FINANCIAL STATEMENT ANALYSIS USING DATA ENVELOPMENT ANALYSIS

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ABSTRACT

This article explains how data envelopment analysis can be used as a decision support system to perform financial statement analysis and demonstrates the benefits DEA offers over traditional financial statement analysis techniques. A major advantage of the DEA approach is that it clearly identifies the factors contributing to the performance of company over its competitors.

INTRODUCTION

Financial statements are a summary of the operating, financing, and investment activities of a firm over a period of time. Financial statements are supposed to contain enough information to help investors and creditors make an informed decision about investing or lending money to the company. Financial statement analysis is the ultimate key that will help investors and creditors gain enough insight into the company to make an informed decision about the company. Financial statement analysis is also used by management to make decisions about the firm in a more informed manner. Financial statement analysis helps identify a firm’s strengths and weaknesses so that management can take advantage of a firm’s strengths and make plans to counter weaknesses. The strengths must be understood if they are to be used to proper advantage and weaknesses must be recognized if corrective action needs to be taken. From management’s viewpoint, financial statement analysis is useful both as a way to anticipate future conditions, starting point for planning actions that will influence the future course of events or to show whether a firm’s position has been improving or deteriorating over time.

Ratio analysis is an integral part of financial statement analysis. Ratio analysis begins with the calculation of a set of financial ratios from the information contained in the financial statements (income statement, balance sheet, statement of cash flows). Ratios analysis is designed to show the relative strengths and weaknesses of a company as compared to

• Other firms in the industry
• Leadings firms in the industry, and
• the previous year of the same firm.

Ratio analysis helps to show whether the firm’s position has been improving or deteriorating relative to its own past or other firms in the industry or industry averages. By benchmarking the firm’s financials against its own peers or industry averages, management can identify the relative strengths and weaknesses of the firm and plan better for the future. Benchmarking will also help investors and creditors better understand the relative position of a firm in the industry and make investment/lending decisions in a more informed manner.

In this paper, we illustrate the use of data envelopment analysis, an operations research technique, to analyze financial statements of firms by benchmarking financial ratios of a firm against its peers as well as against the industry averages. We use the pharmaceutical industry as an example in this study to
conduct our analysis. We show the advantages of data envelopment analysis in benchmarking a firm. Data envelopment analysis also helps identify the areas in which a firm has strengths relative to competition as well as the areas in which the firm is weak relative to competition. Furthermore, data envelopment analysis also lays the areas in which a firm needs improvement relative to its peers and by how much improvement is needed in each of those areas.

The rest of the paper is organized along the following lines. In section II, we provide a review of previous studies that illustrate the use of data envelopment analysis in the area of business. Section III discusses data envelopment analysis and the model used in this study. In section IV, we provide a discussion of empirical results, and section V summarizes and concludes the study.

PREVIOUS STUDIES

A number of studies have been published on different aspects of financial statement analysis. We include only those studies that use data envelopment analysis in either financial statement analysis or analysis of financial performance of firms. Zhu (2000) uses data envelopment analysis to develop a multi-factor financial performance model that recognizes tradeoffs among various financial measures. Kao and Liu (2004) compute efficiency scores based on the data contained in the financial statements of Taiwanese banks. They use this data to make advanced predictions of the performances of 24 commercial banks in Taiwan. Pille and Paradi (2002) analyze the financial performance of Ontario credit unions. They develop models to detect weaknesses in Credit Unions in Ontario, Canada. Oscan and McCue (1996) use data envelopment analysis for measuring and assessing the financial performance for hospitals. They compute a financial performance index (FPI) as a measure of aggregate financial performance. They show that financial performance index across many financial ratios eases the comparison of an individual hospital with its peers. Feroz, Kim and Raab (2003) is the only study that directly talks about financial statement analysis using data envelopment analysis methodology. They show that data envelopment analysis can augment the traditional ratio analysis to a consistent and reliable measure of managerial or operational efficiency of a firm.

METHODOLOGY

WHAT IS DATA ENVELOPMENT ANALYSIS?

Data envelopment analysis is a technique used to assess the productive efficiency of homogenous operating units such as schools, hospitals, banks, or utility companies. It is a powerful technique for measuring performance because of its objectivity and ability to handle multiple inputs and outputs that can be measured in different units. The DEA approach does not require specification of any functional relationship between inputs and outputs or a priori specification of weights of inputs and outputs. DEA provides gross efficiency scores based on the effect of controllable and uncontrollable factors. DEA uses a number of financial ratios to determine how good a company’s performance has been. A firm’s performance is analyzed on the basis of a set of financial ratios that include liquidity ratios (current ratio, quick/acid test ratio), asset management ratios (inventory turnover ratio, asset turnover ratio), debt management ratios (leverage ratio, total debt to total assets, and times interest covered ratio), and profitability ratios (Return on Equity, Return on Assets, and net profit margin). The ratios that need to be maximized serve as outputs and ratios that need to be minimized serve as inputs. Using this information, approach does not require specification of any functional relationship between inputs and outputs or a
priori specification of weights of inputs and outputs. DEA provides gross efficiency scores based on the effect of controllable and uncontrollable factors. DEA uses a number of variables to determine how good a firm is. With these financial ratios as inputs, the DEA-based decision support system calculates an efficiency score for a firm. This score is a relative value computed by comparing the given firm to a pool of well-performing companies that serve as a benchmark for the company under evaluation. Each firm is evaluated against either an existing firm or a hypothetical firm with an identical set of inputs or outputs that is constructed as a combination of good performing companies.

By using the existing good companies as a “role model,” DEA not only helps differentiate well performing (efficient companies from poorly performing (inefficient) firms, but also brings out the reasons why a company may be underperforming. This helps investors and creditors justify their decisions to invest or not to invest their funds in a particular company. This will also help management identify areas of weakness for a firm so that management plans can focus on plugging the weaknesses or taking steps to counter the weaknesses.

USING DEA FOR FINANCIAL STATEMENT ANALYSIS

Traditional financial statement analysis techniques use ratio analysis to compare a firm’s performance against its peers in the industry as well as against the company’s historical performance. On the basis of this comparison, analyst will recommend whether the company is doing well or underperforming relative to its peers or relative to its own past performance. DEA employs relative efficiency, a concept enabling comparison of companies with a pool of known efficient companies. The DEA model compares a firm with the pool of efficient companies by creating an efficiency frontier of good firms — a tolerance boundary created by establishing the efficiency of firms in terms of several sets of financial ratios. Companies lying beyond this boundary can improve one of the input values without worsening the others. The higher the current ratio or quick ratio or inventory turnover ratio or asset turnover ratio, the higher the chances of a firm turning out to be efficient. Similarly, the higher the leverage ratio or total debt to total capital ratios, the higher the chances that the firm will turn out to be bad. The acceptance boundary has firms that are considered to be 100% efficient. Ratio analysis is a commonly used analytical tool for verifying the performance of a firm. While ratios are easy to compute, which in part explains their wide appeal, their interpretation is problematic, especially when two or more ratios provide conflicting signals. Indeed, ratio analysis is often criticized on the grounds of subjectivity, that is the analyst must pick and choose ratios in order to assess the overall performance of a firm. In this paper we demonstrate that Data Envelopment Analysis (DEA) can augment the traditional ratio analysis. DEA can provide a consistent and reliable measure of managerial or operational efficiency of a firm.

EMPIRICAL ANALYSIS

In order to evaluate the effectiveness of DEA to benchmark companies, we collect data on sixteen pharmaceutical companies. We use days of sales outstanding, days cost of goods sold in inventory, total debt/equity as input variables. On the other hand, we use cash flow per share, return on equity, return on assets, return on invested capital, inventory turnover, asset turnover, current ratio, quick ratio, and interest rate coverage as output variables. The DEA model maximizes the output variables and minimizes the input variable to compare the relative performance of different companies. To benchmark companies, we consider each of the companies as a homogenous unit, and we can apply the DEA methodology to assess a comparative performance of these companies. Using the DEA methodology, we can calculate an efficiency score for the 16 companies on a scale of 1 to 100. Table 1
illustrates the efficiency scores of the 16 companies. Further, we also study the peers (model companies) for inefficient companies.

Table 1 illustrates that eleven out of sixteen companies are fully efficient. Furthermore, table 2 presents the efficiency rankings in ascending order. We present the score in percentage value varying between 0% and 100%. We find that the output efficiency of Bayer AG, Abbott, Mylan, AMGN, Schering-Plough, Merck, Bausch and Lomb, Pfizer, Glaxo Smithkline, Johnson and Johnson, and Wyeth is 100%. On the other hand, the output efficiency of the remaining companies are: Baxter – 97%, Novrtis - 92%, Novartis – 92%, Elli Lilly – 88%, Teva – 82%, and Bristol Myers Squibb – 77%. This means that the observed levels of cash flow per share, return on equity, return on assets, return on invested capital, inventory turnover, asset turnover, current ratio, quick ratio, and interest rate coverage are .97 times the maximum output level that Baxter can secure with its current days of sales outstanding, days cost of goods sold in inventory, total debt/equity. The same rationale applies to Elli Lilly, Novartis, Teva, and Bristol Meyers Squibb. The remaining eleven companies turn out to be the best practices.

The best practices companies: Bayer AG, Abbott, Mylan, AMGN, Schering-Plough, Merck, Bausch and Lomb, Pfizer, Glaxo Smithkline, Johnson and Johnson, and Wyeth are 100% efficient. The remaining companies are inefficient. Therefore, the next step is to identify the efficient peer group or companies whose operating practices can serve as a benchmark to improve the performance of these companies.

Table 2 illustrates the peer group for the inefficient companies. As shown in the Table 2, Schering-Plough, Johnson and Johnson, and Bausch and Lomb serve as peer for Teva. In addition, Teva is more comparable to Bausch and Lomb (weight 47%) and less comparable to its more distant peer Johnson and Johnson (weight 33%), and further distant peer Schering-Plough (weight 20%). Thus, Teva should scale down its levels of current days of sales outstanding, days cost of goods sold in inventory, total debt/equity other factors to make them comparable with Bausch and Lomb. Similarly, Merck, Wyeth, Schering-Plough, Pfizer, Bayer AG, and AMGN serve as peers for other companies.

After calculating the efficiency of a company using DEA, and identifying the efficient peers, the next step in DEA analysis is feasible expansion of the output or contraction of the input levels of the company within the possible set of input-output levels. The DEA efficiency measure tells us whether or not a given company can improve its performance relative to the set of companies to which it is being compared. Therefore, after maximizing the output efficiency, the next stage involves calculating the optimal set of slack values with an assurance that output efficiency will not increase at the expense of slack values of the input and output factors. Once efficiency has been maximized, the model does seek the maximum sum of the input and output slacks. If any of these values is positive at the optimal solution to the DEA model that implies that the corresponding output of the company (DMU) can improve further after its output levels have been raised by the efficiency factor, without the need for additional input. If the efficiency is 100% and the slack variables are zero, then the output levels of a company cannot be expanded jointly or individually without raising its input level. Further, its input level cannot be lowered given its output levels. Thus, the companies are pareto-efficient with technical output efficiency of 1. If the company is 100% efficient but one slack value is positive at the optimal solution then the DEA model has identified a point on the efficiency frontier that offers the same level on one of the outputs as company A in question, but it offers in excess of the company A on the output corresponding to the positive slack. Thus, company A is not Pareto-efficient, but with radial efficiency of 1 as its output cannot be expanded jointly. Finally, if the company A is not efficient (<100%) or the efficiency factor is greater than 1, then the company in question is not Pareto-efficient and efficiency
factor is the maximum factor by which both its observed output levels can be expanded without the need to raise its output. If at the optimal solution, we have not only output efficiency > 1, but also some positive slack, then the output of company A corresponding to the positive slack can be raised by more than the factor output efficiency, without the need for additional input. The potential additional output at company A is not reflected in its efficiency measure because the additional output does not apply across all output dimensions. Table 3 illustrates the slack values identified in the next stage of the DEA analysis. The slack variables for 100% efficient companies Bayer AG, Abbott, Mylan, AMGN, Schering-Plough, Merck, Bausch and Lomb, Pfizer, Glaxo Smithkline, Johnson and Johnson, and Wyeth.

These companies are Pareto-efficient as the DEA model has been unable to identify some feasible production point which can improve on some other input or output level. However, the slack variables are non zero for Baxter, Elli Lilly, Novartis, Teva, and Bristol Meyers Squibb. As illustrated in the table, for Teva, besides increasing the output levels of interest rate coverage by 28.73 units, should reduce the days of sales outstanding by 26.05 units. Teva should follow Schering Plough, Johnson and Johnson, Bausch and Lomb as role models. Similarly, we can interpret the slack variables for Elli Lilly, Novartis, Teva, and Bristol Meyers Squibb.

The next step in our analysis is to perform sensitivity analysis of the DEA model. DEA is an extreme point technique because the efficiency frontier is formed by actual performance of best-performing DMUs (Ramanathan 2003). Furthermore, as DEA is a non-parametric technique, statistical hypothesis tests are difficult. It is possible for a DMU to obtain a value of utility by simply improving its performance in terms of only one particular output ignoring others. One way of checking the sensitivity of DEA efficiency of a DMU is by omitting one or more inputs or outputs. Thus, we used 18 different models to calculate efficiency of the pharmaceutical companies. Table 4 summarizes the results of our analysis. Table 4 displays the average efficiency, the standard deviation of the efficiencies, and median efficiency level for each country. Table 5 lists all the countries and their rankings based on average efficiency. As expected, Johnson and Johnson, Merck, Abbott, Bausch and Lomb, and AMGN are the most efficient.

**SUMMARY AND CONCLUSIONS**

This study illustrates the use of data envelopment analysis to analyze financial statements of firms. We compare the relative performance of the 16 pharmaceutical companies using financial ratios. We use days of sales outstanding, days cost of goods sold in inventory, total debt/equity as input variables. On the other hand, we use cash flow per share, return on equity, return on assets, return on invested capital, inventory turnover, asset turnover, current ratio, quick ratio, and interest rate coverage as output variables. The DEA methodology benchmarks best-performing companies against worst-performing companies. Using the DEA methodology, we compute an efficiency score for the 16 companies on a scale of 1 to 100. We find that ten companies are efficient with a score of 100 and six companies show a score below 100 and, therefore, are inefficient. By computing slack variables, we also show the areas in which inefficient firms need to improve. By providing an overall efficiency score, data envelopment analysis eliminates the need to interpret conflicting ratios. Through slack variables, we are also able to identify the areas in which the firm needs improvement.
TABLES & REFERENCES

Tables, references, and full paper available upon request from the authors.