An analysis of the financial performance of defense business segments using data envelopment analysis

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Abstract

This research examines the financial performance of defense-oriented business segments compared to non-defense-business segments for the years 1983–1992. A financial performance measure developed from data envelopment analysis is evaluated both cross-sectionally and longitudinally. The data envelopment analysis is supplemented by, and compared to, traditional financial ratio analysis which provides additional insight into the financial performance of defense-business segments. Generally, the research findings are that the defense-business segments financially outperformed non-defense-business segments for most of the years covered by this study. However, defense segments did deteriorate financially relative to the non-defense-business segments during the time period 1983–1989. Then, beginning in 1990 there are indications that the defense segments reversed this trend and are gaining financial strength and making greater contributions to the financial health of their firms. © 1999 Elsevier Science Inc. All rights reserved.

1. Introduction

In the late 1980s and early 1990s, there were several developments that had the potential to significantly impact the defense-industrial base of the United States (US). The fall of communism in the Soviet Union and the Eastern Bloc

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resulting in a focus on regional conflicts, Operation Desert Storm and other turmoil in the Middle East, defense budget cutbacks, foreign competition for the weapons market, and defense-acquisition reform efforts are examples of situations that have the potential to impact the financial condition of defense firms. Questions have been raised as to the ability of some defense firms to change their business strategies in response to the changing defense industry environment in order to prosper as defense companies (Banks, 1989, p. 119; Velocci, 1991, p. 65; Scott, 1991, p. 58). In addition, the General Accounting Office (GAO) (1987, pp. 20–21) has called for the continuous assessment of the defense-industrial base in order to keep policy makers aware of the financial condition of this important segment of the US economy. Policy makers need to be aware of the defense industry’s financial condition, and trends thereto, in order to help them assess the industry’s ability to contribute to US domestic-economic policy (e.g., employment) and foreign policy.

The purpose of my study is to assess the financial performance of defense businesses in response to the questions raised by the GAO and others noted above. Are there indications that the defense industry has been able to modify its strategies and operations so as to prosper in the new defense operating environment? Is there evidence of poor financial performance by defense businesses? Inadequate financial performance by the defense industry has potential implications for and ramifications on US foreign, domestic, and defense policy. For example, companies might decide not to compete for defense business thereby limiting the availability of suppliers of services and weapon systems needed by the Department of Defense (DoD). Consequently, the government might find it necessary to intervene with policies that make it attractive for companies to continue to do business with the DoD.

As noted below, prior studies of the financial condition of the defense industry generally fell into two categories. One group of studies focused on evaluating the financial condition, normally profitability or market value, of the whole company. A second group of studies included research on the profitability of specific defense contracts.

A limitation of these studies is in the definition of the defense industry. There is no standard industry classification (SIC) for the defense industry. Therefore, the researchers had to define which companies should be included in the defense industry sample. This led to a wide disparity in the amount of defense business each defense company accomplished. The amount of defense business in these studies ranged from a low of 20% to a high of nearly 100%. This broad range of business has the potential to influence conclusions reached on the financial condition of the defense industry because it is difficult to assess whether the defense or commercial side of the firm is causing the good or bad financial performance.

GAO (1971), the Financial Executives Institute (1987), and DoD (1985) are examples of studies assessing the profitability of specific defense contracts (studies in the second category). For these studies, the detailed financial information on specific defense contracts was available. However, this contract information is generally considered to be proprietary in nature and therefore, not available to the general public. Note that DoD (1985) included both categories of studies.

My research takes another approach and focuses on the financial performance of a subset of the defense firm, defense-business segments. This allows me to obtain a different and more precise definition of the defense-industrial base. Hence, I am able to assess the industry’s financial performance and condition in a way which more clearly isolates the influence of defense business on the financial condition of a company and the industry.

In addition, the research methodology I use is different from previous studies in that I use data envelopment analysis (DEA) to evaluate the financial performance of defense-business segments as compared to non-defense-business segments. Use of DEA allows multiple measures of financial performance to be considered simultaneously in determining a single overall measure of financial performance. The DEA analysis is supplemented by, and compared to, traditional financial ratios. Ratio analysis provides additional detailed information that is not available from DEA and thus, provides additional insight into the financial performance of defense-business segments.

My paper is organized in the following manner. Section 2 discusses the research methodology used in my study. This is followed in Section 3 with a discussion on the data that is available and used in the research. Section 4 presents the results of my analysis.

2. Methodology

My research evaluates the financial performance of defense-business segments compared to non-defense-business segments via a cross-sectional comparison of a financial performance measure developed via data envelopment
analysis. Smith (1990) first introduced the idea of extending DEA to analyze financial statements of for-profit organizations. Since then, variations of the DEA model have been applied to financial analysis of the US brewing industry (Day et al., 1995), Turkish banking industry (Oral and Yolalan, 1990), United Kingdom grocery industry (Athanassopoulos and Ballantine, 1995), and the United States defense industry (Bowlin 1993, 1995).

In my study, the DEA financial performance measure is computed for each business segment for each year of the 10-year period, 1983–1992. The DEA measures are then reviewed for changes in the relative relationship between defense segment financial performance and non-defense business over the 10-year period. Consequently, there is a cross-sectional comparison analyzed longitudinally from which to conclude whether there have been changes in the financial performance of defense-business segments over time. In addition, the DEA results are supplemented with a review of traditional financial ratios in order to provide additional insight into the financial performance of defense-business segments.

A 10-year period is used because, in my opinion, it is likely a sufficiently long enough time period to accommodate business and product cycles. Comparison over a shorter period of time may lead to misleading results because defense product and business cycles may differ from commercial cycles.

2.1. Banker, Charnes, Cooper DEA model

My research uses the Banker, Charnes, Cooper (BCC) (Banker et al., 1984) version of the DEA model. The BCC model is used because it allows for variable (non-constant) returns to scale (as compared to the Charnes, Cooper, and Rhodes (CCR) (Charnes et al., 1978) model which evaluates organizations based on constant returns to scale). Variable returns to scale are helpful since business segment managers have relatively little ability to effect the returns to scale within a year. In addition, since the BCC model does not constrain the evaluation to constant returns to scale, it is more flexible in accommodating interindustry differences.

However, it should be noted that Ahn et al. (1988, pp. 254–256) show that the results of different DEA models are relatively robust. As a result, use of a different DEA variation would not be expected to significantly alter or affect the conclusions reached in my study.

The ratio form of the BCC model (Banker et al., 1989, p. 146) is:

\[
\text{maximize } h_o = \frac{\sum_{r=1}^{s} u_r y_{r0} - u_0}{\sum_{i=1}^{m} v_i x_{i0}} \\
\text{subject to } 1 \geq \frac{\sum_{r=1}^{s} u_r y_{rj} - u_0}{\sum_{i=1}^{m} v_i x_{ij}},
\]
for \( j = 1, \ldots, n; \ r = 1, \ldots, s; \) and \( i = 1, \ldots, m. \) The variables (except for \( u_o \)) as described in (quoted from) Bowlin (1995, p. 551) are: \( h_o \) is the performance rating sought for organization \( o \) which is the member of the data set, \( j = 1, \ldots, n, \) that is to be evaluated relative to the other organizations included in the data set; \( u_r \) is the virtual weights for each type of output \( r \) which will be determined by solving the model, \( v_i \) is the virtual weights for each type of input \( i \) which will be determined by the solution of the model, and \( u_o \) is the variable that effectively allows variable returns to scale in the organization under evaluation and is determined from solving the model. Consequently, \( u_o \) allows the organization to be evaluated based on its technical efficiency only without being limited by its scale of operations (i.e., scale efficiency). Continuing with the variable definitions, \( y_{ro} \) is the known (observed) amount of output \( r \) produced by organization \( o \) during the period of observation, \( x_{io} \) is the known (observed) amount of input \( i \) used by organization \( o \) during the period of observation, \( y_{rj} \) is the known (observed) amount of output \( r \) produced by organization \( j \) during the period of observation, \( x_{ij} \) is the known (observed) amount of input \( i \) used by organization \( j \) during the period of observation, and \( \epsilon \) is the non-Archimedean infinitesimal constant that effectively allows the maximization.

Additional details on the BCC model can be found in Banker et al. (1989, pp. 144–146), Banker et al. (1984), Callen (1991, pp. 45–47), and Charnes and Cooper (1985, pp. 74–83).

**2.2. Data envelopment analysis characteristics**

Data envelopment analysis offers several characteristics that are attractive and not readily available in other more traditional financial analysis methodologies (e.g., ratio analysis or regression analysis). These characteristics can be found in several sources which describe the DEA methodology (e.g., Charnes and Cooper, 1985; Banker et al., 1989; Callen, 1991). The characteristics that are particularly significant to my research are summarized below.

First, as can be noted from model (1), DEA produces a scalar measure of overall financial performance while using multiple output and input variables (Charnes and Cooper, 1985, p. 74). Thus, DEA allows an aggregation of several financial statistics, such as operating profit, cash flow, sales, and assets, into a meaningful scalar measure of overall financial performance (\( h_o \) in model (1)). Consequently, a form of multiple financial performance ratios, e.g., return on sales, return on assets, asset turnover, etc., can be assessed simultaneously.
and combined into a single comprehensive financial performance measure which can be used for statistical comparisons.

Second, DEA is a frontier estimation technique with an optimizing principle that does not require an a priori specification of the functional form of the model (Charnes and Cooper, 1985, p. 60). The DEA frontier is based on the observed behavior of the best performing organizations (Charnes and Cooper, 1985, p. 63). Thus, this frontier-level of performance is empirically based (Charnes and Cooper, 1985, p. 91). Hence, the evaluation provided via the DEA model conforms to the actual performance of other entities and can be assumed to be attainable. Summarizing, the best performing (frontier) organizations are identified and become the benchmark for judging the performance of the other organizations without an a priori knowledge or specification of the production function.

Third, since DEA does not require a specified functional form (Charnes and Cooper, 1985, p. 60), flexibility is permitted in the type of production function incurred by each organization under evaluation. Thus, with DEA, each organization is given the best possible rating based on its own specific production function. Consequently, by using DEA I can accommodate different production functions for different business segments and industries and interindustry differences in financial performance measures are not a limiting factor in doing the analysis. Thus, what a segment does best, e.g., produce profit or produce cash flow, is given the greatest weight while still recognizing that the other factor(s) are important.

Finally, the DEA model is Pareto optimal, i.e., the related input variable reduction or output variable augmentation can be effected without worsening any other model variables. Consequently, cross comparisons to weight or evaluate the relative importance of these different financial measures (e.g., sales, profits, etc.) are not needed in arriving at DEA performance evaluations (Banker et al., 1989, p. 127; Charnes and Cooper, 1985, p. 72).

The use of traditional financial ratios, with which most financial analysts are familiar, is possible for a financial analysis study such as this one. However, to avoid complex arrays of ratios, an index number would need to be developed in order to have a single summary number for such activities as statistical analysis and performance ranking (Banker et al., 1989, p. 128). Development of an index number would require selection of a priori weights to reflect the relative importance of each element included in the index number (Banker et al., 1989, p. 128). Difficulties that might be encountered in assigning these weights are bypassed by DEA because the latter does not require a priori weight selections in order to arrive at its overall performance evaluations. The weights assigned by the DEA model to the organization and its variables that are under evaluation are obtained from the data as part of the solution to the mathematical programming problem used to determine DEA evaluations (Banker et al., 1989, p. 128).
The above comparison is not intended to imply that DEA is better than ratio analysis – only that the two methodologies are different. In fact, the two methodologies can be and should be used to complement each other as illustrated later in my paper.

In addition, it should be noted that the resulting weights assigned by the DEA model are not necessarily the correct weights as management or the analyst might assign since the weights are designed to place the organization under evaluation in the best light possible. DEA provides a conservative performance evaluation and gives the firm the best weighting possible whether or not the weightings represent the balance of outputs and inputs desired by management or an analyst. For example, a firm producing a high level of operating income and little operating cash flow may not be considered by an analyst to be as healthy as a firm with a more balanced production of financial outputs. However, it is possible for this less-healthy firm to receive a higher DEA score.

3. Data description

A random sample of 18 firms was taken from the top 100 defense contractors for 1989 as published in the Government Executive (“Top 100 defense contractors”, 1990, pp. 24–25). A copy of the names of the 18 firms can be obtained from the author. Business segments analyzed in my study are the defense and non-defense segments of these companies. The number of business segments in these firms varied from year to year because of reorganizations, mergers, acquisitions, divestitures, etc. Consequently, the total number of business segments in any one year ranged from 66 to 75 with defense segments making up a little more than one-third of the segments. Business segments cover both manufacturing and service industries and include business from all military services – Air Force, Army, and Navy. The segments are as defined by the companies in compliance with Statement of Financial Accounting Standard No. 14, “Financial Reporting for Segments of a Business Enterprise” (FASB, 1976).

Classification of business segments as defense or non-defense related was made by reviewing annual reports and determining the approximate percentage of a business segment’s sales that are defense related. I classified a segment as defense related if more than 50% of its sales were defense related.

Also, FASB (1976, para. 23–27) requires that sales, operating profit, identifiable assets, capital expenditures, and depreciation, depletion, and amortization expenses for each business segment be disclosed. Hence, these are the data elements that are publicly available for use in my research.

Five variables were selected for use in the DEA model. Operating profit, operating cash flows, and sales are included as outputs, and operating expenses
and identifiable assets are included as inputs. These variables were selected based on three considerations. First, how do their characteristics relate to the financial-production process, i.e., what is a segment attempting to produce in financial terms and what are the available inputs (in financial terms)? For example, the business segment is attempting to produce profits (an output) by using its assets (an input). Second, how do variables relate to traditional ratio analysis, e.g., return on assets? Note from model (1) that DEA is a fractional programming model which is a form of ratio analysis. Consequently, DEA can be considered as a variation of ratio analysis. Finally, the selected variables are limited to what is publicly available as prescribed by FASB (1976). The five variables are listed in Table 1 and discussed in more detail in the following paragraphs.

*Operating profit (OP).* OP is selected as an output because it is a product of the financial production process and is generally considered a key component in evaluating the financial condition of a business entity. Segment operating profit indicates the contribution the segment is making to the company’s overall profit.

*Operating cash flows (OCF).* Over the past few years, cash flows have become a more important statistic used to assess the financial performance of a business. This is evidenced by the Financial Accounting Standards Board’s decision (FASB, 1987, para. 3) to require the preparation of a statement of cash flows as one of the basic financial statements. Furthermore, an important consideration for a company is the production of sufficient operating cash flows to run the business and pay its bills (i.e., the liquidity of the company). Thus, a measure of operating cash flows is included as an output in this study.

In my study, OCF are computed by adding operating profit and depreciation, depletion, and amortization expenses. This is a narrower measure of operating cash flows than required by FASB (1987, para. 21–23) primarily because it does not include the impact on operating cash flows of changes in current assets and current liabilities. Unfortunately, information on business segment current assets and current liabilities is not available from corporate annual reports. However, Beaver (1966, pp. 78, 80), in his work on identifying corporate fiscal stress, found this measure of cash flows to be the best predictor of fiscal stress.

**Table 1**

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<th>DEA variables</th>
<th>Inputs</th>
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<tr>
<td>Operating profit</td>
<td>Operating expenses</td>
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<tr>
<td>Operating cash flows</td>
<td>Identifiable assets</td>
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<tr>
<td>Sales</td>
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Sales ($S$). The dollar sales value serves as a measure of market share. In addition, sales level is oftentimes set as a corporate objective separate and distinct from other goals such as profitability and sometimes even at the expense of profits. Thus, it is considered an output for this evaluation.

Identifiable assets ($IA$). The dollar value of identifiable assets represents the assets (equipment, facilities, etc.) available to produce the operating profits, cash flows, and sales and is included as an input for the DEA model. Placing operating profits into a ratio with identifiable assets produces a type of return on assets ratio (also referred to as return on investment). Including operating cash flows as an output and assets as an input develops a type of cash-return on assets measure (Giacomino and Mielke, 1993, p. 57). An asset turnover ratio is also available (sales divided by assets). These ratios measure the segment's ability to effectively use their assets to generate profits, cash flows, and sales.

Operating expenses ($OE$). OE (sales–operating profit) is used as a surrogate measure for the amount of effort expended and resources consumed in producing the profits, cash flows, and sales. Thus, it represents an input to the financial production process.

Using the objective function of the ratio form of DEA from (1), I can symbolize the model as (see Bowlin, 1995, p. 543):

$$
\text{maximize } h_o = \frac{u_{op} \text{OP}_o + u_{ocf} \text{OCF}_o + u_s S_o - u_o}{v_{in} IA_o + v_{oe} OE_o}.
$$

As can be seen, the model relates to financial ratios commonly used to evaluate the performance of a business entity: return on assets (OP/IA), cash-return on assets (OCF/IA), and asset turnover (S/IA). In addition, OP/OE is a form of return on sales (RoS) in a sense. The only difference between this ratio and RoS is that sales has been reduced by the amount of profit (i.e., $OE = S - OP$). In addition, model (2) reflects the relationship between effort expended, resources consumed, and attainment of profits, cash flows, and sales. Hence, the DEA model allows the capturing of important aspects of financial performance such as measures of profitability and cash-flow returns and aggregates them into a single overall measure of performance.

Data for the selected variables were collected from the annual reports of the firms in my sample. Although the data elements are limited in number, they provide insight into the financial performance of business segments as indicated by the required disclosure of these data by the FASB (1987).

DEA requires all variables to be greater than zero (Charnes et al., 1978, p. 430). In my analysis, two output variables, operating profit and operating cash flows, have the potential to have negative values. These negative values are handled by adding a constant to the specific output for each entity in the analysis so as to have the value for that particular output be greater than zero for every organization. For example, if the largest operating loss incurred by a
business segment that is included in a DEA analysis is $100,000, then some constant greater than $100,000 would be added to the operating profit of every entity included in the analysis. See Ali and Seiford (1990, pp. 404–405) and Bardhan et al. (1996, p. 326) for additional information on the translation invariance of the DEA model.

4. Analysis

4.1. Data envelopment analysis

My research considers whether defense-business segments’ financial performance, as measured by a DEA financial performance rating, is better or worse than non-defense-business segments. Consequently, to determine whether there is a significant difference in DEA evaluations between the defense and non-defense samples, I use a statistical test advocated by Banker (1989, 1993). Banker (1989, pp. 236–237; 1993, pp. 1271–1272) suggests a form of an $F$-test of a measure of the variance around the reciprocal of the DEA rating (i.e., $1/h_j^*\). Assuming that $1/h_j^*$ is distributed exponentially, the test statistic is (Banker, 1989, p. 236):

$$
\frac{\sum_{j \in N_1} (1/h_j^* - 1)/n_1}{\sum_{j \in N_2} (1/h_j^* - 1)/n_2},
$$

where $h_j^*$ is the financial performance measure computed from the DEA model in (1), $n_1$ is the number of firms included in the defense sample ($N_1$), and $n_2$ is the number of firms included in the non-defense sample ($N_2$).

The test statistic follows the $F$-distribution with $2n_1$ and $2n_2$ degrees of freedom (Banker 1989, p. 236; 1993, p. 1272). Also, note that for my study the defense sample ($N_1$) is always in the numerator. Thus, I used a two-tail test of significance.

The results of the statistical analysis are shown in Fig. 1. A test-statistic value of greater than one indicates that the non-defense-business segments have higher DEA ratings than the defense-business segments. Hence, the non-defense-business segments did relatively better financially than the defense-business segments. A test-statistic value of less than one indicates that the defense-business segments did relatively better than the non-defense-business segments. The numbers in the body of the graph represent the level of significance of the test statistic. These values reflect the probability that the DEA financial performance measure for the two samples of business segments come from the same universe. For example, in 1983 the test-statistic value is 0.374 indicating that the defense-business segments were better off financially than
the non-defense-business segments. The 0.0002 in the body of the graph is the level of significance (two-tailed) for the test statistic and indicates that there is nearly a zero probability that the two samples came from the same population. Thus, the difference in DEA performance measures between the two samples is because of difference in financial performance and not due to the sample distribution.

As can be seen from Fig. 1, there is a steady worsening in the financial condition of the defense segments relative to the non-defense segments from 1983 through 1989. The test statistic steadily increases from 0.374 in 1983 to 1.259 in 1989 with the related probabilities being nearly 100% that the defense segments were doing better than the non-defense segment in 1983 but by 1989 the non-defense segments were outperforming the defense segments (but the
difference is not statistically significant). Thus, during that seven-year period, there is a complete reversal in the fortunes of the defense segments relative to the non-defense segments. In 1983, the defense segments appear to be making a greater contribution to the success of the firms than are the non-defense segments. By 1989, this is reversed and non-defense segments are making a greater contribution to the financial health of the firms.

However, after 1989 the results are mixed. There is no statistical significance in the difference in performance between the categories of business segments in 1990 and 1992. But in 1991, defense segments significantly outperformed non-defense segments.

4.2. Comparison to other studies

Three of the studies noted earlier (Bowlin, 1995, GAO, 1986, and DoD, 1985) include years which overlap the time period covered by my study. Therefore, in this section, I provide a brief comparison of those studies and my current research.

Bowlin’s (1995) findings differ from those obtained in this study. Bowlin (1995, pp. 545–547) found that the financial condition of non-defense firms was better than that of defense firms for the years included in my current study (1983–1992) and found the difference to be statistically significant for many of those years. However, Bowlin (1995, p. 544) assessed performance at the firm level and used firm-level variables such as market value, stockholders’ equity, and other variables. A possible explanation for this difference is that defense firms were outperformed by non-defense companies, but the defense firms’ weaker performance was caused, at least partially, by the weak contributions made by their non-defense segments.

The only year to overlap between the DoD study and my current study was 1983, and DoD’s findings for that year (see DoD, 1985, pp. V-29, V-32, V-41, V-42) were similar to this current study. Based on versions of return on assets and return on sales ratios, DoD concluded (p. V-58) that defense firms outperformed non-defense firms. The GAO study also supports the findings of my current study and found (see GAO, 1986, pp. 85–92) that defense contractors outperformed commercial firms for the years 1980–1983 on return on assets, return on sales, and return on equity.

Other studies such as FEI (1987, pp. 11–12) predicted that defense business would become unprofitable because of changes in the defense-acquisition environment. The results of my research, as shown in Fig. 1, indicate that there was a deterioration in financial condition of defense-business segments through 1989. However, since then the financial condition of defense-business segments has improved relative to the non-defense segments to the point where there is no statistical difference between the two categories of segments.
4.3. Virtual weight analysis

To obtain insight into the DEA financial performance ratings, the contribution each input and output makes to the DEA rating was analyzed. This was done by reviewing the optimal virtual weights (i.e., $u^*$ and $v^*$ from model (1)) applied to each variable in the DEA model. For each business segment, the contribution each input and output variable makes to the DEA rating for that unit was determined by taking the proportion that each input and output variable’s virtual weight is of the total of the virtual weights assigned to each unit. For example, a defense business segment of one of the firms in my study had the following optimal virtual weights for 1992: operating profit $= 0.00007$, sales $= 0.00014$, operating cash flows $= 0.00096$, and assets $= 0.00006$. The total of these virtual weights is 0.00124. Thus, operating profit’s proportion of and contribution to the DEA rating received by this segment was 5.6% ($0.00007/0.00124$). The virtual weight proportion was used instead of the absolute value of the weight because the absolute value is not comparable across business segments since it would be influenced by the size of the input or output variable value similar in effect on the coefficient in regression analysis.

Fig. 2 shows the average percentage weight each variable contributed to the DEA rating. For example, in 1983 sales contributed, on average, 42.8% of the weight used in determining the DEA rating. Operating expenses contributed 47.9% of the virtual weights. The closeness in proportions for these two weights is not unexpected since the difference between sales and operating expenses is only the operating profit. At the other end of the continuum, operating profit contributed very little to determining the DEA rating. In some years, operating profit was virtually ignored.

These findings are the result of the DEA model placing each business segment in the best light possible and are interpreted to mean that operating profit was not a significant factor in assessing the overall financial performance of the segment and determining the DEA rating. However, sales and operating expenses were influential factors.

4.4. Ratio analysis

In order to provide additional detail on the financial performance of defense-business segments and insight into the DEA ratings, ratios available from the data used in the DEA model and commonly used to analyze financial performance are reviewed. The ratios include asset turnover (AT), return on sales (RoS), cash-return on sales (CRoS), return on assets (RoA), and cash-return on assets (CRoA).

Fig. 3 compares average actual asset turnover (sales/identifiable assets) for the defense and non-defense samples. It shows that for the entire study period, defense segments have a higher asset turnover than non-defense segments.
Defense segments were able to better use their assets to generate sales than were non-defense segments. However, between 1983 and 1989 there is a deterioration in the defense segments ability to generate sales. Then, beginning in 1990 there is an upturn in the AT ratio, and it appears that defense segments are beginning to generate an improved level of sales for their level of assets.

Figs. 4–7 present the average actual RoS, CRoS, RoA, and CRoA for the defense and non-defense samples. Generally, these ratios show a decline in the financial performance of the defense-business segments through 1989 and the beginning of a recovery from 1990 to 1992. While defense segment performance declined through 1989, the financial ratios indicate that non-defense segment financial performance generally improved or remained the same.

Summarizing, in the first year covered by this study (1983), all ratios show the defense segments outperforming the non-defense segments. By 1989 this has reversed with all of the ratios (except asset turnover) showing that the non-defense segments were performing better. Then during the later years of the
study, 1990–1992, the ratios show that defense segments were generally improving their financial performance relative to the non-defense segments.

The results for the ratio analysis parallel those of DEA and offer some insights into, and support for, the DEA ratings presented in Fig. 1. For example, in 1983, all the ratios consistently show a better financial performance for the defense-business segments as compared to the non-defense segments. Consequently, there is obvious agreement between the DEA results, which showed that the defense segments significantly outperformed the non-defense segments, and the ratios.

In other years, the ratios do not necessarily favor one category of segments over the other and thus, highlight a difference between ratio analysis and data envelopment analysis and reflect how ratio analysis might complement DEA by providing information not readily available from DEA. For example, in 1987 the ratios reflect a mix of financial performance with RoS and CRoS indicating that non-defense segments perform better and the RoA, CRoA, and

![Fig. 3. Average observed asset turnover. Asset Turnover equals Sales/Identifiable Assets. The values in the table under the graph are the average observed asset turnover for defense and non-defense business segments. For example, in 1983 defense segments had an average of $3.279 of sales for each dollar of identifiable assets.](image-url)
AT ratios indicating the defense segments are financially healthier. Thus, in 1987 non-defense segments were better able to convert their sales to profits and cash flows than were defense segments. But, defense segments were better able to use their assets to generate profits, cash flows, and sales than were non-defense segments.

Recall that the DEA results (see Fig. 1) indicate that in 1987 the defense segments were rated financially healthier than the non-defense segments but the difference was not statistically significant (a test statistic value of 0.854 with a level of significance of 0.269). This might be expected because of the mix of results shown by the ratios.

In 1989, all of the ratios, except AT, show the non-defense segments outperforming the defense segments. This corresponds with the DEA rating which shows that the non-defense segments had a higher average DEA rating than did the defense segments. However, the difference in DEA ratings between the two categories of segments was not statistically significant (see Fig. 1).

Fig. 4. Average observed return on sales. Return on Sales equals Operating Profit/Sales. The values in the table under the graph are the average observed return on sales. For example, in 1983 defense segments had an average return on sales of 9.4%.

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</tr>
<tr>
<td>Non-defense Segments</td>
<td>•</td>
<td>0.055</td>
<td>0.071</td>
<td>0.067</td>
<td>0.043</td>
<td>0.079</td>
<td>0.066</td>
<td>0.064</td>
<td>0.068</td>
<td>0.040</td>
</tr>
</tbody>
</table>
As previously mentioned, the only ratio to favor the defense segments in 1989 was asset turnover. Also, the weight analysis findings (see Fig. 2) indicated that sales were a significant factor in determining the DEA ratings. Thus, the AT ratio in conjunction with the weight analysis would seem to indicate that a reason for the difference between defense and non-defense 1989 DEA ratings not being statistically significant is the sales variable. Even though the RoS, CRoS, RoA, and CRoA ratios indicate that non-defense segments performed better financially than defense segments, the strength of the sales variable apparently kept the difference in DEA ratings from being statistically significant.

Note that using average ratio values to provide insight into the DEA ratings should be done with caution (Bowlin, 1995, p. 548). DEA uses an optimizing principal which focuses on the individual business segment and does not use averages. Thus, average ratios may not completely correspond with DEA ratings. Second, reviewing multiple average ratios separately may not capture

Fig. 5. Average observed cash-return on sales. Cash-Return on Sales equals Operating Cash Flows/Sales. The values in the table under the graph are the average actual cash-return on sales. For example, in 1983 defense segments had an average cash-return on sales of 11.7% while non-defense segments had an average cash-return on sales of 10.3%.
the simultaneous interactions among variables that is captured in the DEA model.

4.5. **DEA with sales deleted as an output**

In the data envelopment analysis discussed earlier, sales were considered an output variable, and the weight values (i.e., $u_k$ in (2)) which correspond to the sales variable indicated that sales were influential in determining the DEA ratings. In addition, recall that the asset turnover ratio indicated that defense-business segments were able to generate more sales per dollar of assets than were non-defense-business segments. Hence, to test the sensitivity of the previous DEA results to including sales as an output variable, I completed a DEA evaluation deleting sales as an output variable. The new DEA model had two outputs: operating income and operating cash flows, and two inputs: operating expenses and identifiable assets.
Fig. 8 compares the DEA test statistic for the two model formulations, i.e., the first model with sales as an output variable and the second model with sales deleted from the model. As before, the numbers in the body of the paper indicate the level of significance for the test statistic – the probability that the defense segment financial performance, as indicated by the DEA performance measure, is statistically significantly different from the non-defense segments.

Excluding sales as an output does make a difference in my findings. The results of this analysis show a significant deterioration in the financial contribution made by defense-business segments through 1990. For the time period from 1983 to 1990, the financial condition of defense segments is worsening relative to the non-defense segments as was true when sales was included as an output in the DEA model. However, the decline is much more severe when sales is eliminated as an output variable.
The change in results is especially interesting for the years 1988–1990. When sales are included as an output, the results indicate that the financial performance of defense and non-defense business segments is not statistically different. This is changed when sales are deleted as an output. Under this case, non-defense segments have significantly better financial performance than did defense segments for 1988–1990.

These results further confirm the AT ratio findings (see Fig. 3) that defense segments generated greater level of sales than did non-defense segments during 1988–1990. This follows from the expectation that if defense sales are relatively higher than non-defense sales, then when sales are used as an output, I would expect the defense businesses to receive a relatively higher DEA rating if defense sales were relatively higher than non-defense sales (all other factors being equal). The results of the initial DEA model support this scenario. On the other
hand, when sales are deleted as an output, I would expect defense business to be considered relatively inefficient and receive a lower DEA rating than non-defense business. This is the findings from the second DEA model. These results also imply that defense-business segments had lower profitability and cash flows than did non-defense segments.

In summary, the results from the DEA analysis deleting sales as an output complement the DEA evaluation where sales are considered an output and the ratio analysis. The aggregate effect of these analyses is that it appears that the defense-business segments did a relatively good job in generating sales for 1988–1990, but did not convert these sales into operating profits and cash flows.

4.6. Limitations

There are limitations of this research which may influence the conclusions reached. Perhaps the most important one for this study is the scarcity of data on which to base the assessment. I was only able to use publicly reported data which are very limited. Consequently, important performance measures may have been excluded. For example, the number of employees for each business segment was not available which may result in a bias favoring labor-intensive firms and industries and a bias against capital-intensive firms.

A second limitation is the possibility of mis-classifying a business segment as non-defense when it should actually be considered a defense-business segment. Some firms do not identify a business segment as defense in the title or do not clearly identify the amount of defense business a segment accomplishes. Consequently, there is a chance that a business segment classified as non-defense should have been classified as defense. It is also possible that a business segment may provide a product to another company with the end product of that company being sold to the DoD. In other words, the business segment is a subcontractor on a defense contract. These types of transactions are not generally identified in the annual report. Therefore, this business segment may be improperly characterized as non-defense. However, I attempted to minimize these mis-classifications by closely scrutinizing the annual reports and other company literature.

Third, the makeup of business segments is not static during the ten-year period covered by this research. Mergers, acquisitions, divestitures, and reorganizations occurred and all affected the character of business segments.

Fourth, it is necessary to rely on accounting data reported in accordance with FASB (1976). There is a possibility of inconsistent accounting treatment and reporting practices between companies even when following SFAS No. 14.

Finally, there is no proven theoretical construct for the variables used. However, the individual elements and resulting ratios are in common use and have face validity, i.e., the variables used in the model are reasonable.
5. Summary

In this research, I approached financial analysis of the defense industry in a way different from approaches used in the past. First, I focused on defense-business segments instead of the whole company or specific defense contracts as was common in the past. Second, I used data envelopment analysis along with the more traditional financial ratio analysis. The purpose behind using a different methodological approach (i.e., DEA) in this study was to take advantage of the characteristics of the DEA methodology and illustrate its potential as an alternative and complementary tool for financial analysis. In addition, when dealing with potential public policy considerations as I am here, it is important that a question be reviewed from different perspectives so that policy makers can feel more comfortable in reaching a decision. DEA provides this different view. The DEA evaluations were buttressed by a variety of other assessments to include reviewing DEA virtual weight information and ratio analyses.

The results of these evaluations (DEA and ratio analyses) show that in 1983 defense-business segments clearly outperformed the non-defense segments. Then between 1983 and 1989/1990 there was a steady decline in the DEA financial performance rating and financial ratios of defense segments versus non-defense segments. This indicates a deterioration in the financial contribution of defense-business segments relative to non-defense-business segments for the firms sampled. The difference in performance between the two categories of segments narrowed during that time period, and by 1988 non-defense segments were performing better than defense segments on most of the financial performance measures used in my study.

The two DEA analyses (one with sales as an output measure and one excluding sales) assessed in conjunction with one another and asset turnover ratio analysis indicate that defense segments did a better job in generating sales than non-defense segments. But, during the 1988–1990 time period the defense segments did not turn these sales into profits and net cash inflows.

Finally, the years 1990–1992 show the financial performance of defense segments beginning to recover, and the defense segments generally outperform the non-defense segments (although for some of these years the performance gap is not statistically significant). Thus, there is an indication that companies have been able to adjust their business strategies and operations to the changing defense acquisition environment.

Although there are indications that the financial performance of defense segments was improving by 1992, this segment of the economy needs to be continually monitored since the defense-acquisition environment continues to evolve. Policy makers need to be kept aware of financial trends in the defense industry in order to appropriately consider the industry’s ability to contribute to both domestic-economic policy and foreign policy.
References


