	640	228821	150160	354173	36194	16142	19060	546393
27	642	303888.9	89306	431703.2	39541	16541.75	22097	629821.8
28	621	591	285636	116035	25592	1536	777	4116
29	12656	3303003	600909	4055974	472330	140109	1028465	1716212
Mean	1679.929	278176.7	106930	387084.8	107888.8	20402.78	49800.25	261165.2

Table 9: Sample of Output Targets (Output Oriented DEA, Scale Assumption: VRS)

DMU	NVA	NI
1	15695	13289
2	18557	21653
3	24808	21653
4	27041	23753
5	33675.93	28785.51
6	40418.84	33220.45
7	51303.74	40245.81
8	54130.29	44563.57
9	63307	53079
10	73231.03	57102.81
11	81660	55318.05
12	6600.07	13474
13	10679	17609
14	101463	80613
15	46793.65	22547.67
16	52347.11	32022.67
17	70620.72	41112.35
18	116767.7	58316.66
19	137128.3	72605.04
20	250717.2	81621.24
21	252144.1	108320.6
22	257688	176840
23	57905	65168
24	235769	26661
25	125600	49463
26	107364	54759
27	90702	22399
28	616915	598
29	1062762	868909
Mean	140820.5	75369.05

Table 10: Result of Regression Exercise with Efficiency Score as a dependent Variable (Under CRS Assumption).

Variables	Coefficient	t-Statistic	P- Value
Constant	1.1219	8.93	0.00
IMC	-0.000107	-4.59	0.00
SC	-0.00000117	-0.67	0.211
WC	0.00000209	1.6	0.128
IC	0.00000125	0.74	0.47
NE	-0.00000189	-1.25	0.228
WW	-0.00000346	-1.51	0.149
FuC	-0.00000123	-1.84	0.082
MC	-0.00000096	-3.12	0.006
NVA	-0.00000118	-2.09	0.051
NI	0.0000496	3.01	0.007
Adj. R Square	0.76		
F Statistics	5.68		

Notes: The coefficients are significant at 5 percent levels.

Table 11: Comparison between various Rankings

	DEA -CRS	**DEA – VRS**	
DMU	**TE**	**TE**	**Scale Efficiency**
1	0.985	1	0.985 drs.
2	1	1	1
3	1	1	1
4	1	1	1
5	0.913	0.938	0.974 drs.
6	0.808	0.821	0.983 drs.
7	0.720	0.724	0.994 drs.
8	0.860	0.879	0.978 drs.
9	1	1	1
10	0.776	0.780	0.994 drs.
11	0.926	0.935	0.990 drs.
12	0.989	1	0.989 drs.
13	1	1	1
14	1	1	1
15	0.498	0.734	0.678 drs.
16	0.762	0.993	0.767 drs.
17	0.716	0.872	0.821 drs.
18	0.728	0.766	0.950 drs.
19	0.729	0.755	0.965 drs.
20	0.601	0.616	0.975 drs.
21	0.692	0.697	0.992 drs.
22	1	1	1
23	1	1	1
24	0.861	1	0.861drs.
25	0.997	1	0.997 drs.
26	1	1	1
27	0.630	1	0.630 drs.
28	1	1	1
29	1	1	1
Mean	0.868	0.914	0.949

***scale efficiency = Technical efficiency CRS/Technical efficiency VRS**

* drs = decreasing return to scale *TE = Technical Efficiency

Table 12: Result of Sensitivity Analysis

DMU	SCORE	Dropping	Dropping	Dropping	Dropping	Dropping
		(X_1)	**(X_2)**	**(Y_2)**	**(DMU-4)**	**(DMU-22)**
1		0.893	0.912	0.905	0.965	1
2		1	1	1	1	1
3		1	1	1	1	1
4		1	1	1		1
5		0.897	0.812	0.765	0.754	0.843
6		0.788	0.822	0.811	1	1
7		0.78	0.801	0.833	0.886	0.912
8		0.84	0.784	0.791	0.823	0.822
9		1	1	1	1	1
10		0.773	0.778	0.832	0.797	0.775
11		0.921	1	0.918	0.911	0.943
12		0.943	0.921	0.899	0.876	0.885
13		1	1	0.879	1	1
14	1	1	1	0.889	1	1
15	0.498	0.511	0.611	0.623	0.754	0.668
16		0.723	0.755	0.743	0.765	0.756
17		0.776	0.855	0.811	0.821	0.887
18		0.811	0.713	0.673	0.774	0.923
19		0.888	0.811	0.822	0.823	0.877
20		0.679	0.835	0.726	0.657	0.711
21		0.754	0.743	0.772	0.712	0.754
22	1	1	1	1	1	1
23		1	1	1	1	1
24		0.895	0.814	0.804	0.778	0.773
25		0.998	0.993	0.991	0.987	0.975
26		1	1	1	1	1
27		0.991	0.754	0.854	0.875	0.866
28		1	1	1	1	1
29		1	1	1	1	1

Table 13: Measures Used in the Model

MEASURE	**DESCRIPTION**
Internal Manufacturing Capacity	It is the total capacity of goods produced by the company with optimum utilization of Resources
Supply chain cost	The cost incurred for the supply chain related activities like logistics, warehousing, inventory etc.
Working capital	The capital required for the day to day expenses.
Invested capital	Capital invested for purchasing assets, like purchasing machine, land etc.
Number of employees	Total number of staff present for delivering service
Wages to workers	Total amount required for wages
Material consumer	The raw material required for the production
Fuel	The cost of fuel for production
Net Income	The income after all deduction
Net value added	The value achieved due to supply chain is taken into account. For example the income is possible only due to the on-time delivery of the goods, or due to better supply chain information form the customer etc.

Appendix B - Figures

Figure 3: Efficiency Score of each DMU (Out put Oriented DEA, Scale Assumption: CRS)

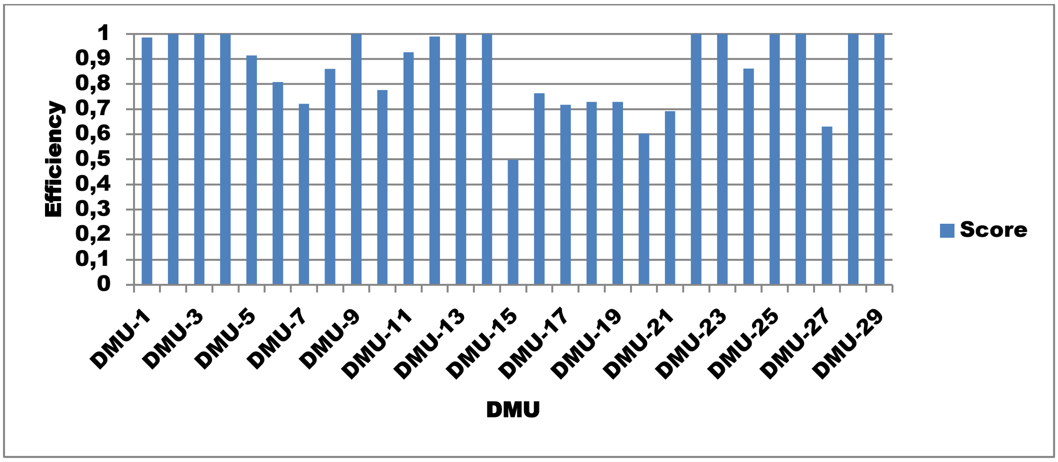
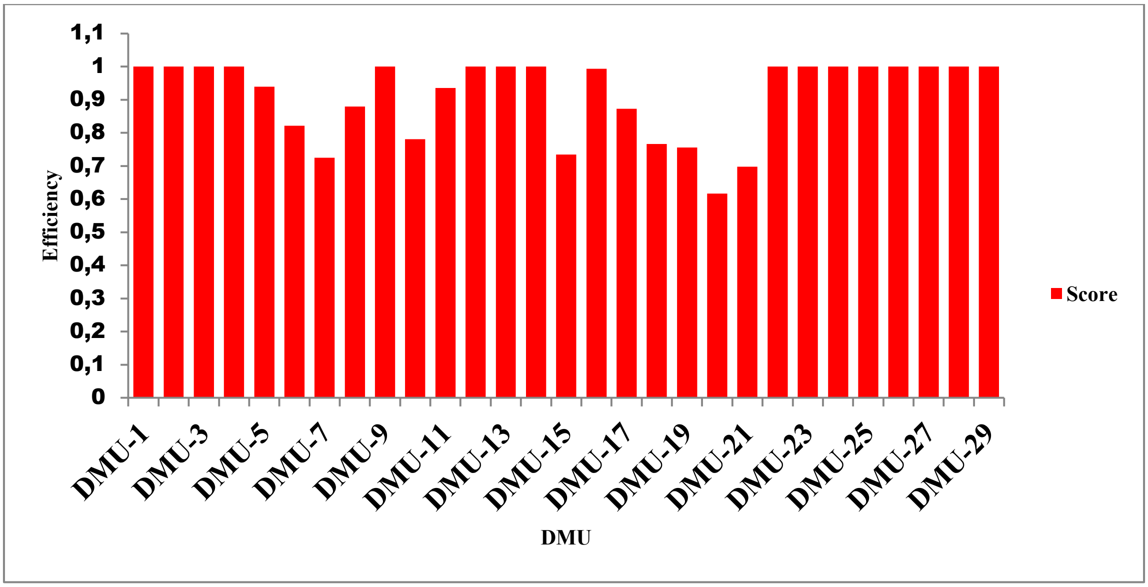


Figure – 4: Efficiency Score of each DMU (Output Oriented DEA, Scale Assumption: VRS)



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