Measuring Supply Chain Efficiency: A Case of Pharmaceutical Companies of India

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Abstract

Supply chain performance depends on the efficiency of supply chain. The efficiency depends on the inputs utilized and their outcome(s). In this paper an attempt has been made to measure the efficiency of supply chain of pharmaceutical companies in India. Efficiency is measured by quantum of inputs like internal manufacturing capacity, supply chain cost, working capital, invested-capital, number of employees, wages to workers, materials consumed and fuel used in production. The outputs are net value added by supply chain and net income gained. Data Envelopment Analysis and Tobit model of regression is used for the analysis of data.

Keywords: Supply Chain, Efficiency, Data Envelopment Analysis, Efficiency

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 in 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, constituent parts of these processes include material suppliers, production facilities, distribution services and customers all of which are linked together.

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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 data and unavailability of requisite 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 of the direct suppliers and their 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 focusing purely 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' to ultimate customer, the measure could still be addressed as the supply chain efficiency within the internal organization context. This study uses Data Envelopment Analysis (DEA) model as a tool to measure internal supply chain efficiency.

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 for enabling managers to make reasonable judgment on the efficiency of the analyzed units. This paper uses a DEA model to evaluate the supply chain efficiency in different companies. This model helps management identify the inefficient operations and provide remedies to improve its supply chain efficiency. In general, the paper is organized as follows. First, a brief description of some of the traditional ways of measuring supply chain performance and problems associated with them is given. It is followed by a review of DEA and its application in supply chain. Then, the methodology and DEA models developed to measure supply chain efficiency are explained.

Review of Literature

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 was 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 factors influencing 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) and 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 techniques of gap analysis 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. There is a problem with comparison via ratios also it 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 index for judgment. The evaluation of supply chain efficiency needs to look into multidimensional construct.

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 suffice 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 used.

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 promotes 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 forming 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 information about customers, competitors, potential channel partners, and emerging business avenues and information is the key in managing supply chain agencies. As the origin of supply chain management is not specific, its development starts along the line of physical distribution and transport (Croom et al. 2000). Both approaches focus on the single element in the chain that cannot assure the effectiveness of whole system (Croom et al. 2000). Supply chain management was introduced first by consultants in 1980s and it has gained tremendous attention (La Londe, 1998). A typical supply chain is generally a network of materials, information and services that are linked with the characteristics of supply, transformation and demand. The term SCM is not only used to explain the logistic activities and the planning and control of materials and information flow but also 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 literature on SCM. In this paper we examine and consolidate various articles. This study may be the most comprehensive analysis of the multidisciplinary, research on SCM. Selection of suppliers is a complex problem due to number of criteria required for evaluation and their interdependence. In general, the problem of selection of supplier in supply chain system is a group decision which is made 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).

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 in-depth 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 total 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 comparative 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 DEA approach. Wong and Wong (2007) explained the motivation of using DEA as a supply chain performance measurement tool, by giving ample evidences, literature support and reasons on the suitability of DEA as a decision-making tool in supply chain management.

Empirical Analysis

Analysis of data is based on DEA which requires (i) identification of inputs; (ii) identification of outputs; and (iii) Link between inputs and output by means of the productive process of transformation of inputs into outputs. So first, we describe the identification of inputs and outputs.

Classification of Inputs and Outputs

The following table provides information about the identification and classification of inputs and outputs used in DEA.

Table 1: Classification of Inputs and Outputs

Inputs	Outputs
X_1: Internal Manufacturing Capacity (IMC) (million tons per day) X_2: Supply chain cost (SC)[Rs. in lakh] X_3: Working Capital (WC) [Rs. in lakh] X_4: Invested Capital (IC) [Rs. in lakh] X_5: Number of Employees (NE) X_6: Wages to Workers (WW) [Rs. in lakh] X_7: Materials Consumed (MC) [Rs. in lakh] X_8: Fuels Consumed (FC) [Rs. in lakh]	Y_1: Net Value Added due to supply chain (NVA) [Rs. in lakh] Y_2: Net Income (NI) [Rs. in lakh]

Data selected for this study relate to Indian industries manufacturing drugs and medicines and these data have been taken from indiastat.com as well as annual reports of companies. The data were screened according to the requirement of inputs and outputs which account for supply chain efficiency. The boundary of supply chain consists of financial and operational measure. The input and output variables are categorized according to the performance metrics listed in the supply chain operations reference. 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. Supply chain cost is the cost associated with operating the supply chain. It includes the cost incurred for different supply chain activities ranging from inventory management cost, logistics cost, and warehousing cost.

Similarly, two outputs like net value added and net income have been taken for analysis. The net value added measures the creation of wealth. It is the contribution of the supply process to the system. The net value added is the value of output less the value of both intermediate consumption and consumption of fixed capital. It has been measured as total revenue less material purchase and non supply chain cost.

Each year is considered as a Decision Making Unit (DMU).The data used covers the period 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.

Table 2: Correlation Matrix of Inputs and Outputs

	IMC	SC	WC	IC	NE	WW	FuC	MC	NVA	NI
IMC	1	0.921	0.787	0.921	0.887	0.770	0.888	0.775	0.725	0.912
FC		1	0.884	0.999	0.870	0.805	0.947	0.874	0.827	0.972
WC			1	0.895	0.648	0.769	0.800	0.796	0.914	0.819
IC				1	0.865	0.808	0.946	0.879	0.835	0.970
NE					1	0.718	0.910	0.633	0.663	0.927
WW						1	0.695	0.551	0.563	0.722
FuC							1	0.811	0.842	0.985
MC								1	0.732	0.838
NVA									1	0.836
NI										1

From the correlation analysis (Table2), it has been found that the correlation between internal manufacturing capacity and supply chain cost is 0.921. So we dropped the supply chain cost (SC) variable. The correlation between invested capital and net income is 0.970. Hence we have dropped the invested capital (IC) variable. The correlation between working capital and fuel consumed is 0.800. So we have dropped the variable, Fuel consumed (FUC). Similarly the correlation between supply chain cost and material consumed is 0.874. Therefore we have dropped the supply chain cost as a variable. This leaves us only with uncorrelated inputs/outputs. We proceed to calculate the BCC efficiency taking following 4 inputs and 2 outputs which are shown in Table-3.

Table 3: Inputs and outputs for calculating BCC Efficiency

Inputs	Outputs
• Internal Manufacturing Capacity (IMC) • Working Capital (WC) • Wages to Worker (WW) • Materials Consumed (MC)	• Net Value Added (NVA) • Net Income (NI)

Table 4: BCC Efficiency Scores of DMUs

DMU	BCC_Efficiency	DMU	BCC_Efficiency
1	1	16	0.773245122
2	1	17	0.669703055
3	1	18	0.467424943
4	0.925129717	19	0.515180546
5	0.818194038	20	0.326522974
6	0.770861436	21	0.421777108
7	0.690292644	22	0.723112571
8	0.852955507	23	1
9	1	24	1
10	0.757344044	25	1
11	0.787023443	26	1
12	1	27	0.931240135
13	1	28	1
14	0.973396516	29	1
15	0.517323855	**Mean**	**0.824853**

It is observed from Table-4 that twelve DMUs are efficient. DMU-4, DMU-14, and DMU-27 are having a value more than 0.9. Similarly DMU-18, DMU-20, DMU-21 are less than 0.5. Hence their performance is not effective. These DMUs must be taken care by the management. The mean BCC efficiency score is 0.8248.

The following is the BCC scores histogram:

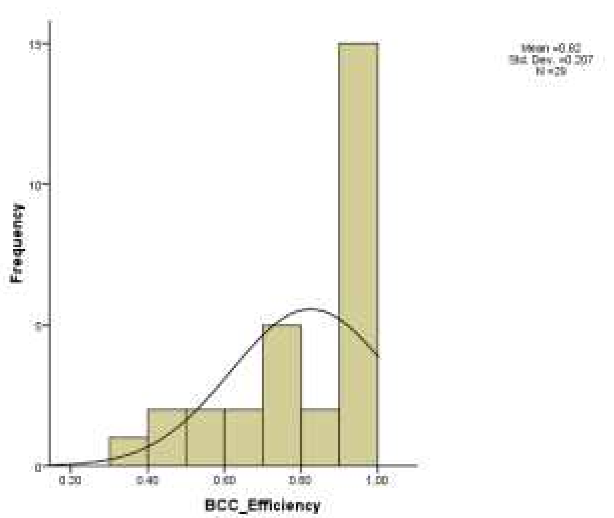

Figure 1: BCC Efficiency histogram

In order to clearly examine the determinants of efficiency, we further applied Tobit regression model; we regress the BCC efficiency (as shown in Table-4) as dependent variable. It is evident from the histogram (Figure-1) of BCC efficiency that, the efficiencies are censored above. As per DEA literature, Coelli (1998), Patel and Smriti (2012), Tobit regression model is suitable when the dependent variable is censored.

The Tobit regression model is reported below:

$$\theta_i = \alpha_i + \beta_1 (IMC)i + \beta_2 (WC)i + \beta_3 (WW)i + \beta_4 (MC)i + \beta_5 (NVA)i + \beta_6 (NI)i + \epsilon_i$$

where, θ_i is the efficiency score for the ith DMU computed from the BCC model.

Results of estimate of Tobit model are reported in the table below:

Table 5: Tobit Regression model

Variable	Value	Std. error	z-value	p-value
Constant	1.0255	3.2619 X 10^{-2}	31.4389	
IMC*	-1.8744 X 10^{-4}	2.059 X 10^{-5}	-9.11264	0.0215X10^{-2}
WC	-1.0668 X 10^{-5}	9.7573 X 10^{-7}	-1.0933	0.137
WW*	6.3814 X 10^{-6}	1.8868 X 10^{-6}	3.3822	0.00359539
MC	-9.4904 X 10^{-8}	1.53 X 10^{-7}	-0.6203	0.268
NVA	6.2896 X 10^{-7}	4.6481 X 10^{-7}	1.3532	0.088
NI*	1.8243 X 10^{-6}	5.6607 X 10^{-7}	3.2228	0.00063

**Significant at 5 percent level*

Table 6: BCC efficiency statistics

	Minimum	Median	Mean	Maximum	SD
BCC Eff.	0.326523	0.92513	0.824853	1.00000	0.207495

The $\chi 2$ test statistics (= 391.1) with 6 degrees of freedom associated with p value (= 2.28898 X 10-81) shows that the model is a good fit to the data. We also find that the value of constant 2 (e-2.4206 = 0.8886828) from the Tobit model is much less than the standard deviation (= 0.2074949), which again shows that model appears to fit the data well. The results of Tobit regression are presented in Table–5 and Table-6.

The results obtained from Tobit regression shows that internal manufacturing capacity, wages to worker, net income significantly contribute significantly to the efficiency of DMU. For an increase in wages to workers and net income, the efficiency of the DMU will increase by 0.000063814 and 0.0000018243. However, the sign of coefficient of internal manufacturing capacity is negative. This indicates that efficiency of the DMU will fall by (-0.00018744) for the increase in internal manufacturing capacity. The materials consumed, material consumed and net value added were not found to be significant contributors to the efficiency

Table-7: Comparison between various Rankings

DMU	DEA-CRS	DEA-VRS	Scale Efficiency
	TE	TE	
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
$r(I,II) = 0.799 r(I-III) = 0.656$			

**Scale Efficiency = Technical efficiency CRS/Technical efficiency VRS*
**Drs = Decreasing Return to Scale *TE = Technical Efficiency*

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 from output oriented CRS model is 0.868. The average technical efficiency of DMUs calculated from 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 following hypotheses are set for testing:

$$H_{01}: Efficiency\ score\ of\ DEA-CRS = Efficiency\ score\ of\ DEA-VRS$$

$$H_{11}: Efficiency\ score\ of\ DEA-CRS \neq Efficiency\ score\ of\ DEA-VRS$$

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.

Sensitivity Analysis

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 in 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.

Table-8 shows the result of Sensitivity Analysis. 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

Table 8: Result of Sensitivity Analysis

DMU	Technical Efficiency	Dropping (X_1)	Dropping (X_2)	Dropping (Y_2)	Dropping (DMU-4)	Dropping (DMU-22)
1	0.985	0.893	0.912	0.905	0.965	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1		1
5	0.913	0.897	0.812	0.765	0.754	0.843
6	0.808	0.788	0.822	0.811	1	1
7	0.720	0.780	0.801	0.833	0.886	0.912
8	0.860	0.840	0.784	0.791	0.823	0.822
9	1	1	1	1	1	1

10	0.776	0.773	0.778	0.832	0.797	0.775
11	0.926	0.921	1	0.918	0.911	0.943
12	0.989	0.943	0.921	0.899	0.876	0.885
13	1	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	0.762	0.723	0.755	0.743	0.765	0.756
17	0.716	0.776	0.855	0.811	0.821	0.887
18	0.728	0.811	0.713	0.673	0.774	0.923
19	0.729	0.888	0.811	0.822	0.823	0.887
20	0.601	0.679	0.835	0.726	0.657	0.711
21	0.692	0.754	0.743	0.772	0.712	0.754
22	1	1	1	1	1	
23	1	1	1	1	1	1
24	0.861	0.814	0.814	0.804	0.778	0.773
25	0.997	0.993	0.993	0.991	0.987	0.975
26	1	1	1	1	1	1
27	0.630	0.754	0.754	0.854	0.875	0.866
28	1	1	1	1	1	1
29	1	1	1	1	1	1

remain efficient. The deviation in efficiency score observed when the output Net Income is dropped from the analysis. DMU11, DMU12, DMU14 is becoming inefficient when Net Income is not considered. Hence Net Income is an important output for the company.

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. The average efficiency score obtained through VRS model is found to be comparatively higher with the average score being 0.914. The performance of each year is not same, as we are calculating the relative efficiency. In 1988-89, 1989-90 and 2000-2001 the efficiency is 60-70 percent because others have performed well in those years. The reason is competition from global players and the price of the drugs plays an important role.

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