Using Data Envelopment Analysis to Rate Pharmaceutical Companies; A case study of IRAN

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Abstract: Efficiency analysis and performance comparison among homogeneous firms provides the field of using tools and economic indicators in financial management, allocation of resources and other managerial decisions. The aim of this research is measuring and identifying the productivity changes of some Pharmaceutical Companies. This research has done on the efficiency of 28 Companies, using DEA. In this study we used Total assets/ net working capital, Total assets/ net profit, Total Debt/ Cash Flow and profit margin and the Total assets/Total Debt as well as the Total assets/Long term debt as outputs and input variables. The findings show that which companies have efficiency and which companies need to change their processes.

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Introduction

Numerous multicriteria (i.e. multiattribute) decision support tools have been developed for structuring and supporting decision making (Olson, 1996; Larichev and Olson, 2001). Many of these techniques are related to and in general based upon multi-attribute utility theory (Fishburn, 1970; Keeney and Raiffa, 1976).

One popular procedure that incorporates such features is the simple multi-attribute rating technique, or SMART, which determines additive multi-attribute value (MAV) scores for finite sets of alternatives (Edwards and Barron, 1994). Stimson (2002), in one of the few articles incorporating a multi criteria approach to vendor selection, proposed an approach involving the use of ranks as inputs for scoring alternatives. Another popular multi criteria technique is the analytic hierarchy process (AHP) (Chan et al., 2004; Chou et al., 2005; Saaty, 1977), which determines weights and scores through a pairwise comparison process.

A multi criteria technique not generally used to assist in selecting from a set of alternatives but more typically for evaluating decision-making outcomes is data envelopment analysis (DEA) (Charnes et al., 1978).

Evaluating and comparing the performance of similar units of an organization is an important part of the responsibilities of organization management. One of the most important tools of relative performance comparing these units is a quantitative, precise and powerful approach called Data Envelopment Analysis (DEA).

This technique is considered not only in performance evaluation but also in management; it is more precisely recognized in units under control. This method also has some major shortcomings the most important of which are impossibility of predicting efficiency, inability in determining acceptable risk level for the managers in the direction of achieving the predicted efficiencies in each unit, and unreal weight distribution to the inputs and outputs.

The aim of this study is to evaluate the efficiency of pharmaceutical companies that are in IRAN Stock exchange. In this study we are going to illustrate that how this company can be better according to change their processes with the help of financial rates.

Literature review

In 2000 Juma'h & Wood examined the business performance of UK firms by taking into consideration outsourcing implications on profitability, liquidity, employment cost, return on equity, research and development expenditures and changes in equity of the company.

The results of their research showed that profitability (Operating Profits and Return on Equity) firstly decreases in the year of outsourcing (1988-1991) and tends to increase the profitability in the subsequent years i.e. after outsourcing announcements (1993-1996). While operating profit and return on equity of the sampled firms are above the average of all UK firms employment cost has been decreased by the outsourcing expectation, research and development expenditure decreases after years of outsourcing.

In 1990 two researchers in India in their research, intensively examined the relationship between profitability and structure, using a sample of thirty-eight pharmaceutical firms in India for the period 1970-1982. They have used two measures of profitability i.e., ratio of net profit to total sales revenue and the ratio of net profits to total assets, to find out the determination of profitability. The coefficient of growth rate of sales was positive and significant, suggesting that factors on the demand side of a firm had greater impact on profitability than on the supply side.

White & Liu In 1998 examined the performance of pharmaceutical firms on the basis of scale and studies the shift in key performance. In their research 66 firms were selected and financial, employee and operational data for 2 years were analyzed by using OLS regression and longitudinal data. Production output, scales and profits, number of employees and fixed assets were taken as indicator for scale based performance while ratios and profits as percentage of output value, Return on Output, Return on Sales and Return on Assets were chose as indicator for efficiency based measures of performance.

In another study by Debasish Sur and kaushik Chakraborty in 2006 about financial performance of Indian Pharmaceutical Industry, they claimed that it is the 5th largest in terms of volume and 14th largest in value terms in the world. Their comparative study analyzed the financial performance of Indian pharmaceutical industry for the period 1993 to 2002 by selecting six notable companies of the industry. I this study they compared almost all points of view regarding financial performance using relevant statistical tools.

According to these studies; scale based measures of performance are highly correlated with the firm's to increase factor of production and sale and growth of physical inputs. It means that the firms endowment of fixed assets. The significant correlation has been observed by the efficiency based ratio with intangible assets and their related activities that means highly related to store of production related engineering and technical skills, and firm's ability to leading new products. Data was analyzed by measuring all the financial ratios.

DEA

Data envelopment analysis (DEA) is a mathematical programming methodology. It has been employed successfully for assessing the relative performance of a set of firms, usually called decision-making units (DMU), which use the same inputs to produce the same outputs. Assume that there are N DMUs, and that the DMUs under consideration convert I inputs to J outputs. In particular, let the mth DMU produce outputs y_{jm} using x_{im} inputs. The objective of the DEA exercise is to identify the DMUs that produce the greatest amount of outputs by consuming the least amount of inputs. A DMU is deemed to be efficient if the ratio of weighted sum of outputs to the weighted sum of inputs is the highest. Hence, the DEA program maximizes the ratio of weighted outputs to weighted inputs for the DMU under consideration subject to the condition that similar ratios for all DMUs be less than or equal to one. Thus a model for calculating the efficiency of the mth DMU (called the base DMU) is the following (Charnes et al., 1994; Ramanathan, 2003):

$$\max \frac{\sum_{j=1}^{j} v_{jm} y_{jm}}{\sum_{i=1}^{I} u_{im} x_{im}},$$

Subject to:

$$0 \le \frac{\sum_{j=1}^{J} v_{jm} y_{jn}}{\sum_{i=1}^{I} u_{im} x_{in}} \le 1; n = 1,2,...,N,$$

$$v_{jm}, u_{im} \ge \varepsilon > 0; i = 1,2,...,I; j = 1,2,...,J,$$

Where the subscript i represents inputs, j represents outputs and n represents the DMUs. The variables uim and vjm are the weights of inputs and outputs, respectively, to be determined by the above mathematical program. They are usually called DEA multipliers. The second subscript m represents the base DMU for which the efficiency is being calculated. The symbol 1 is an infinitesimal or non-Archimedean constant. The optimal value of the objective function is the DEA efficiency score assigned to the mth DMU. If the efficiency score is 1, the mth DMU satisfies the necessary condition to be DEA efficient and is said to be located on the frontier that envelopes all the data (usually called the "efficiency frontier"); otherwise, it is DEA inefficient.
The efficiency is relative to the performance of other DMUs under consideration.

Input and output of DEA model
The inputs for DEA model are following:
1- Total assets/Total Debt
2- Total assets/Long term debt

And the outputs for DEA model are following:
1- Current ratio
2- Total assets/ net working capital

3- Total assets/ net profit
4- Total Debt/ Cash Flow
5- profit margin

Data analysis
As already mentioned, the DEA method usually is used to determine the efficiency and productivity of units. We must first consider quantities as input and output values of the companies under study. Considering the purpose of realistic investors, in this study, the Current ratio of each company, Total assets/ net working capital, Total assets/ net profit, Total Debt/ Cash Flow and profit margin were taken as their outputs and the Total assets/Total Debt as well as the Total assets/Long term debt were taken as their inputs.
We illustrate the above DEA procedures with 28 pharmaceutical companies (DMUs) given in Table 1.

Table 1; the quantities of Inputs and Outputs variables

Pharmaceutical companies (DMUs)	Total assets/Total Debt	Total assets/Long term debt	Current ratio	Total assets/ net working capital	Total assets/ net profit	Total Debt/ Cash Flow	profit margin
Company 1	0.55	0.074	1.72	0.33	0.27	0.045	0.25
Company 2	0.668	0	1.3	0.196	0.136	0.086	0.17
Company 3	0.001	0.83	1.12	-0.16	0.075	0.04	0.065
Company 4	0.37	0	1.7	0.23	0.1	0.0089	0.17
Company 5	0.717	0	1.2	0.133	0.049	0.013	0.055
Company 6	0.23	0	2.72	0.4	0.33	0.076	0.073
Company 7	0.54	0.013	1.64	0.316	0.115	0.13	0.15
Company 8	0.62	0	1.18	0.66	0.11	0.014	0.25
Company 9	0.54	0.013	1.64	0.316	0.115	0.13	0.15
Company 10	0.58	0.005	1.32	0.18	0.07	0.124	0.1
Company 11	0.64	0.003	1.4	0.82	0.014	0.025	0.25
Company 12	0.378	0	2.19	0.4	0.38	0.03	0.34
Company 13	0.66	0	1.19	0.13	0.21	0.02	0.3
Company 14	0.76	0.48	1.07	0.055	0.099	0.024	0.1
Company 15	0.82	0.15	0.81	-0.15	0.006	0.02	0.012
Company 16	0.72	0	1.34	0.24	0.12	0.065	0.15
Company 17	0.55	0	1.5	0.29	0.28	0.062	0.4
Company 18	0.77	0.073	0.73	-0.18	0.066	0.04	0.15
Company 19	0.63	0	1.38	0.23	0.136	0.1	0.18
Company 20	0.41	0.124	1.28	0.1	0.11	0.08	0.18
Company 21	0.6	0.007	1.21	0.12	0.038	0.06	0.042
Company 22	0.86	0.79	0	-0.17	0.025	0.026	0.57
Company 23	0.57	0	1.2	0.12	0.17	0.0198	0.18
Company 24	0.053	0.066	1.37	0.63	0.016	0.2	0.2
Company 25	0.75	0	1.12	0.094	0.12	0.016	0.15
Company 26	0.65	0	1.22	0.14	0.197	0.067	0.272

Company 27	0.71	0.065	1.077	0.049	0.089	0.063	0.1
Company 28	0.78	0	1.18	0.13	0.11	0.007	0.13

The covering input oriented CCR model of the above table is as follows:

$$\min Z_1 = \theta$$

$St:$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r1}$$
$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i1}$$
$$\lambda_j \geq 0$$

The result is as table 2:

Table 2; the result input oriented CCR model

company	efficiency	company	efficiency
Company 1	0.610168	Company 15	1
Company 2	0.405605	Company 16	0.32071
Company 3	0.295938	Company 17	0.31923
Company 4	1	Company 18	0.746762
Company 5	0.844796	Company 19	0.799025
Company 6	0.258129	Company 20	0.377536
Company 7	0.400216	Company 21	0.82963
Company 8	1	Company 22	0.132901
Company 9	0.400216	Company 23	0.58651
Company 10	0.466697	Company 24	0.546673
Company 11	0.623097	Company 25	0.339176
Company 12	1	Company 26	0.476041
Company 13	0.4662	Company 27	0.847836
Company 14	0.247109	Company 28	0.295128

One of the features of DEA model is its returns to scale structure. Returns to scale can be fixed or variable. CCR models, is one of the constant returns to scale models. Therefore the above model will be tested again by variable returns to scale of BCC model.

$$Max\, Z_1 = \theta$$
$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i1}$$
$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r1}$$
$$\sum_{j=1}^{n} \lambda_j = 1$$
$$\lambda_j \geq 0$$

Table 3; the result input oriented BCC model

company	efficiency	company	efficiency
Company 1	0.640401	Company 15	1
Company 2	0.488317	Company 16	0.408711
Company 3	0.376326	Company 17	0.387279
Company 4	1	Company 18	1
Company 5	1	Company 19	0.846769
Company 6	0.321718	Company 20	0.454563
Company 7	0.496214	Company 21	0.861303
Company 8		Company 22	0.134647
Company 9	0.496214	Company 23	0.591935
Company 10	0.46673	Company 24	0.601251
Company 11	0.626044	Company 25	0.429971
Company 12	1	Company 26	0.540436
Company 13	0.48	Company 27	1
Company 14	0.320359	Company 28	0.375385

Because of the weak in measuring of scale efficiency in expression of increasing or decreasing of returns to scale for unit under study we use a non-increasing return to scale model.

NIRS model

$$MIN\ Z_1 = \theta$$
$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{j1}$$
$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i1}$$
$$\sum_{j=1}^{n} \lambda_j \leq 1$$
$$\lambda_j \geq 0$$

Table 4; the result of input oriented NIRS model

company	efficiency	company	efficiency
Company 1	0.640401	Company 15	1
Company 2	0.488317	Company 16	0.408711
Company 3	0.376326	Company 17	0.387279
Company 4	1	Company 18	0.746762
Company 5	0.844796	Company 19	0.846769
Company 6	0.321718	Company 20	0.454563
Company 7	0.496214	Company 21	0.861303
Company 8	1	Company 22	0.134647
Company 9	0.496214	Company 23	0.591935
Company 10	0.466697	Company 24	0.601251
Company 11	0.626044	Company 25	0.429971
Company 12	1	Company 26	0.540436
Company 13	0.48	Company 27	0.847836
Company 14	0.320359	Company 28	0.375385

The nature of single scale inefficiency (due to increasing or decreasing returns to scale) for a particular unit is obtained by solving NIRS and BCC models. If the technical efficiency of NIRS was equal to BCC model the return to scale is decreasing and if else it is increasing.

Table 5; the results of comparing CCR, BCC and NIRS

Company	NIRS efficiency	BCC efficiency	CCR efficiency	Return to scale
Company 1	0.640401	0.640401	0.610168	Decreasing
Company 2	0.488317	0.488317	0.405605	Decreasing
Company 3	0.376326	0.376326	0.295938	Decreasing
Company 4	1	1	1	fixed
Company 5	0.844796	1	0.844796	Increasing
Company 6	0.321718	0.321718	0.258129	Decreasing
Company 7	0.496214	0.496214	0.400216	Decreasing
Company 8	1		1	fixed
Company 9	0.496214	0.496214	0.400216	Decreasing
Company 10	0.466697	0.46673	0.466697	Increasing
Company 11	0.626044	0.626044	0.623097	Decreasing
Company 12	1	1	1	fixed
Company 13	0.48	0.48	0.4662	Decreasing
Company 14	0.320359	0.320359	0.247109	Decreasing
Company 15	1	1	1	fixed
Company 16	0.408711	0.408711	0.32071	Decreasing
Company 17	0.387279	0.387279	0.31923	Decreasing
Company 18	0.746762	1	0.746762	Increasing
Company 19	0.846769	0.846769	0.799025	Decreasing
Company 20	0.454563	0.454563	0.377536	Decreasing
Company 21	0.861303	0.861303	0.82963	Decreasing
Company 22	0.134647	0.134647	0.132901	Decreasing
Company 23	0.591935	0.591935	0.58651	Decreasing
Company 24	0.601251	0.601251	0.546673	Decreasing
Company 25	0.429971	0.429971	0.339176	Decreasing
Company 26	0.540436	0.540436	0.476041	Decreasing

Company 27	0.847836	1	0.847836	Increasing
Company 28	0.375385	0.375385	0.295128	Decreasing

Conclusion

This study used Data Envelopment Analysis approach (DEA) to compare the relative performance of the 28 companies using seven financial ratios. The DEA methodology benchmarks best-performing companies against worst performing companies. Current ratio of each company, Total assets/ net working capital, Total assets/ net profit, Total Debt/ Cash Flow and profit margin and the Total assets/Total Debt as well as the Total assets/Long term debt were employed as outputs and input variables. This study also illustrated the possibility of achieving a higher level of economic performance analysis. The analysis indicated that the inefficient companies should make policy changes to manage their financial ratios. The study also indicated the areas in which inefficient member companies were lagging behind and how they could improve their performance to bring them to a suitable competitive level. In addition, development of a family of DEA models using principal component analysis facilitated analysis of the impact of variables, such as long-term debt to total. The data envelopment analysis is a powerful technique for performance measurement. DEA is a multifactor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision-making units. The major strength of DEA is its objectivity. DEA identifies efficiency ratings based on numeric data as opposed to subjective human judgment and opinion. In addition, DEA can handle multiple input and outputs measured in different units. In addition, unlike statistical methods of performance analysis, DEA is non-parametric, and does not assume a functional form relating inputs and outputs.

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