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Strategic management decision support for a firm in pursuit of the displaced ideal utilizing data envelopment analysis and entropy

Velayas, James Michael, Ph.D.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

STRATEGIC MANAGEMENT DECISION SUPPORT FOR A FIRM IN PURSUIT OF THE DISPLACED IDEAL UTILIZING DATA ENVELOPMENT ANALYSIS AND ENTROPY

James Michael Velayas, B.S., M.S., M.B.A.

A Dissertation Presented to the Faculty of the Graduate School of Saint Louis University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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A firm engaged in competition with other firms is constantly evolving as it pursues its goal of maximizing shareowner wealth. This evolution can be thought of as the firm pursing the goal of becoming the ideal firm.

An ideal firm would be one that embodies all of the superior characteristics of the firms that are in competition with one another. Clearly, with the passage of time firms become more efficient and effective in the pursuit of their goal. So as the firms change so does the ideal firm's characteristics.

The purpose of this research is to develop a procedure and illustrate the use of data envelopment analysis (DEA) and entropy as analytical techniques in providing strategic guidance to the firm.

The information provided by the companies evaluated under this procedure will originate from the companies' annual reports. This research will use the set of the seven publicly traded Bell Holding Companies in the formation of the empirical database. The database will be used to illustrate the procedure developed in this research.

The database will contain financial and operational information concerning each firm's performance. Then this information will be linked with DEA and entropy measures and will provide a normative framework upon which each firm's decision makers can determine the direction they wish to follow in pursuit of the ideal.

The analysis will be conducted based upon the publicly available information contained in the seven companies annual reports during the years 1984 through 1989. Additionally a qualitative dimension will be incorporated into the study to provide additional insight.

This research will present the value of DEA and entropy being linked together as a procedure to assist in the strategic management of the firm. The ability to apply these two nontraditional analytical methods in providing strategic direction to the firm will be shown to be a valuable managerial asset.

COMMITTEE IN CHARGE OF CANDIDACY:

Professor Reuven R. Levary,
Chairperson and Advisor

Professor Ik-Whan Kwon

Associate Professor Thomas V. Wright

DEDICATION

This effort is dedicated to my wife Jan. Throughout the long and difficult demands associated with this study, she was always there with her love, understanding and encouragement.

ACKNOWLEDGEMENTS

As this study draws to a close, I would like to acknowledge the contributions made by many fine people.

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To my friends and colleagues through the years who have always been there with your friendship.

Finally, to my parents James and Marianne and siblings Fred, Patty and John. In good times and bad, you have always been there with your love.

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CHAPTER 1

INTRODUCTION

A firm engaged in competition with other firms is constantly evolving as it pursues its goal of maximizing shareowner wealth. This evolution can be thought of as the firm pursing the goal of becoming the ideal firm.

An ideal firm would be one that embodies all of the superior characteristics of the firms that are in competition with one another. Clearly, with the passage of time firms become more efficient and effective in the pursuit of their goal. So as the firms change so does the ideal firm's characteristics.

The firm's senior management is constantly striving for the means to transform their firm into becoming the ideal firm. In this pursuit the ability to leverage the firm's resources, or inputs, to maximize shareholder wealth, or outputs, is management's overriding challenge.

The fundamental aim of this digest is to provide a normative procedure within which the firm can identify and pursue the ideal. This normative procedure will be general in nature and as such it can be easily extended

to any combination of competitive firms that may be candidates for evaluation.

Information Sources

As the information age advances, the firm's senior managers find themselves being subjected to myriad providers of information based on which decisions can be made. However, the availability of this bountiful supply of information providers does have its drawbacks. For the firm's management must allocate resources to: seek out who the appropriate information providers are; determine the value of the various providers information; and then select - and pay for - the information. The resources required to select the appropriate set of providers reduces the resources available to evaluate the information and decide upon the optimal managerial course to follow.

Print information providers range from the daily local newspaper; to national daily newspapers; to weekly financial publications; and to a wide array of information specialists. Electronic information providers include news retrieval services; computerized data bases; and real-time subscription services.

When confronted with this overload of potential information, the firm's managers may find themselves in the position of allocating their research resources in

a nonoptimal manner. Specifically, the management may find themselves spending an inordinate amount of time in trying to decide which information providers to utilize. Time that could be better utilized in the analysis of the information.

In this decision making environment not only are the number of providers enormous, but also the types of information they are offering differ. While most, to one degree or another, rely on the interpretation and modelling of quantitative data, others present qualitative interpretations of relevant information.

Hence, the decision maker confronts an ever increasing array of information providers to select from. Based upon the information provided to the firm's management, decisions are then made.

Corporate Reporting

Among the publicly traded corporations in the United States the primary source of information concerning corporate operations comes from the corporations themselves. Corporations are required to provide information concerning their ongoing operations.

While most corporations provide a wide variety of information to the potential investor, perhaps the single greatest source of information relating to the

firms ongoing operational and financial results are to be found in the firm's annual report (Shohet and Rikert 1989). In each annual report the balance sheets from the firm's most recent two years and the income statements from the most recent three years can be found.

Thus, it would seem rational that the annual report would constitute one of the most important components in the decision maker's arsenal of information. Additionally, the information available is consistent as the decision maker looks at the reports of those firms that are considered to be the main competitors of the firm.

Bell Holding Companies

On January 1,1984 seven new telecommunications companies were created as the result of a consent decree (Temin 1987) entered into by the United States Government and the American Telephone & Telegraph Company (AT&T). The seven companies created by the divestiture are known as the Bell Holding Companies (BHCs) and are called Ameritech, Bell Atlantic, Bell South, Nynex, Pacific Telesis, Southwestern Bell and US West.

These companies were formed by geographically dividing up the regulated telephone and yellow pages

advertising holdings of AT&T in the 48 contiguous states.

As newly constituted companies they were allowed to enter new and unregulated lines of business subject to limitations outlined in the consent decree. These new lines of business changed the nature of these companies away from that of being a completely regulated monopoly and towards that of being a competitive company in its nonregulated lines of business. However, in the telephone operations areas they are still fully regulated.

In this new environment that the BHCs find themselves competing in, they are also competing for the investor and are subject to the reporting regulations of all other publicly traded companies.

Additionally, these firms find themselves competing for the attention of the investment community as well as investors. Clearly, given the tremendous homogeneity that exists between these companies, the greater the overall efficiency of the firm the greater will be the likelihood of the firm's success in attracting not only the desired attention but also the investor's funds.

Research Purpose

The purpose of this research is to develop a procedure and illustrate the use of data envelopment analysis (DEA) and entropy as analytical techniques in providing strategic guidance to the firm.

The information provided by the companies evaluated under this procedure will originate from the companies' annual reports. This research will use the set of the seven publicly traded Bell Holding Companies in the formation of the empirical database. The database will be used to illustrate the procedure developed in this research.

The database will contain financial and operational information concerning each firm's performance. Then this information will be linked with DEA and entropy measures and will provide a normative framework upon which each firm's decision makers can determine the direction they wish to follow in pursuit of the ideal.

The analysis will be conducted based upon the publicly available information contained in the seven companies annual reports during the years 1984 through 1989. Input measures, or the raw material with which a firm had to conduct its business, will be based upon each firm's balance sheets. Output measures for how

well each firm utilized its resources will be drawn from each firm's income statement.

Additionally a qualitative dimension will be incorporated into the study to provide additional insight. The narratives included in the annual reports often include reviews of business successes and failures. These narratives will be evaluated in the review of the quantitative findings.

A Caveat

The database formed for this study is designed to provide an illustrative example of applying the normative procedure developed in this paper. The inputs, outputs and ratios used in this study aren't necessarily the key variables of the BHCs themselves. Different stakeholder groups may select different data with which to conduct the analysis based upon their own requirements.

In the actual application of this procedure the selection of variables would be a critical step in the analysis. While this caveat will be stressed throughout the study, the reader should keep it in mind while reading this study.

Value of Research

This research will present the value of DEA and entropy being linked together as a procedure to assist

in the strategic management of the firm. The ability to apply these two nontraditional analytical methods in providing strategic direction to the firm will be shown to be a valuable managerial asset.

While the companies involved in this research will be limited to the seven Bell Holding Companies, the systematic application of the methodology applied could be extended. Other corporations and sectors of the economy where the companies' lines of business are homogeneous could gain from this approach.

Additionally the linkage of data envelopment analysis and entropy to the strategic management of the firm will allow for an enrichment of the literature in both areas.

Summary of Research

Chapter two will contain a thorough literature review of the relevant information. A review of the development of DEA and entropy will be presented. Beyond this a presentation on some of the relative points on strategic management and multiple criteria decision making will be made.

Chapter three will develop the normative procedure that will be presented in this study. The mathematics of DEA and entropy will be presented as they relate to this study. The specific type of information to be utilized

will be presented. Also the rationale behind the application of the procedure to the BHCs will be presented.

Chapter four will present the empirical data used in this research process. Also the development and execution of the analytical models on the data will be presented. The expert decision making system will be based on the results of the executions of these analytical models.

Chapter five will focus on an analysis of the results from the models developed and executed in chapter four. A separate section will be presented for each of the seven BHCs included in this study. In this chapter the expert decision making system will be fully realized.

Chapter six will provide a bridge between the quantitative findings of this study and some of the managerial decisions of the firms. Through this qualitative discussion greater insight may be gained into the firm's actions during the years covered by this study.

Chapter seven will then summarize the findings of this research and suggest future areas of research based upon these findings.

CHAPTER 2

REVIEW OF RELATED LITERATURE

The first portion of this review will be on the strategic management function and its niche in today's business environment. This review will focus on the important aspect of explicability. Explicability is the ability of management to explain its objectives and the business rationale behind those objectives.

In the second part of this review of the related literature, the focus will be on the implications of firms that have homogeneous industry influences. The established relevance of evaluating firms in the context of a competitive environment framework will be presented.

The final component in this review will be on the analytical methods which are utilized in this study. Both data envelopment analysis (DEA) and entropy are reviewed. This review will focus on both the historical development of DEA and entropy as well as applications utilizing these procedures. The review will be expository in nature. A detailed mathematical treatment of both procedures will be presented in chapter 3.

Strategic Management

The strategic management function is one of connecting rational and analytical evaluation procedures with the realities of the firm's behavioral and political environment (Fahey 1981). This linkage of knowing what should be done and being able to communicate that message to the firm's various stakeholders is one of the key responsibilities of the firm's management (Freeman 1984).

The strategic management literature on decision making implementation is well summarized by Nutt (1989). In his work he presents the four implementation tactics of intervention, persuasion, participation and edict. Depending upon the internal circumstances and the external pressures upon the firm, differing methods may be required.

As Freeman (1984) develops his presentation on strategic management he argues that competition is the cornerstone of our capitalistic society. In this context it is clear that management's ability to explain its actions vis-a-vis the competition would be well received by the firm's various stakeholders.

Zeleny (1982) provides a linkage between operational, tactical and strategic management. He sees the functions of these three groups as being those of efficiency, effectiveness and explicability,

respectively. Thus, decisions must integrate the functions of the these three management groups as they are implemented.

The opportunity to incorporate a procedural change in management strategy may be more difficult to accomplish depending on the tenure of the corporation's CEO. Miller (1991) provides evidence that the longer the tenure of the CEO, the greater is the reluctance of management to change strategy to improve the organization's performance. Thus, it may be that the ability of a decision to be explicable is of even greater importance to well entrenched management teams.

Homogeneous Industries

When firms engage in homogeneous lines of business those firms' overall returns are known to be positively correlated. Thus, it follows that competition is not only an emotional state but is also a well established economic condition.

Firms in competition with one another are not only competing in the marketplace but also compete for the attention of the investment community. Thus, the ability of the firm to market, or explain, its actions relative to its competitors can result in the firm improving its performance in the financial markets.

In this section a review of the research responsible for this finding will be presented along with procedures utilized in determining which firms within a given sector are the most efficient.

Industry Effect

The relationship of stock price movement among firms in similar lines of business was subjected to statistical analysis by King (1960). In this work he tracked the performance of 63 publicly traded securities during a period of over 30 years.

King's conclusion was that after removing the overall market effect, individual stock returns were highly correlated by industry grouping. Furthermore all large positive correlations were found among firms operating in homogeneous industries.

Meyers (1973) augmented King's study with additional firms and industries. Overall he found that at differing time intervals and in different industry groups the industry effect varies significantly. He was able to confirm King's findings while introducing the concept that the industry component varies by time and by industry.

Further evidence of industry effect has been presented by Perry, Henderson and Cronan (1984) and by Altman and Katy (1976). In these works involving the

analysis and prediction of corporate bond ratings they found specific industry information knowledge contributed to the success of their analysis.

Hassell, Jennings and Lasser (1988) show that the estimation of firm earnings is enhanced through the use of industry data. Also Scanlon, Trifts and Pettway (1989) showed that shareholder wealth is diminished when large firms acquire firms outside of their specific industry. These two studies combine to show that from different points-of-view industry knowledge has significant impact on both the ability to predict and attain earnings.

As Reilly (1979) points out, industry affiliation in the investment decision making process is very important. Within the Markowitz (1952 and 1959) framework the positive correlations that firms in homogeneous industries share with respect to their earnings add little to portfolio diversification and risk reduction. Thus the clear implication is that the investor should be parsimonious when it comes to the selection of which stocks to include in the portfolio when the stocks are from companies in homogeneous industries.

Evaluation Procedures

In this section the focus will be on the current analytical procedures utilized when evaluating firms

engaged in homogeneous industries. As such it will not focus on firms across industry lines. Thus many of the traditional methods utilized in the evaluation of investment alternatives that focus on firms engaged in heterogeneous industries will not be reviewed here.

Insight can be gained on firms that engage in homogeneous activities when financial information first becomes available from one of the firms in the sector. Foster (1981) showed that intra-industry earnings announcements appear to be related. Clinch and Sinclar (1987) showed that not only are the earnings announcements related but that they also flow in the same direction within the industry sector.

Within the context of evaluating firms in homogeneous industries one of the more traditional means of comparing firms is through ratio analysis. Schall and Haley (1980) point out that ratios can be used to help evaluate a firm's liquidity, leverage, activity and profitability or alternatively state how effective the firm is in achieving its objective of maximizing shareowner wealth.

The application of ratio analysis continues to be researched and developed. Altman (1968) incorporated multiple discriminant analysis into the application of ratio analysis and Deakin (1976) suggests a normal distribution on financial accounting ratios within

industry groups. However, the continued use and abuse of ratio analysis is fraught with controversy.

Lev and Sunder (1979) charge that the application of financial ratios is based upon tradition and convenience. They are of the opinion that the application of such ratios does not rise from a firm theoretical foundation nor from a careful statistical analysis. However, it is clear from the popularity of ratio analysis that it remains a viable method of evaluating the firm.

Following the work of Sharpe (1963 and 1971), Elton, Gruber and Padberg (1979) have developed a multi-index approach in the selection of individual securities from within an industry. While Sharpe had originally conceived of relating the returns of a security with a market index return, Elton, Gruber and Padberg relate the securities return to the market index as well as an industry index.

Elton, Gruber, and Padberg (1979) have also employed a matrix inversion solution procedure to arrive at the optimal portfolio selection according to their assumptions. Earlier solution procedures had employed quadratic programming and piecewise linear programming approximations in arriving at optimal solutions.

The evaluation of firms in the investment process is of the utmost importance. However, the most common form of decision making in the stock selection process falls into the realm of what Zeleny (1982) refers to as inspirational or intuitive decision making. With so many decisions on whether or not to invest and with so much information both quantitative and qualitative upon which to base the decision, it is not surprising that after careful consideration of the facts the decision maker is "inspired" to make the optimal decision.

In the investment decision environment one of the most relied upon sources of information is the security analyst. Indeed these analysts are quite often the decision making model. Levine and Sunder (1975) observe that within the decision making framework of firms within an industry he separates the firms into subgroups with similar growth prospects and then selects those companies that he believes will fare best in the current and expected economic environment.

It is apparent that while some efforts have taken place in the area of evaluating firms in homogeneous industries, opportunities exist to strengthen the existing body of knowledge.

Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a fairly recent development in the decision and management sciences. In this section an overview of the development, extensions and applications of DEA will be presented. Most of this development has occurred during the past decade and provides a fertile area for research and applications.

DEA Development

The first publication of Data Envelopment Analysis was by Charnes, Cooper and Rhodes (1978). The work by Charnes and Cooper (1985) provides an excellent treatment in introducing the concept of DEA as well as summarizing the foundations upon which DEA has been developed. They also provided a rigorous mathematical derivation and provide proofs of the underlying theoretical structure.

Charnes and Cooper (1985) review the introduction of DEA as an analytical procedure developed to help measure the efficiency of Decision Making Units (DMUs). Charnes and Cooper (1985) show that DMUs efficiency measures are based upon the use of the input units to produce the output units. DEA doesn't require that any a priori weights or functional relationships exist

between the inputs and outputs, nor do the units of measure need to be of homogeneous origin.

In assessing the attainment of efficiency, Charnes and Cooper (1985) restrict and formalize their definition of efficiency to be that of pareto optimality or that of relative efficiency as opposed to true or theoretical efficiency. Although, if a theoretical efficiency is known to exist then DEA conforms to that higher constraint. Under this relative efficiency concept any given DMU is said to be 100% efficient relative to the other DMUs only when the prior DMU can't be shown to be inefficient.

In DEA, relative efficiency is formally defined by Charnes and Cooper as follows:

> 100% efficiency is attained for any DMU only when:
> (a) None of its outputs can be increased without either:
> (i) increasing one or more of its inputs or
> (ii) decreasing some of its other outputs.
> (b) None of its inputs can be decreased without either:
> (i) decreasing some of its outputs or
> (ii) increasing some of its other inputs.
> (Charnes and Cooper 1985,75)

Therefore, under DEA the DMUs are rated on how efficiently they utilize their inputs to produce their output relative to all the other DMUs in the group.

In the next chapter of this digest the modelling process will be formally introduced along with the

attended mathematical constructs. For the present discussion it will suffice to state that the original DEA formulation appears as a nonlinear problem with linear fractional objective function and linear fractional side constraints. However, Charnes and Cooper (1985) have shown that the model can be reformulated to appear as an ordinary linear programming problem in terms of both the objective function and side constraints.

Evidence to date indicates that DEA outperforms the heavily utilized ratio analysis (index numbers) and regression approaches in not only the evaluation of efficient DMUs, but also of more importance in being able to identify sources of and estimating amounts of inefficiency in the DMUs (Bowlin et al. 1985 and Sherman 1981). However, it should be pointed out that in DEA analysis it is assumed that once inefficiencies are detected then corrective action is possible. Thus, DEA is seen as an intervention oriented analytical procedure.

However, if corrective action is not possible or will not be taken, DEA may not be the proper procedure. If the goal is to predict future behavior then the application of regression based approaches may be the appropriate analytical technique (Bowlin et al. 1985).

DEA Extensions

Since the development of DEA, numerous additional refinements have been introduced to enhance the analytical effectiveness of the process. Primary among these extensions has been the development of the "window analyses" concept.

In DEA a potential problem is in the lack of sufficient "degrees of freedom." This occurs when, as in a statistical regression based procedure, the number of inputs and outputs combined approaches the number of DMUs. As this condition arises the efficiency scores must be approached with caution (Charnes et al. 1985).

In conducting window analyses the objective is to essentially create additional DMUs by disagregating the data. The data for each DMU is segmented across time, and efficiency measures are recomputed for the set of DMUs at each point in time. As a result of this windowing process it becomes possible to track the performance of the DMUs at the macro level and also the performance of each DMU over time.

Another extension to DEA is the comparison of DMUs via the use of "facets." Since DEA is based upon relative efficiency ratings the selection of the appropriate efficient DMUs to contrast with the inefficient DMU is an important consideration, especially when more than one DMU may be judged to be

100% efficient. The DEA optimization process tends to select DMUs with high degrees of similarity within the evaluation process so that the efficient DMUs can contribute to the understanding of the inefficient DMUs.

Bessent, Bessent and Elam (1988) proposed an extension to DEA that they refer to as Constrained Facet Analysis (CFA). They call upon the work of Clark (1983) to attest to the difficulty in interpreting inefficient units under traditional DEA. According to Bessent, Bessent and Elam (1988) the determination of the frontier from where the evaluation of inefficient DMUs can be made is modified to improve the efficiency measures.

Another area of DEA that continues to be developed is that of sensitivity analysis. Charnes et al. (1985) point out that traditional methods of sensitivity analysis utilized in ordinary linear programming are not directly applicable under DEA. This is primarily due to the fact that in linear programming it is assumed that the inverse of the simplex tableau is unaffected by the variations to the outputs being considered.

Charnes et al. (1985) develop procedures for examining variations to a single output for a particular DMU. They single out 100% efficient DMUs and

determine ranges of variation where the efficiency rating is not adversely impacted.

DEA Applications

In the decade since the original work in DEA the applications have been focused on the areas of education, health services and military operations. It doesn't appear any research has been conducted in the evaluation of profit making institutions.

In the educational area Bessent and Bessent (1980) applied DEA in comparing the efficiency of 55 different schools. Output measurements of school performance were the reading and mathematics test scores from the California Achievement Test at the end of the academic year. Input measurements included the same test scores from the end of the previous year; measures of neighborhood and home conditions; school organizational climate indicators; and an index measurement to asses the degree of individualized instruction. The paper found DEA to be a significant improvement over presently used procedures, including statistical regression, for management information.

Other applications of DEA in education can be found in Bessent et al. (1982) and Charnes, Cooper, and Rhodes (1981).

In the health services field the work by Bowlin et al. (1985) evaluates the efficiency of 15 hypothetical hospitals with DEA, ratio analysis and statistical regression. The outputs in this study consist of the number of regular patients and severe patients treated as well as the number of medical students taught. The input units consist of bed days available, dollars spent on supplies and staff size. The study concludes that of the three procedures considered DEA is the superior method to assess the efficiency of the hospitals operations.

Other applications of DEA in the health sciences can be found in Banker, Conrad and Strauss (1986), Sherman (1981).

Measuring the efficiency of military operations is yet another area where DEA has been applied. Charnes et al. (1985) apply DEA to evaluate efficiency of maintenance units at United States Air Force tactical fighter wings. The objective is to determine the efficient tactical fighter wings and in so doing find out which wings are inefficient and where the inefficiencies exist.

In this study the output measures consist of number of sorties flown; number of hours the wing's aircraft were and were not capable of fulfilling their mission; and maintenance completed on time. Input

measures included number of aircraft; force manpower available; external factors impacting operations such as weather and air traffic control; and the need to cannibalize aircraft for spare parts.

Additional applications to military operations can be found in Bowlin (1987); to academic operations in Tomkins and Green (1988); and to bank branch operations in Sherman and Gold (1985).

Entropy

Entropy as an analytical procedure has enjoyed success in a wide variety of applications since its initial development. In this section an overview of the development, extensions and applications of entropy will be presented.

Entropy Development

While the early development of entropy can be traced back to the 1870's Shannon and Weaver's work (1949) provides a detailed development of the process in communications theory. It is presented in Levine and Tribus (1979) that the name entropy was suggested to Shannon by John Von Neuman from the concept in thermodynamics.

Entropy is a measure of the amount of information conveyed by a given information source (Zeleny 1982). Alternatively stated it is a measure of the uncertainty

surrounding a transmitted message (Levary and Choi 1987).

Entropy Applications

Since the work by Shannon and Weaver (1949) the application of entropy has been extended to a wide variety of disciplines.

In the two volume work by Erickson and Smith (1988a and 1988b) an extensive review of theoretical foundations and applications is presented.

Kuhn (1963) and Horowitz and Horowitz (1976) present a review on the economic and business applications of entropy. Their work provides the historical perspective of the business application of entropy. So a framework rationalizing the application of entropy in the business environment exists.

Other applications of entropy range from psychiatry (Neufeld 1977) to bacterial populations (Kaneka, Atlas and Krichevsky 1977). Thus it is readily apparent that entropy has enriched the level of knowledge in many disciplines.

Summary

The study that follows links together the concepts developed in this review and unites data envelopment analysis and entropy in an analytical procedure. This procedure is then used to assist in the strategic

management of the firm. Measuring the efficiency of the firm, determining prime areas for improving the firm and communicating how the firm is going to improve to the firms stakeholders is the fundamental purpose of the procedure.

CHAPTER 3

THE NORMATIVE PROCEDURE

In this chapter the normative procedure will be developed. The development of this procedure will focus on both the managerial rational and the quantitative techniques utilized in the procedure.

The procedure will begin by developing a formal goal of a competitive firm. This will illustrate the relevance of the procedure in the corporate mission. The strategic managerial environment will be the focus of the procedures framework.

After the establishment of the framework, a review of the two quantitative techniques will be presented. This review will present the relevant mathematical statements, assumptions and theorems of both data envelopment analysis (DEA) and entropy.

Following the development of DEA and entropy the application of the procedure to the evaluation of industries engaged in homogeneous businesses will be developed. This development will focus in on the seven Bell Holding Companies (BHCs) and it will illustrate how it could be applied in evaluating other competitive sets of companies.

This application to the evaluation of competitive firms will be an extension to the areas where DEA and entropy have been applied. It will also be the first linkage of the two analytical techniques.

Foundation

Within the competitive environment firms struggle against one another to become the best or most successful company. This procedure utilizes as a framework the concept expanded on by Zeleny (1982) of the displaced ideal.

However, as Zeleny points out later in the same work, it is not enough to pursue the displaced ideal. Management must be able to explain to its various stakeholders the rationale behind its actions as it pursues this ideal.

Displaced Ideal

The concept of the displaced ideal as utilized in this work is that a company strives to attain the set of attributes that represent the best states achieved by all competitors and itself. For example the ideal firm could have the highest revenue, fewest assets, least debt and so on of all the firms in the competitive set. Mathematically this can be stated as:

Let $x_{i,j}$ represent the measure of the ith attribute for the jth company where:

$i = 1, 2, \ldots, m;$

$j = 1, 2, \ldots, n;$

m = number of attributes; and

n = number of companies.

Then let x^*_i represent the best $x_{i,j}$ value across all j firms in the competitive set for each attribute i. Depending on the variable measured the best could be either the largest or the smallest value.

Hence, the ideal nonexistent firm, n+1, would posses as a set of measures the best measure for each attribute across all firms. While it may well be impossible for any real firm to achieve the dimensions of this ideal firm it is, nevertheless, set up as a goal to be strived for.

The concept of the displaced ideal arises in that over time the firms in the competitive set evolve. That is the $x_{i,j}$ assume differing values at different points in time. As such at each point in time the ideal firm assumes different values of its attributes. It would seem conceivable that after periods of time that ideal firms early on could evolve into becoming inferior to actual firms later on.

Framework

It would seem that a reasonable goal of a firm is to pursue the displaced ideal within the context of its competitive set. Given this the DEA and entropy based analytical techniques provide a framework for the firm to address this goal.

In the section on DEA in this chapter a procedure for evaluating efficiency in a displaced ideal context is developed. DEA affords the management of the firm the opportunity to ascertain their performance relative to the ideal. Additionally they can relate this performance next to all of the other companies in the competitive set.

It is not enough, however, for the firm to be able to evaluate its efficiency. It must be able to take this knowledge and transform that into useful and meaningful actions. Then, be able to explain those actions in a well known environment.

The section on entropy will detail a procedure for incorporating the attributes employed in the DEA procedure to develop an explicable action plan. The plans would be based upon the widespread acceptance of financial ratio analysis.

DEA Mathematics

This section will rely heavily on the work of Charnes and Cooper (1985) and Charnes et al. (1985). Their work provides the seminal treatment of DEA and as such forms the cornerstone of all DEA developments. The objective of this section on DEA is to provide the reader with an overall understanding of DEA and as such will be rather limited in scope. For additional details including mathematical proofs and motivations the above sources should be reviewed.

DEA Model and Notation

In this development the notation used will conform to the format of Charnes and Cooper (1985). The model is designed so that two conditions are met. The first condition is that inputs and outputs are weighted so that each unit is compared to all others and is constrained not to be larger than the best input/output ratio for any DMU and secondly, the weights are constructed to give the largest ratio value for any unit subject to the first constraint.

Symbolically this may be expressed as:

$$\text{Maximize: } h_{jo} = \Sigma^{s}_{r=1}\, u_r y_{ry} \,/\, \Sigma^{m}_{i=1}\, v_i x_{ijo} \qquad (1)$$

Subject to:

$$\Sigma^{s}_{r=1}\, u_r y_{rj} \,/\, \Sigma^{m}_{i=1}\, v_i x_{ij} \leq 1 \qquad (2)$$

for all j;

and:

$$u_r, v_i, x_{ij}, y_{rj} > 0 \qquad (3)$$

for: $i = 1,\ldots,m;\quad j = 1,\ldots,jo,\ldots,n;$

and $r = 1,\ldots,s.$

where: x_{ij} = the observed input of the i-th type for the j-th DMU,

y_{rj} = the observed output of the r-th type for the j-th DMU,

jo = the jo-th DMU being evaluated,

u_r and v_i are calculated by the model.

The maximum $h_{jo} = h^*_{jo} = 1$ is required for efficiency so when $h^*_{jo} < 1$ implies that efficiency has not been achieved. A separate h^*_{jo} is determined for each DMU under consideration and so the pareto optimality conditions can be determined from the "n" optimizations.

Accompanying this model is an important theorem regarding the measurement units associated with the inputs and outputs. This theorem states that the optimal h^*_{jo} is independent of units in which the inputs and outputs are measured as long as they are the same for each DMU (Charnes and Cooper 1985). So while there is no need to be concerned with measurement units it may be desirable to scale units of measure from time-

to-time so that the appearance of the data sets are consistent for reasons of presentation.

Equivalent Linear Program

The conceptional fractional programming model presented above allows an effective basis upon which the concept of efficiency can be developed. However, in order for the model to be operational in form it is transferred into an ordinary linear programming model.

The transformation will not be duplicated in this study. However, a treatment on the development of this transformation can be found in Charnes and Cooper (1985).

Under DEA the equivalent linear programming model is symbolically stated as:

Maximize: z_o

Subject to:

$$y_{ro}z_o - \Sigma^n_{j=1} y_{rj}\lambda_j + s^+_r = 0 \qquad (4)$$

for $r = 1,\ldots,s$

and:

$$\Sigma^n_{j=1} (x_{ij}\lambda_j) + s^-_i = x_{io} \qquad (5)$$

for $i = 1,\ldots,m$

and:

$$y_{rj},\ x_{ij} > 0 \qquad (6)$$

$$\lambda_j,\ s^+_r,\ s^-_i \geq 0 \qquad (7)$$

for: $i = 1,\ldots,m;\quad j = 1,\ldots,jo,\ldots,n;$

and $r = 1,\ldots,s.$

where: y_{rj} = the r-th valued output measurement for DMU j

x_{ij} = the i-th valued input measurement for DMU j

λ_j = model determined weight for the j-th DMU

s_r = r-th amount of output slack

s_i = i-th amount of input slack

This model is constructed for each DMU under consideration. The optimal z^*_o calculated for each DMU is an inefficiency value. The optimal h^*_{jo} value is determined by taking the reciprocal or that $h^*_{jo} = 1/z^*_o$. For every DMU the efficiency measure will be bounded between 0 and 1. So a DMU with an h^* of 95 is only 95% as efficient as the most efficient DMU.

While DEA was developed with a nonlinear fractional programming approach the transformation of the problem to the more traditional linear programming form allows for the application of some of the more traditional analytical procedures.

Slack conditions are encountered for inefficient DMUs when the efficient DMUs are getting greater output per unit of input. Hence, the traditional connotation associated with "slack" variables in linear programming hold for the extension to DEA.

One difference in the terminology associated with DEA methodology as opposed to the traditional linear programming is in the term "opportunity cost." Here opportunity cost is referred to as how much the value of the objective function would improve if one unit of input was withdrawn. This improvement in efficiency which would be achieved by producing the same level of output with one less unit of input is due to the model solving for the reciprocal of the efficiency value (Bessent and Bessent 1980).

The Mathematics of Entropy

In this section a discussion of entropy will be presented. Entropy has a much longer and richer history as an analytical technique. Extensions and greater detail beyond the level of this presentation can be found in Levine and Tribus (1979), Zeleny (1982) and Levary and Choi (1987).

Entropy Model and Notation

Traditionally, financial ratios have been utilized to compare firms with one another (Schall and Haley

1980 and Boyadjian and Warren 1987). However, one of the difficulties with ratio analysis is that different ratios transmit different pieces of information. These differences can serve to confuse the decision maker as the decision process evolves.

Entropy serves as a method to estimate the uncertainty surrounding a message and a measure of information in each message. So with the financial and operational ratios providing a source of information it serves to utilize entropy to evaluate the information content of each ratio.

Each ratio can be thought of as sending a piece of information to the decision maker. Under entropy the signals s_k (where k = 1, 2, ..., m) occur at random with probabilities P_k. Then the total entropy, H, of the stochastic process that is generating these signals is defined as:

$$H = - \sum^{m}_{k=1} P_k \ln P_k \qquad (8)$$

Let $x_{i,k}$ (all $x_{i,k} > 0$) be the value of the i-th ratio (where i = 1, 2, ..., n) for the k-th firm (where k = 1, 2, ..., m). Also x_i^* is defined as the best or ideal value of the i-th ratio. With x_i^* being either the largest or smallest $x_{i,k}$ for each ratio define $D_{i,k}$ as being the closeness of $x_{i,k}$ to x_i^* where:

$$D_{i,k} = \begin{cases} x_{i,k} / x_i^* \text{ when } x_i^* = \max x_{i,k} \\ \quad \text{for each i across all k.} \\ \\ x_i^* / x_{i,k} \text{ when } x_i^* = \min x_{i,k} \\ \quad \text{for each i across all k.} \end{cases} \qquad (9)$$

In evaluating entropy three types of calculations are possible depending upon the source of the uncertainty under consideration. Joint or total entropy calculations relate the n ratios to the m companies. Marginal entropies could be computed for either the ratios or the companies with each being independent of the other. Finally, a conditional entropy of the importance of a ratio to a company could be measured.

It is the conditional entropy measurement that this study will focus on. Additional, detailed discussion on joint, marginal and conditional entropy is available in Theil (1967) as well as Levary and Choi (1987).

The conditional entropy of ratio i to ranking the companies is measured as:

$$H(d_{i,k}/d_i) = \Sigma^m_{k=1} (d_{i,k}/d_i) \ln(d_i/d_{i,k}) \qquad (10)$$

$$\text{Where: } d_{i,k} = D_{i,k} / \Sigma^n_{i=1} \Sigma^m_{k=1} D_{i,k} \qquad (11)$$

$$\text{and:} \quad d_i = \Sigma^m_{k=1} d_{i,k} \; . \tag{12}$$

The conversion of the $D_{i,k}$ to $d_{i,k}$ allows all $x_{i,k}$ to be converted into the [0,1] interval. The largest entropy measure, H_{max}, occurs when all $d_{i,k}/d_i$ are equal and H_{max} results in a value of ln(m). By normalizing the entropy calculations of the $d_{i,k}/d_i$ by H_{max} results in the entropy measure of the relative importance of the i-th ratio, $e(d_i)$, being of the form:

$$e(d_i) = -(1/\ln(m)) \; \Sigma^m_{k=1} \; (d_{i,k}/d_i) \ln(d_{i,k}/d_i) \tag{13}$$

This allows the entropy measures to fall in the interval [0,1] and can be used to assign relative weights of importance to the companies. By definition, the larger the $e(d_i)$ the smaller is the value of the i-th ratio. By convention, the quantity $1-e(d_i)$ is computed so that the larger the value the greater the importance of the ratio.

A weighing system is now developed so that a direct relationship exists between the relative weights of the ratios and the entropy measures . Let θ_i be the relative weight of the i-th ratio. Then θ_i needs to fulfill the characteristics of:

$$0 \leq \theta_i \leq 1; \tag{14}$$

and

$$\Sigma^{n}_{i=1}\ \theta_i = 1. \qquad (15)$$

The first requirement (14) is fulfilled by the quantity $1 - e(d_i)$ so the second requirement (15) becomes the binding one. To satisfy this requirement normalize the quantity $1-e(d_i)$ by letting:

$$\theta_i = [1 - e(d_i)] \ / \ (n - E) \qquad (16)$$

where E is the total entropy across all of the ratios and is defined as:

$$E = \Sigma^{n}_{i=1}\ e(d_i). \qquad (17)$$

So each θ_i represents the weighted value of each of the n ratios and the larger the value of θ_i the greater is the value of the information contained in the i-th ratio.

A Priori Information

Initially, the decision maker may have some a priori inclination as to which ratios may be of greater value. Even if initially it was considered that the value of each ratio was identical that may not be true over a given time interval. For example consider that at time t = 0 the decision maker may have no a priori beliefs regarding which of the ratios contain the

greatest amount of information. However, at the end of the first time period, t = 1, clearly the decision maker obtains some information as to which ratios will be concentrated on during the time period t = 2. Thus, at the end of t = 2 the decision maker has a priori beliefs from t = 1.

Let w_i be the a priori relative importance of the i-th ratio. Combining this weight in a Bayesian fashion with the relative importance obtained in the entropy calculation results in a combined weight of λ_i defined as:

$$\lambda_i = \theta_i w_i \; / \; \Sigma^n_{i=1} \; \theta_i w_i \qquad i = 1, 2, \ldots, n. \qquad (18)$$

Note that the two characteristics of a weighing function, equations (14) and (15), still hold in that each lambda is bounded between zero and one and that the sum of the lambda's is equal to one.

Analysis of Ratios

For each of the k firms in the competitive set, a measure of each firms closeness to the best ratio value across all n ratios is:

$$S_k = \Sigma^n_{i=1} \; \lambda_i \; (d^*_i - d_{ik}). \qquad (19)$$

By this definition the smaller the S_k value the closer is the k-th firm to the weighted overall best

set of ratios. Each S_k value will range between zero and one. If a firm had the best financial and operational ratio for each of the n ratios under consideration then its S_k value would be zero.

With the S_k values it becomes possible to determine the proportion of information conveyed by each individual ratio for each firm. For the k-th firm determine for each of its n ratios the quantity:

$$\pi_{ik} = (d^*_i - d_{ik}) \; / \; S_k. \qquad (20)$$

Here the larger the π_{ik}-th ratio the greater is the distance of the k-th firm from the best valued i-th ratio. With this data it now becomes possible to rank the impact that each of the ratios has in both an ordinal and absolute fashion.

This ranking allows management to identify those ratios where the firm has the greatest potential for improvement. Thus a basis is formed which relates the disparate financial and operational measures. Upon this basis management gains an element of explicability as it relates to its planned actions.

DEA and Entropy Linkage

The link between DEA and entropy is accomplished through the communality of the DEA based input and output measures and the ratios analyzed under entropy.

That is the DEA variables are utilized to create the ratios for the entropy calculations.

To illustrate this linkage let α and β represent the sets of DEA input and output variables respectively. Then, in order to link the DEA and entropy let the set of ratios to be evaluated in the entropy analysis be represented by δ. The set δ should be defined from the elements of α and β. This will logically link the efficiency calculations from DEA to the explicability rationale developed in the entropy analysis.

Later is this chapter a section on the variables selected in this study will be presented. However, in the selection of variables the analyst must combine a priori knowledge on which variables and ratios are the most important in the competitive set under analysis. Beyond this the variables and the ratios should share a relationship so that they are homogeneous in the nature of the information they contain. This linkage is key to providing a common basis of data in the procedure.

The selection of inputs and outputs to be analyzed becomes a source of much concern and deliberate thought. No procedure is suggested here regarding which variables should be selected. Indeed, it may very well be that in different competitive environments different variables may be required. However, the ability to

construct meaningful ratios from the inputs and outputs is extremely important in utilizing this procedure.

In this procedure DEA provides insight on the under performing variables and entropy provides specific information on which ratios offer the greatest opportunity for improvement. This linkage fulfills the two fundamental objectives of this procedure which are: (1) a basis upon which managerial decisions can be made in the firm's pursuit of becoming the ideal firm; and (2) an ability to explain the rationale behind the firm's specific actions to the firm's various stakeholders.

Bell Holding Company Analysis

To illustrate the application of the normative procedure, a data set will be developed. This data will cover a competitive set formed by the seven regional Bell Holding Companies (BHC).

BHC Background

At midnight on January 1, 1984 the American Telephone and Telegraph Company (AT&T) divested itself of its state regulated telephone operations and its yellow pages operations (Temin 1987). In so doing seven new publicly traded companies were formed (Ameritech, Bell Atlantic, Bell South, Nynex, Pacific Telesis, Southwestern Bell, and US West) with each having assets

in excess of 20 billion dollars and over 60,000 employees. These companies are referred to as the Bell Holding Companies or the BHCs.

While the BHCs have somewhat diversified their lines of business since divestiture their largest revenue sources are still their regulated telephone and yellow pages operations. Additionally, while some of the diversification efforts that have taken place are unique, e.g. Nynex operating retail computer stores or U.S. West providing financial services, most of the diversification efforts tend to be along homogeneous lines. Specifically, they are providers of cellular services; paging systems; and sellers of telecommunications equipment; albeit that they have all entered these markets to differing degrees and in different geographic locations.

The focus of this study will be on the performance of the seven BHCs during the five year period, 1985 to 1989 inclusive. The first year of their operation, 1984, is omitted from this analysis due to the accounting irregularities and inconsistencies on their financial reports as a result of the divestiture.

DEA Relevancy

The performance of the BHCs will be evaluated with respect to their efficiency. This efficiency evaluation

will be based upon the DEA methodology of determining how much output is generated by each BHC given the various levels of inputs they had available. Thus in this treatment each BHC may be thought of as a DEA decision making unit (DMU).

It is important to note that in DEA a distinction is made between the efficiency of DMUs and the effectiveness of DMUs (Charnes et al. 1985). DEA focuses in on the efficiency and not the effectiveness of the DMUs under consideration. The efficiency is in the utilization of inputs to produce the desired outputs. Whether or not a DMU is effective is viewed as a managerial judgement and as such is not part of the DEA analysis.

DEA is a relevant methodology to measure the efficiency due to the fact that the BHCs engage in homogeneous industries. From an operational point-of-view DEA should prove to be an extremely relevant methodology not only due to the fact that efficient and inefficient BHCs will be determined, but also that the sources of the inefficiencies can be found along with estimates generated of the amount of inefficiency at each BHC (Bowlin et al. 1985).

Entropy Relevancy

While DEA will identify and rank efficiency the application of entropy will allow a means to evaluate where adjustments should be made. Through the application of entropy on various financial and operational ratios the firm's management is in a position to explain their proposed actions.

Entropy is a relevant and logical link to DEA in this analysis. This is due to the homogeneous nature of the information contained in the DEA and the set of relevant financial and operational ratios. Entropy allows the inputs and outputs utilized in the DEA analysis to be evaluated in a ratio analysis. It is then possible to determine which ratios the differing firms should be focusing their efforts on.

To illustrate this linkage consider the case when number of employees could be one of the DEA input variables and firm revenue could be one of the DEA output variables. Then, in the entropy analysis one of the ratios could be average revenue per employee which provides the linkage between DEA and entropy.

Data Sources

In the execution of this analysis the chief source of information are the annual reports generated by the BHCs. From Shohet and Rikert (1989) it is known that

access to the BHCs balance sheets and income statements is publicly available information. Thus, these annual reports will form the input and output data sets.

In this analysis the BHCs balance sheets will be considered as the companies' "inputs." That is the balance sheets report the companies assets, liabilities and shareholders' equity at the end of the fiscal year (the fiscal and calendar years coincide at all BHCs). Thus, these are the resources with which the companies enter the new fiscal year.

To evaluate the efficiency of the firms operations the income statement will be viewed as the BHCs output data set. At the end of every fiscal year the companies document their revenues, expenses, taxes and net income on the income statement and in so doing make available their accomplishments during the fiscal year.

As the BHCs entered their fiscal year of operation on January 1, 1985 the information regarding the balance sheet data they carried with them is available. In a similar manner at the end of the fiscal year on December 31, 1989 the income statement reports the results of their operations. Thus, using the information from these two sources provides the requisite data sources with which this procedure can be conducted.

However, as it will be expanded upon in the later portions of this chapter, this analysis will not be limited to the inputs from 1985 and the outputs from 1989. Rather the set of inputs and outputs from all years between 1985 and 1989 inclusive will be included in the course of this analysis.

Variable Selection

As was previously mentioned great care must be exercised in the selection of the variables. In the construction of the DEA model there are three primary factors which must be considered when determining which variables are to be included in the input and output (Bessent and Bessent 1980, Bowlin et al. 1985 and Charnes and Cooper 1985) . These three considerations are:

- Selection of input variables that are "discretionary" or controllable by management.
- Selection of "nondiscretionary" or uncontrollable inputs when they are believed to have significant effects.
- Adhering to the "degrees-of-freedom" concept in limiting the total number of inputs and outputs to be less than the number of DMUs.

After considering these issues tables 1 and 2 present the five variables, of which three are input and two are output variables, which will form the basis of the data set in this study. Other variables

may be more appropriate in other situations and the analyst should exercise care and deliberation in the selection process. However, for purposes of this study these five variables form a reasonable set.

It should be stressed here that these variables were selected only to illustrate the application of this studies methodology. These variables and the ratios formed from them later on in this chapter are by no means purported to be "the best" data for these or any other sector of industry. Indeed, variable and ratio selection could constitute a separate research endeavor.

Table 1

Input Variables

Input	Description
TOTAST	The total assets of the firm less accumulated depreciation.
TOTLIB	The total liabilities of the firm.
TOTEMP	The total number of employees in the firm.

Table 2

Output Variables

Output	Description
REVENUE	The companies total revenue.
NETINC	The companies net income as a percent of revenue.

Clearly the single most constraining consideration arises from the degrees-of-freedom constraint. With seven DMUs six or fewer variables must be entered into the analysis to allow for the distinction between efficient and inefficient DMUs to be made. Hence, the selection of five permits as great a distinction to be made as possible while retaining the essence of the firms operational measures.

In the selection of the three input variables the only variable that is not from the companies' balance sheet is the number of employees. However, in these times of firms dramatically altering their workforce composition the recognized impact of the size of the employee population on profitability makes it a key variable.

The two balance sheet variables of total assets and total liabilities represent the two key components of the balance sheet. Company management is in effect using these two categories to produce the firm's output

and as such has considerable influence on the composition and utilization of these categories.

In determining the output measures, revenue is clearly a key measure of the firm's output as are the firm's ability to control expenses. The revenue reporting of these companies differs from the reporting of most publicly traded companies with respect to the revenues section. Since these companies are regulated with respect to their telephone operations these revenues are reported separately from their nonregulated lines of business. As a result of this the growth, in terms of revenue, of these separate lines of business becomes possible. However, in this analysis the focus will be on the firm's total revenue across all lines of business.

On the expense side, a similar single aggregate measure of net income will be included as a measure of firm output. This seems logical in that the management of these companies would view expense control as a critical managerial obligation regardless of the line of business that is being operated. However, it would once again be possible to segregate the regulated and unregulated net incomes if desired.

Ideal Firm Data

With the goal of the firm being to pursue the ideal firm it is necessary to quantify the ideal firm. In this analysis the ideal firm posses all of the best characteristics of the firms in the competitive set.

In this study, the ideal firm will be a composite of the firm with the fewest assets, liabilities and employees. It will also have the greatest revenue and net income as a percent of revenue figures.

Each year it becomes possible to determine the characteristics of the new ideal firm. This allows for the concept of the displaced ideal (Zeleny 1982) to be incorporated into the analysis.

Financial Ratios Generated

Drawing upon the work of Schall and Haley (1980) and Westwick (1973) a series of financial ratios will be computed utilizing the same data used to generate the DEA estimates and their relationship to those estimates will be examined. Five financial ratios will be generated from the variables selected.

The specific ratios generated are the debt, profit margin on sales, total assets turnover, return on equity and employee revenue ratios. The debt ratio is formed by dividing total liabilities, an input, by another input, total assets. The asset turnover ratio

is formed by dividing an output variable, revenue by assets, an input variable. The profit margin is the companies' net income as a percent of revenue and is the output variable NETINC. The return on equity for each company is defined as the output net income divided by the difference between the two input variables assets and liabilities multiplied by 100. The average revenue generated per employee is the output variable total revenue divided by the input variable number of employees.

These ratios are illustrative of the types of ratios that could be derived from the inputs and outputs utilized in the DEA analysis. Clearly, if in a specific industry sector certain ratios are considered to be extremely important then the selection of the DEA variables should reflect these concerns.

Window Analysis

One of the developments in DEA has been the development of the "window" concept (Charnes et al. 1985). Under window analysis additional efficiency measures of the DMUs are made over time. That is, the set of original DMUs are considered to be different as they operate in different time periods.

BHC Windows

Returning to the BHCs as the DMUs in the approach outlined calls on each of the seven companies to be evaluated as to their efficiency during the period between 1985 and 1989. Under the windowing procedure each of the BHCs can be considered as different entities during each fiscal year. The most direct interpretation of this approach would call on an analysis for each of the seven BHCs for each of the five years of operation plus the ideal firm each year.

Under this scenario there will be 40 separate DMUs in the efficiency evaluation. However, it is the objective of this study to conduct an extended analysis. In this analysis five separate executions of the procedure will be made.

Table 3 presents a summary of the number of DMUs and years covered in each execution.

Table 3

Number of DMUs by Group Size

Execution	Years Included	Number of DMUs
1	1985 Only	8
2	1985 to 1986	16
3	1985 to 1987	24
4	1985 to 1988	32
5	1985 to 1989	40

To illustrate the windows approach consider one of the DMUs. In the first execution with windows of size one the DMU is evaluated in 1985. This evaluation is against the other six DMUs and the ideal firm. In the second execution for 1985 and 1986 each DMU from each of the two years along with the two ideal firms is used in the analysis. This process continues until the fifth execution when the 35 actual DMUs and the five ideal firms are included.

This systematic sequential growing of the database allows for the examination of efficiency shifts over time. From this it is possible to simulate what the strategic options were had this procedure been followed over the stated time frame.

Summary

In this chapter the formal DEA model has been presented in both its original nonlinear fractional form and in its equivalent linear programming form. Entropy as a measure of information content of financial and operational ratios was presented. This was followed by the procedural linkage between DEA and entropy.

The Bell Holding Companies were introduced as the sector of firms that this study will utilize in its empirical test as to the viability of this approach.

The specific sets of input and output measurements to be used in the DEA phase of the procedure were introduced. This was followed by a discussion of the financial and operational ratios that will be utilized in the entropy phase of the procedure.

Finally, this chapter covered the extension to window analysis as an analytical decision making model in the evaluation of a firm's efficiency. This methodology allows the financial decision maker to include all time frames in the efficiency evaluation of the firms.

The next chapter will apply the methodology developed in this chapter as it relates to the empirical BHC data. The application of this model to obtain the efficiency estimates will utilize software developed by the Center for Cybernetic Studies at the University of Texas at Austin (Assad 1986). Following this an analysis of those results will be conducted and suggestions for future research directions will be presented.

CHAPTER 4

TESTING OF THE NORMATIVE PROCEDURE

In this chapter the normative procedure as developed in Chapter 3 will be applied to the set of Bell Holding Companies. The data obtained from the companies' annual reports will be presented first. This will then be followed by the data envelopment analysis and entropy calculations. In Chapter 5 an extended analysis of these results will be conducted.

BHCs Quantitative Data

In this section the quantitative data obtained from the BHCs annual reports will be presented and some summary and descriptive statistics will be computed. This section will contain the input and output data for the DEA phase of calculations as well as the financial ratios for the entropy calculations.

Input Data

As mentioned in Chapter 3 three input variables are to be utilized in the analysis of the BHCs between 1985 and 1989 inclusive. Specifically, the total assets in millions of dollars (TOTAST), total liabilities in

millions of dollars (TOTLIB), and number of employees to the nearest hundred (TOTEMP) are the input variables. In the balance of this paper whenever dollars are the unit of measure they will be expressed in millions of dollars unless otherwise noted.

Tables 4 to 10 which follow present the input variable values in a separate table for each BHC. The input variable values were obtained from the previous year's annual report unless they were corrected in a subsequent annual report. For example the data for Ameritech in table 4 for 1985 was obtained from the company's 1984 annual report. In so doing the inputs available at the end of 1984, or beginning of 1985, are used to produce the 1985 outputs.

Table 4

Input Variables for Ameritec

Year	TOTAST	TOTEMP	TOTLIB
1985	17,635	74,100	10,547
1986	18,149	70,900	10,547
1987	18,739	71,200	11,130
1988	18,780	71,900	11,170
1989	19,163	71,900	11,319

Table 5

Input Variables for Bell Atlantic

Year	TOTAST	TOTEMP	TOTLIB
1985	18,684	82,800	11,175
1986	19,788	79,300	11,867
1987	21,091	80,200	12,770
1988	21,245	81,000	12,503
1989	24,729	81,000	15,552

Table 6

Input Variables for Bell South

Year	TOTAST	TOTEMP	TOTLIB
1985	23,673	96,000	14,258
1986	25,008	92,500	14,810
1987	26,218	96,900	14,956
1988	27,417	98,700	15,438
1989	28,472	100,300	16,633

Table 7

Input Variables for Nynex

Year	TOTAST	TOTEMP	TOTLIB
1985	19,853	94,900	11,999
1986	20,682	89,600	12,333
1987	22,032	90,200	13,164
1988	23,006	95,300	13,809
1989	25,362	97,400	15,942

Table 8

Input Variables for Pacific Telesis

Year	TOTAST	TOTEMP	TOTLIB
1985	18,433	76,900	11,951
1986	19,538	71,500	12,221
1987	20,321	74,900	12,568
1988	21,056	71,900	13,166
1989	21,191	69,700	13,106

Table 9

Input Variables for Southwestern Bell

Year	TOTAST	TOTEMP	TOTLIB
1985	18,042	71,900	11,047
1986	19,291	71,400	11,894
1987	20,300	67,500	12,482
1988	21,500	67,100	13,309
1989	20,985	64,900	12,481

Table 10

Input Variables for US West

Year	TOTAST	TOTEMP	TOTLIB
1985	17,100	70,800	10,452
1986	18,422	70,200	11,478
1987	20,048	69,400	12,769
1988	20,981	68,500	13,525
1989	22,416	69,800	14,630

Between 1985 and 1989, on the average, the BHCs increased the value of their assets by over 21% from $19,060 to $23,188 while at the same time increasing total liabilities by over 22% from $11,063 to $14,238. However, the employee population at the BHCs decreased

However, the employee population at the BHCs decreased by a little over 2% from an average of 81,100 to an average of 79,300.

Following the concept developed in Chapter 3 input data for the ideal firm is now presented. This hypothesized firm will be named "Ideal". The input values for each year are the lowest observed values for each real BHC firm in each year and are presented in the following table.

Table 11

Input Variables for Ideal

Year	TOTAST	TOTEMP	TOTLIB
1985	17,100	70,800	10,452
1986	18,149	70,200	10,699
1987	18,739	67,500	11,130
1988	18,780	67,100	11,170
1989	19,163	64,900	11,319

To illustrate the selection process utilized to build table 11 consider the year 1989. In that year Ameritec had the lowest dollar value of assets and liabilities of $19,163 and $11,319, respectively, of any of the BHCs. In that same year Southwestern Bell had the fewest employees of any BHC at 64,900.

Output Data

As detailed in Chapter 3 two variables are observed as the outputs from the BHCs operations in 1985 through 1989. They are the firm's total revenues in millions of dollars (TOTREV) and the firm's profit margin as a percent (PRMARG).

Tables 12 through 18 present the firms output variable values for each BHC. Unlike the input variables the output variables were obtained from each BHCs annual report for the year stated or from a future annual report where the figures have been corrected. That is, for example, the total revenues and net income reported for Ameritech in 1985 comes from the income statement in the 1985 annual report unless they were corrected in a subsequent annual report.

Table 12

Output Variables for Ameritech

Year	TOTREV	PRMARG
1985	9,058	11.9
1986	9,385	12.1
1987	9,548	12.4
1988	9,903	12.5
1989	10,211	12.1

Table 13

Output Variables for Bell Atlantic

Year	TOTREV	PRMARG
1985	9,084	12.0
1986	10,054	11.6
1987	10,747	11.5
1988	10,880	12.1
1989	11,449	9.4

Table 14

Output Variables for Bell South

Year	TOTREV	PRMARG
1985	10,664	13.3
1986	11,401	13.9
1987	12,230	13.6
1988	13,597	12.3
1989	13,996	12.4

Table 15

Output Variables for Nynex

Year	TOTREV	PRMARG
1985	10,314	10.6
1986	11,341	10.7
1987	12,084	10.6
1988	12,661	10.4
1989	13,211	6.1

Table 16

Output Variables for Pacific Telesis

Year	TOTREV	PRMARG
1985	8,498	10.9
1986	8,977	12.0
1987	9,156	10.4
1988	9,483	12.5
1989	9,593	12.9

Table 17

Output Variables for Southwestern Bell

Year	TOTREV	PRMARG
1985	7,925	12.6
1986	7,902	12.9
1987	8,003	13.1
1988	8,453	12.5
1989	8,730	12.5

Table 18

Output Variables for US West

Year	TOTREV	PRMARG
1985	7,819	11.8
1986	8,381	11.0
1987	8,697	11.6
1988	9,221	12.3
1989	9,691	11.5

With a few exceptions between 1985 and 1989 the BHCs as a group saw their total revenues increase by slightly more than 21%. Over the same 5 years the profit margins within each BHC, with a few exceptions, stayed in a rather narrow range.

Output data for the Ideal firm is generated following the procedure developed for selecting the input variables. However, this time the largest revenue and profit margins are selected. Following this procedure table 19 was constructed.

Table 19

Output Variables for Ideal

Year	TOTREV	PRMARG
1985	10,664	13.3
1986	11,401	13.9
1987	12,230	13.6
1988	13,597	12.5
1989	13,996	12.9

To illustrate table 19 consider the year 1989. In that year Bell South generated the largest revenue of $13,996 while Pacific Telesis had the highest profit margin of 12.9%. The other years of the ideal firm were selected in a similar procedure.

Ratio Data

Five ratios are to be used in the entropy phase of the procedure. The five ratios as defined in Chapter 3 are the debt (DEBT) in percent; profit margin (PRMARG) in percent; asset turnover (ASTURN) in percent; return on equity (ROE) in percent; and the average revenue per employee (REVEMP) in thousands of dollars. The data for the seven BHCs are contained in the following tables.

Table 20

Financial Ratios for Ameritech

Year	REVEMP	ASTURN	ROE	PRMARG	DEBT
1985	128	49.9	14.5	11.9	59.0
1986	132	50.1	15.0	12.1	59.4
1987	133	50.8	15.6	12.4	59.5
1988	138	51.7	15.8	12.5	59.1
1989	143	51.5	16.1	12.1	61.2

Table 21

Financial Ratios for Bell Atlantic

Year	REVEMP	ASTURN	ROE	PRMARG	DEBT
1985	115	45.9	13.8	12.0	60.0
1986	125	47.7	14.0	11.6	60.5
1987	133	50.6	14.2	11.5	58.9
1988	134	44.0	14.4	12.1	62.9
1989	145	43.7	12.5	9.4	67.2

Table 22

Financial Ratios for Bell South

Year	REVEMP	ASTURN	ROE	PRMARG	DEBT
1985	115	42.6	13.9	13.3	59.2
1986	118	43.5	14.1	13.9	57.0
1987	124	44.6	13.9	13.6	56.3
1988	136	47.8	14.1	12.3	58.4
1989	138	46.6	13.4	12.4	56.7

Table 23

Financial Ratios for Nynex

Year	REVEMP	ASTURN	ROE	PRMARG	DEBT
1985	115	49.9	13.1	10.6	59.6
1986	126	51.5	13.7	10.7	59.7
1987	127	52.5	13.9	10.6	60.0
1988	130	49.9	14.0	10.4	62.9
1989	138	51.0	8.6	6.1	63.8

Table 24

Financial Ratios for Pacific Telesis

Year	REVEMP	ASTURN	ROE	PRMARG	DEBT
1985	119	43.5	12.7	10.9	62.5
1986	120	44.2	13.9	12.0	61.8
1987	127	43.5	12.0	10.4	62.5
1988	136	44.8	14.7	12.5	61.8
1989	140	45.3	15.7	12.9	62.8

Table 25

Financial Ratios for Southwestern Bell

Year	REVEMP	ASTURN	ROE	PRMARG	DEBT
1985	111	41.1	13.5	12.6	61.7
1986	117	38.9	13.1	12.9	61.5
1987	119	37.2	12.8	13.1	61.9
1988	130	40.3	12.5	12.5	59.5
1989	132	41.3	13.1	12.5	60.5

Table 26

Financial Ratios for US West

Year	REVEMP	ASTURN	ROE	PRMARG	DEBT
1985	111	42.4	13.3	11.8	62.3
1986	121	41.8	12.7	11.0	63.7
1987	127	41.5	13.5	11.6	64.5
1988	132	41.1	14.5	12.3	65.3
1989	137	38.1	13.8	11.5	68.3

Financial ratios for the ideal firm are not generated since they will not be utilized in the entropy phase of this procedure. The concept of the ideal firm is not relevant to the entropy section of this methodology. The entropy process provides management with an ability to explain its firm's actions. Since the ideal firm takes no action there is no need to perform the calculations on the mythical firm.

DEA Model Preparation

In Chapter 3 the historical development of DEA was presented. The objective of this section is to provide the transition from the general form of the model to the operational form for the BHC case. Following this transformation the results of the executions of that model in all of the appropriate window configurations will be presented.

Model Statement

Taking the operational linear programming format from equations (4), (5), (6) and (7) and converting it to the specific requirements of the BHC case the specific form to be evaluated is:

Maximize: z_o (21)

Subject to:

$$y_{ro}z_o - \Sigma^7_{j=1}\, y_{rj}\lambda_j + s^+_r = 0 \quad \text{for } r = 1,2,3 \tag{22}$$

$$\Sigma^7_{j=1}\, (x_{ij}\lambda_j) + s^-_i = x_{io} \quad \text{for } i = 1,2 \tag{23}$$

$$y_{rj},\ x_{ij} > 0 \tag{24}$$

$$\lambda_j,\ s^+_r,\ s^-_i \geq 0 \tag{25}$$

for: $i = 1,2$; $j = 1,\ldots,jo,\ldots,7$; and $r = 1,2,3$.

where: y_{1j} = the TOTREV measurement for BHC j

y_{2j} = the PRMARG measurement for BHC j

x_{1j} = the TOTAST measurement for BHC j

x_{2j} = the TOTEMP measurement for BHC j

x_{3j} = the TOTLIB measurement for BHC j

λ_j = model determined weight for BHC j

s_r = r-th amount of output slack

s_i = i-th amount of input slack

This model is constructed for each BHC under consideration in each window configuration. The optimal

z^*_o calculated for each BHC is an inefficiency value. The optimal h^*_{jo} value is determined by taking the reciprocal or that $h^*_{jo} = 1/z^*_o$. For every BHC the efficiency measure will be bounded between 0 and 1.

Slack conditions are encountered for inefficient BHCs when the efficient BHCs are getting greater output per unit of input. Hence, the traditional interpretation associated with "slack" variables in linear programming hold for the extension to DEA.

Preparation of Computer Runs

In the preparation for the execution of DEA the first step was to obtain, install and verify the software required to conduct the analysis. The selected software was obtained from the Center for Cybernetic Studies at The University of Texas - Austin (Assad 1986).

The Computer program Additive was installed and tested on a COMPAQ DESKPRO 386s minicomputer without any special hardware or any additional software packages. The program was tested against benchmark data provided by the Center for Cybernetic Studies and the test results on the COMPAQ were identical to those in the accompanying documentation.

Window Structure

As detailed in Chapter 3 the ability to artificially increase the number of DMUs via the creation of windows is an important enhancement. In so doing finer differences in operational efficiencies can be detected.

In this analysis due to the annual recording of the data it is possible to construct windows of size one through five containing from eight to forty DMUs respectively. Table 3 in Chapter 3 illustrates this phenomenon.

In tables 27 through 31 the window structure for each computer run is illustrated. The word "in" in each table shows which DMUs are included in each computer execution.

To illustrate the tables consider table 27. It shows that with windows of size one that only the BHCs from 1985 plus the 1985 ideal firm will be in the run.

Table 27

BHCs in First Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	in				
Bell Atlantic	in				
Bell South	in				
Nynex	in				
Pacific Telesis	in				
Southwestern Bell	in				
US West	in				
Ideal	in				

Table 28

BHCs in Second Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	in	in			
Bell Atlantic	in	in			
Bell South	in	in			
Nynex	in	in			
Pacific Telesis	in	in			
Southwestern Bell	in	in			
US West	in	in			
Ideal	in	in			

Table 29

BHCs in Third Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	in	in	in		
Bell Atlantic	in	in	in		
Bell South	in	in	in		
Nynex	in	in	in		
Pacific Telesis	in	in	in		
Southwestern Bell	in	in	in		
US West	in	in	in		
Ideal	in	in	in		

Table 30

BHCs in Fourth Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	in	in	in	in	
Bell Atlantic	in	in	in	in	
Bell South	in	in	in	in	
Nynex	in	in	in	in	
Pacific Telesis	in	in	in	in	
Southwestern Bell	in	in	in	in	
US West	in	in	in	in	
Ideal	in	in	in	in	

Table 31

BHCs in Fifth Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	in	in	in	in	in
Bell Atlantic	in	in	in	in	in
Bell South	in	in	in	in	in
Nynex	in	in	in	in	in
Pacific Telesis	in	in	in	in	in
Southwestern Bell	in	in	in	in	in
US West	in	in	in	in	in
Ideal	in	in	in	in	in

So in the evaluation of efficiency under DEA as the time span is enlarged the number of DMUs in each window increases. As will be noted in Chapter 6 this feature allows for the possibility of greatly enhancing the procedure. However, in this study the focus is on the fundamental development of the methodology.

DEA Model Execution

In this section the results of the computer runs evaluating the BHCs efficiencies are detailed. Execution time for each run was under a minute of computer time. Appendix A of this digest contains the primary input files while appendix B contains the detailed output files from the runs.

The results of the five computer runs across the five window configurations are presented in tables 32

through 36. These tables are identical in structure to table 27 through table 31 in the previous section.

To illustrate the interpretation of these tables consider table 32. In this table the BHCs are evaluated on efficiency during 1985. The Ideal firm with a value of 1 has a relative efficiency rating of 100%. Ameritech with an efficiency of .952 was 95.2% as efficient as the ideal firm in 1985.

Table 32

BHCs DEA Results From First Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	0.952				
Bell Atlantic	0.873				
Bell South	0.754				
Nynex	0.791				
Pacific Telesis	0.908				
Southwestern Bell	0.953				
US West	0.975				
Ideal	1.000				

Table 33

BHCs DEA Results From Second Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	0.952	0.976			
Bell Atlantic	0.874	0.893			
Bell South	0.756	0.769			
Nynex	0.793	0.824			
Pacific Telesis	0.908	0.943			
Southwestern Bell	0.953	0.940			
US West	0.975	0.964			
Ideal	1.000	1.000			

Table 34

BHCs DEA Results From Third Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	0.952	0.976	0.945		
Bell Atlantic	0.858	0.874	0.858		
Bell South	0.742	0.769	0.729		
Nynex	0.778	0.808	0.800		
Pacific Telesis	0.899	0.923	0.890		
Southwestern Bell	0.941	0.920	0.939		
US West	0.975	0.955	0.929		
Ideal	1.000	1.000	1.000		

Table 35

BHCs DEA Results From Fourth Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	0.952	0.976	0.935	0.929	
Bell Atlantic	0.848	0.864	0.848	0.844	
Bell South	0.740	0.769	0.729	0.713	
Nynex	0.770	0.799	0.788	0.755	
Pacific Telesis	0.884	0.911	0.879	0.894	
Southwestern Bell	0.934	0.912	0.933	0.917	
US West	0.975	0.937	0.917	0.915	
Ideal	1.000	1.000	1.000	1.000	

Table 36

BHCs DEA Results From Fifth Computer Run

Company	Year 1985	1986	1987	1988	1989
Ameritech	0.946	0.961	0.926	0.921	0.910
Bell Atlantic	0.841	0.849	0.833	0.830	0.794
Bell South	0.736	0.769	0.729	0.701	0.686
Nynex	0.757	0.785	0.774	0.742	0.713
Pacific Telesis	0.878	0.895	0.864	0.878	0.894
Southwestern Bell	0.930	0.892	0.919	0.901	0.930
US West	0.975	0.931	0.900	0.898	0.874
Ideal	1.000	1.000	1.000	1.000	1.000

Continuing the interpretation now consider data in table 36. Here all of the BHCs across all of the years, and the Ideal firm, are evaluated at the same time. During 1985 Ameritech was estimated as being 94.6% as efficient as the ideal set of firms when all forty of the DMUs are evaluated as a group.

Contrast the Ameritech 1985 efficiency rating of 95.2% for 1985 in table 32 with the 94.6% rating in table 36. The difference may be attributed to the fact that the ideal has been displaced between 1985 and 1989. With the ideal firm having shifted over time the evaluation of Ameritech's 1985 results also shifts. An analysis of these results will be expanded upon in the next chapter. For now let it suffice to observe that if a set of firms are becoming more efficient over time then this sort of result is consistent and should be expected.

Entropy Calculations

In this section entropy calculations will be performed based upon the financial ratios data presented in table 20 through table 26. A separate entropy analysis will be conducted for each year in the study, 1985 to 1989. The goal of this analysis is to provide management with a rational for explaining the actions of the firm. These actions are to be based on

the widespread acceptance and familiarity that the financial ratios have among the firm's stakeholders.

Entropy - 1985

Table 37 presents the results of selecting the financial ratio data for the seven BHCs in 1985. The variable names and units of measure are as presented in the development of tables 20 to 26. Additionally, the abbreviations for the BHCs will be: AM for Ameritech; BA for Bell Atlantic; BS for Bell South; NY for Nynex; PT for Pacific Telesis; SB for Southwestern Bell; and US for US West.

Table 37

1985 Financial Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	128	49.9	14.5	11.9	59.0
BA	115	45.9	13.8	12.0	60.0
BS	115	42.6	13.9	13.3	59.2
NY	115	49.9	13.1	10.6	59.6
PT	119	43.5	12.7	10.9	62.5
SB	111	41.1	13.5	12.6	61.7
US	111	42.4	13.3	11.8	62.3

Next these ratios are normalized utilizing a standard Z transformation. This transformation allows the units of measure between the ratios to be uniform and the variances of the measures to be standardized. Table 38 presents the area under the standard normal

probability distribution between the computed z score and minus infinity.

Table 38

1985 Normalized Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.977	.903	.945	.500	.136
BA	.421	.579	.655	.540	.345
BS	.421	.242	.726	.933	.184
NY	.421	.903	.242	.081	.242
PT	.692	.345	.081	.159	.903
SB	.184	.136	.460	.212	.758
US	.184	.242	.345	.460	.864

Following the entropy development from Chapter 3, the $d_{i,k}$ quantities are determined from equation 11. These values are presented in table 39 .

Table 39

1985 $d_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	1.000	1.000	1.000	0.536	1.000
BA	0.431	0.641	0.693	0.579	0.394
BS	0.431	0.268	0.768	1.000	0.739
NY	0.431	1.000	0.256	0.087	0.562
PT	0.708	0.382	0.086	0.170	0.151
SB	0.188	0.151	0.487	0.227	0.179
US	0.188	0.268	0.365	0.493	0.157

Table 40 presents the $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ values computed following equation 10 in Chapter 3.

Table 40

1985 $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.360	.353	.355	.304	.364
BA	.263	.303	.315	.314	.259
BS	.263	.190	.328	.365	.339
NY	.263	.353	.186	.100	.306
PT	.328	.234	.088	.159	.145
SB	.161	.130	.269	.192	.162
US	.161	.190	.230	.293	.148

From the information contained in table 40 the quantities $e(d_i)$, θ_i and λ_i are computed. These quantities are computed from equations 13, 16 and 18 in Chapter 3. Table 41 presents the results of these computations.

Table 41

1985 $e(d_i)$, θ_i and λ_i Values

Ratio	$e(d_i)$	θ_i	λ_i
REMP	.925	.153	.153
ASTURN	.901	.202	.202
ROE	.910	.184	.184
PRMARG	.888	.229	.229
DEBT	.886	.233	.233

In table 41 note that the θ_i and λ_i values are identical. This is due to the fact that in the first iteration of this procedure no a priori concepts

regarding the importance of one ratio over the other are held.

Table 41 reveals that the information content of the debt ratio is greater than that of any other ratio. The debt ratio conveys 23.3% of the information content of all five financial ratios. The revenue generated per employee contains the least amount of information at 15.3%.

The next step in the procedure is to determine for each of the BHCs the ratio where the most improvement is possible. For each firm a value S_k is computed from equation 19 in Chapter 3. Table 42 presents the quantities $\lambda_i (d^*_i - d_{i,k})$ from which S_k is determined by summing across all ratios for each firm.

Table 42

1985 $\lambda_i (d^*_i - d_{i,k})$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT	S_k
AM	.000	.000	.000	.106	.000	.106
BA	.087	.073	.056	.096	.141	.453
BS	.087	.148	.043	.000	.061	.339
NY	.087	.000	.137	.209	.102	.535
PT	.045	.125	.168	.190	.198	.726
SB	.124	.171	.094	.177	.191	.757
US	.124	.148	.117	.116	.196	.701

The quantity S_k in table 42 is a weighted measure of the total distance the k-th firm is from having the best ratio value in each measurement. The S_k value from

each firm ranges between zero and one. A value of zero would imply that the firms ratio value was the best for each ratio. Thus no information would be available for where improvement could be made.

In 1985 Ameritech had the lowest total entropy measurement of .106 while Southwestern Bell had the highest at .757. It follows that Ameritech is closest to having the overall best set of ratios while Southwestern Bell has the worst set of ratios. Best and worst must be kept in the context of the five ratios under consideration and not necessarily across all potential sets of ratios.

The final step in the entropy calculations is to determine where the greatest potential for improvement exists for each firm. Table 43 presents the quantities, $\pi_{i,k} = [\ \lambda_i\ (d^*_i - d_{i,k})\ /\ S_k\ ] * 100$, computed for each ratio for each BHC.

Table 43

1985 $\pi_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	0.0	0.0	0.0	100.0*	0.0
BA	19.2	16.1	12.4	21.2	31.1*
BS	25.7	43.7*	12.7	0.0	18.0
NY	16.3	0.0	25.6	39.1*	19.1
PT	6.2	17.2	23.1	26.2	27.3*
SB	16.4	22.6	12.4	23.4	25.2*
US	17.7	21.1	16.7	16.5	28.0*

In Table 43 each $\pi_{i,k}$ represents the percentage improvement that was possible for each ratio to each of the BHCs. The trivial case for Ameritech is that the only way it could have improved its overall relative performance, S_k, was through its profit margin. Similarly, Nynex's greatest under performance was also with its profit margin. However, Ameritech also could improve its performance in all ratios except the asset turnover ratio.

At Bell Atlantic, Pacific Telesis, Southwestern Bell and US West those firms' greatest source for potential improvement was in the debt ratio. However, note that the potential for improvement varies by each firm. Bell Atlantic's debt ratio had the greatest room for improvement at 31.1% while Southwestern Bell's was the smallest at 25.2%. Also note that Bell South's area of opportunity for improvement was with respect to its under performance in the asset turnover ratio.

In Chapter 5 the discussion and analysis of these results as well as all other results in this chapter will be expanded upon.

Entropy - 1986

Table 44 presents the results of selecting the financial ratio data for the seven BHCs in 1986. The

variable names and units of measure are as presented in the development of the 1985 entropy measures.

Table 44

1986 Financial Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	132	50.1	15.0	12.1	59.4
BA	125	47.7	14.0	11.6	60.5
BS	118	43.5	14.1	13.9	57.0
NY	126	51.5	13.7	10.7	59.7
PT	120	44.2	13.9	12.0	61.8
SB	117	38.9	13.1	12.9	61.5
US	121	41.8	12.7	11.0	63.7

Next these ratios are normalized utilizing a standard Z transformation. Table 45 presents the area under the standard normal probability distribution.

Table 45

1986 Normalized Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.964	.841	.945	.540	.309
BA	.655	.692	.618	.345	.500
BS	.184	.345	.655	.955	.045
NY	.726	.903	.460	.115	.345
PT	.309	.382	.540	.500	.726
SB	.136	.081	.184	.788	.692
US	.382	.212	.067	.184	.933

Following the entropy development the $d_{i,k}$ quantities are determined from equation 11. These values are presented in table 46. Table 47 presents the

$(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ values computed following equation 10 in Chapter 3. From the information contained in table 47 the quantities $e(d_i)$, θ_i and λ_i are computed. These quantities are computed from equations 13, 16 and 18 in Chapter 3. Table 48 then presents the results of these computations.

Table 46

1986 $d_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	1.000	0.931	1.000	0.565	0.146
BA	0.679	0.766	0.654	0.361	0.090
BS	0.191	0.382	0.693	1.000	1.000
NY	0.753	1.000	0.487	0.120	0.130
PT	0.321	0.423	0.571	0.524	0.062
SB	0.141	0.090	0.195	0.825	0.065
US	0.396	0.235	0.071	0.193	0.048

Table 47

1986 $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.358	.344	.354	.291	.223
BA	.319	.322	.307	.231	.166
BS	.159	.230	.315	.356	.281
NY	.331	.351	.268	.114	.209
PT	.220	.243	.289	.281	.129
SB	.130	.088	.156	.338	.134
US	.247	.171	.076	.157	.108

Table 48

1986 $e(d_i)$, θ_i and λ_i Values

Ratio	$e(d_i)$	θ_i	λ_i
REMP	.906	.128	.094
ASTURN	.899	.137	.132
ROE	.907	.126	.108
PRMARG	.909	.123	.132
DEBT	.642	.486	.533

In table 48 note that the θ_i and λ_i values are not identical as opposed to the 1985 results. This is due to the fact that now we posses a priori concepts regarding the importance of one ratio over the other are held. The weights are the θ_i values from the previous years results.

Table 48 reveals that the information content of the debt ratio is greater than that of any other ratio. The debt ratio conveys 53.3% of the information content of all five financial ratios. The revenue generated per employee contains the least amount of information at only 9.4%.

For each firm a value S_k is computed from equation 19 in Chapter 3. Table 49 presents the quantities $\lambda_i (d^*_i - d_{i,k})$ from which S_k is determined for each BHC by summing across all ratios for each firm.

Recall that the quantity S_k in Table 49 is a weighted measure of the total distance the k-th firm is

from having the best ratio value in each measurement. The S_k value from each firm ranges between zero and one. A value of zero would imply that the firms ratio value was the best for each ratio. Thus no information would be available for where improvement could be made.

In 1986 Bell South had the lowest total entropy measurement of .191 while US West had the highest at .872. Thus during 1986 Bell South has the overall best set of ratios while US West has the worst set of ratios.

Table 49

1986 $\lambda_i (d^*_i - d_{i,k})$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT	S_k
AM	.000	.009	.000	.057	.455	.521
BA	.030	.031	.037	.084	.485	.667
BS	.076	.082	.033	.000	.000	.191
NY	.023	.000	.055	.116	.464	.658
PT	.064	.076	.046	.063	.500	.749
SB	.081	.120	.087	.023	.498	.809
US	.057	.101	.100	.107	.507	.872

The final step in the entropy calculations is to determine where the greatest potential for improvement exists for each firm. Table 50 presents the quantities, $\pi_{i,k} = [\ \lambda_i (d^*_i - d_{i,k}) / S_k\ ] * 100$, computed for each ratio for each BHC.

In Table 50 each $\pi_{i,k}$ represents the percentage improvement that was possible for each ratio to each of the BHCs. In 1986 the dominance of the debt ratio as

presented in Table 48 is driving the information content of all of the ratios.

Table 50

1986 $\pi_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	0.0	1.7	0.0	10.9	87.3*
BA	4.5	4.6	5.5	12.6	72.7*
BS	39.8	42.9*	17.3	0.0	0.0
NY	3.5	0.0	8.4	17.6	70.5*
PT	8.5	10.1	6.1	8.4	66.8*
SB	10.0	14.8	10.8	2.8	61.6*
US	6.5	11.6	11.5	12.3	58.1*

Bell South's much lower, and hence much superior, debt ratio causes the entropy computations to signal the inadequacy of the other BHCs debt ratios. Bell South's primary shortcomings are found in the asset turnover ratio closely followed by the revenue per employee ratio.

Entropy - 1987

Table 51 presents the results of selecting the financial ratio data for the seven BHCs in 1987. The variable names and units of measure are as presented in the development of the 1985 entropy measures.

Table 51

1987 Financial Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	133	50.8	15.6	12.4	59.5
BA	133	50.6	14.2	11.5	58.9
BS	124	44.6	13.9	13.6	56.3
NY	127	52.5	13.9	10.6	60.0
PT	127	43.5	12.0	10.4	62.5
SB	119	37.2	12.8	13.1	61.9
US	127	41.5	13.5	11.6	64.5

Next these ratios are normalized utilizing a standard Z transformation. Table 52 presents the area under the standard normal probability distribution. Following the entropy development the $d_{i,k}$ quantities are determined from equation 11. These values are then presented in Table 53 .

Table 52

1987 Normalized Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.885	.816	.955	.655	.345
BA	.885	.788	.655	.382	.274
BS	.274	.421	.579	.919	.055
NY	.500	.885	.579	.136	.421
PT	.500	.345	.067	.115	.758
SB	.045	.067	.212	.841	.692
US	.500	.212	.421	.421	.933

Table 53

1987 $d_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	1.000	0.922	1.000	0.713	0.159
BA	1.000	0.890	0.686	0.416	0.201
BS	0.310	0.476	0.606	1.000	1.000
NY	0.565	1.000	0.606	0.148	0.131
PT	0.565	0.390	0.070	0.125	0.073
SB	0.051	0.076	0.222	0.915	0.079
US	0.565	0.240	0.441	0.458	0.059

Table 54 presents the $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ values computed following equation 10 in Chapter 3.

Table 54

1987 $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.345	.338	.355	.315	.221
BA	.345	.335	.315	.243	.252
BS	.197	.254	.299	.352	.312
NY	.275	.347	.299	.127	.197
PT	.275	.227	.076	.113	.135
SB	.055	.075	.171	.344	.143
US	.275	.169	.256	.256	.117

From the information contained in table 54 the quantities $e(d_i)$, Θ_i and λ_i are computed. These quantities are computed from equations 13, 16 and 18 in Chapter 3. Table 55 presents the results of these computations.

Table 55

1987 $e(d_i)$, θ_i and λ_i Values

Ratio	$e(d_i)$	θ_i	λ_i
REMP	.908	.136	.060
ASTURN	.897	.152	.074
ROE	.910	.133	.060
PRMARG	.899	.149	.064
DEBT	.708	.431	.741

Table 55 reveals that the information content of the debt ratio is greater than that of any other ratio. The debt ratio conveys almost three fourths (74.1%) of the information content of all five financial ratios. The revenue generated per employee and return on equity contain the least amount of information at only 6.0% each.

Next for each firm a value S_k is computed from equation 19 in Chapter 3. Table 56 presents the quantities λ_i $(d^*_i - d_{i,k})$ from which S_k is determined for each BHC by summing across all ratios for each firm.

Table 56

1987 λ_i (d^*_i - $d_{i,k}$) Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT	S_k
AM	.000	.006	.000	.018	.623	.647
BA	.000	.008	.019	.037	.592	.656
BS	.041	.039	.024	.000	.000	.104
NY	.026	.000	.024	.055	.644	.749
PT	.026	.045	.056	.056	.687	.870
SB	.057	.068	.047	.005	.682	.859
US	.026	.056	.034	.035	.697	.848

In 1987 Bell South had the lowest total entropy measurement of .104 while Pacific Telesis had the highest at .870. Thus during 1986 Bell South has the overall best set of ratios while Pacific Telesis has the worst set of ratios.

The final step in the entropy calculations is to determine where the greatest potential for improvement exists for each firm. Table 57 presents the quantities, $\pi_{i,k} = [\ \lambda_i\ (d^*_i - d_{i,k})\ /\ S_k\ ] * 100$, computed for each ratio for each BHC.

Table 57

1987 $\pi_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	0.0	0.9	0.0	2.8	96.3*
BA	0.0	1.2	2.9	5.6	90.2*
BS	39.4*	37.5	23.1	0.0	0.0
NY	3.5	0.0	3.2	7.3	86.0*
PT	3.0	5.2	6.4	6.4	79.0*
SB	6.6	7.9	5.5	0.6	79.4*
US	3.1	6.6	4.0	4.1	82.2*

In table 57 each $\pi_{i,k}$ represents the percentage improvement that was possible for each ratio to each of the BHCs. Again in 1987, as was the case in 1986, the dominance of the debt ratio as presented in table 55 is driving the information content of all of the ratios.

Bell South's continuing much lower, and hence much superior, debt ratio causes the entropy computations to signal the inadequacy of the other BHCs debt ratios. Bell South's primary shortcomings are found in the revenue per employee ratio closely followed by the asset turnover ratio.

Entropy - 1988

Table 58 presents the results of selecting the financial ratio data for the seven BHCs in 1988. The variable names and units of measure are as presented in the development of the 1985 entropy measures.

Table 58

1988 Financial Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	138	51.7	15.8	12.5	59.1
BA	134	44.0	14.4	12.1	62.9
BS	136	47.8	14.1	12.3	58.4
NY	130	49.9	14.0	10.4	62.9
PT	136	44.8	14.7	12.5	61.8
SB	130	40.3	12.5	12.5	59.5
US	132	41.1	14.5	12.3	65.3

Next these ratios are normalized utilizing a standard Z transformation. Table 59 presents the area under the standard normal probability distribution.

Table 59

1988 Normalized Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.919	.919	.933	.692	.184
BA	.540	.345	.540	.500	.726
BS	.758	.692	.421	.618	.115
NY	.115	.841	.382	.014	.726
PT	.758	.421	.655	.692	.421
SB	.115	.115	.036	.692	.212
US	.309	.136	.579	.618	.933

Following the entropy development the $d_{i,k}$ quantities are determined from equation 11. These values are presented in table 60.

Table 60

1988 $d_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	1.000	1.000	1.000	1.000	0.625
BA	0.588	0.375	0.579	0.723	0.158
BS	0.825	0.753	0.451	0.893	1.000
NY	0.125	0.915	0.409	0.020	0.158
PT	0.825	0.458	0.702	1.000	0.273
SB	0.125	0.125	0.039	1.000	0.542
US	0.336	0.148	0.621	0.893	0.123

Table 61 presents the $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ values computed following equation 10 in Chapter 3.

Table 61

1988 $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.351	.352	.351	.309	.332
BA	.288	.229	.287	.266	.159
BS	.331	.322	.253	.294	.367
NY	.112	.344	.240	.020	.159
PT	.331	.256	.312	.309	.223
SB	.112	.113	.047	.309	.314
US	.214	.127	.296	.294	.135

From the information contained in Table 61 the quantities $e(d_i)$, θ_i and λ_i are computed. These quantities are computed from equations 13, 16 and 18 in Chapter 3. Table 62 presents the results of these computations. Table 62 reveals that the information content of the debt ratio is still greater than that of any other ratio. The debt ratio conveys about half

(52.1%) of the information content of all five financial ratios. The return on equity and profit margin ratios contain the least amount of information at only 10% each.

Table 62

1988 $e(d_i)$, θ_i and λ_i Values

Ratio	$e(d_i)$	θ_i	λ_i
REMP	.894	.212	.132
ASTURN	.896	.208	.146
ROE	.918	.164	.100
PRMARG	.925	.150	.100
DEBT	.868	.265	.521

Next, for each firm a value S_k is computed from equation 19 in Chapter 3. Table 63 presents the quantities λ_i $(d^*_i - d_{i,k})$ from which S_k is determined for each BHC by summing across all ratios for each firm.

Table 63

1988 λ_i $(d^*_i - d_{i,k})$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT	S_k
AM	.000	.000	.000	.000	.195	.195
BA	.054	.091	.042	.028	.439	.654
BS	.023	.036	.055	.011	.000	.125
NY	.116	.012	.059	.098	.439	.724
PT	.023	.079	.030	.000	.379	.511
SB	.116	.128	.096	.000	.239	.579
US	.088	.124	.038	.011	.457	.718

In 1988 Bell South once again had the lowest total entropy measurement at .125 while Nynex had the highest at .724. Thus during 1988 Bell South has the overall best set of ratios while Nynex has the worst set of ratios.

The final step in the entropy calculations is to determine where the greatest potential for improvement exists for each firm. Table 64 presents the quantities, $\pi_{i,k} = [\ \lambda_i\ (d^*_i - d_{i,k})\ /\ S_k\ ] * 100$, computed for each ratio for each BHC.

Table 64

1988 $\pi_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	0.0	0.0	0.0	0.0	100.0*
BA	8.3	13.9	6.4	4.3	67.1*
BS	18.4	28.8	44.0*	8.8	0.0
NY	16.0	1.7	8.1	13.5	60.6*
PT	4.5	15.5	5.9	0.0	74.2*
SB	20.0	22.1	16.6	0.0	41.3*
US	12.3	17.3	5.3	1.5	63.6*

In table 64 each $\pi_{i,k}$ represents the percentage improvement that was possible for each ratio to each of the BHCs. Again in 1988, as was the case in 1987 and 1986, the dominance of the debt ratio as presented in table 64 is driving the information content of all of the ratios. However, as the analysis in Chapter 5 will present this dominance is greatly reduced from the level's of the previous two years.

Bell South's continuing much lower, and hence much superior, debt ratio continues to cause the entropy computations to signal the inadequacy of the other BHCs debt ratios. Bell South's primary shortcomings in 1988 are found in its return on equity ratio.

Entropy - 1989

Table 65 presents the results of selecting the financial ratio data for the seven BHCs in 1989. The variable names and units of measure are as presented in the development of the 1985 entropy measures.

Next these ratios are normalized utilizing a standard Z transformation. Table 66 presents the area under the standard normal probability distribution. Following the entropy development the $d_{i,k}$ quantities are determined from equation 11. These values are then presented in table 67.

Table 68 presents the $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ values computed following equation 10 in Chapter 3.

Table 65

1989 Financial Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	143	51.5	16.1	12.1	61.2
BA	145	43.7	12.5	9.4	67.7
BS	138	46.6	13.4	12.4	56.7
NY	138	51.0	8.6	6.1	63.8
PT	140	45.3	15.7	12.9	62.8
SB	132	41.3	13.1	12.5	60.5
US	137	38.1	13.8	11.5	68.3

Table 66

1989 Normalized Ratios

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.841	.903	.864	.692	.345
BA	.919	.382	.382	.242	.864
BS	.421	.618	.500	.726	.055
NY	.421	.885	.029	.023	.579
PT	.579	.500	.841	.788	.500
SB	.045	.212	.460	.726	.726
US	.309	.067	.579	.579	.903

Table 67

1989 $d_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	0.915	1.000	1.000	0.878	0.159
BA	1.000	0.423	0.442	0.276	0.064
BS	0.458	0.684	0.579	0.921	1.000
NY	0.458	0.980	0.034	0.029	0.095
PT	0.630	0.554	0.973	1.000	0.110
SB	0.049	0.235	0.532	0.921	0.076
US	0.336	0.074	0.670	0.735	0.061

Table 68

1989 $(d_{i,k}/d_i)$ ln $(d_{i,k}/d_i)$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	.342	.348	.341	.312	.232
BA	.350	.239	.236	.165	.131
BS	.253	.304	.272	.318	.286
NY	.253	.346	.039	.031	.170
PT	.296	.276	.338	.328	.187
SB	.056	.168	.261	.318	.147
US	.213	.075	.292	.288	.126

From the information contained in Table 68 the quantities $e(d_i)$, θ_i and λ_i are computed. These quantities are computed from equations 13, 16 and 18 in Chapter 3. Table 69 presents the results of these computations.

Table 69

1989 $e(d_i)$, θ_i and λ_i Values

Ratio	$e(d_i)$	θ_i	λ_i
REMP	.906	.131	.126
ASTURN	.902	.137	.126
ROE	.914	.120	.090
PRMARG	.904	.134	.090
DEBT	.657	.478	.570

Table 69 indicates that the information content of the debt ratio continues to be greater than that of any other ratio. The debt ratio conveys slightly over half (52.1%) of the information content of all five

financial ratios. The return on equity and profit margin ratios contain the least amount of information at only 9% each.

Next for each firm the value S_k is computed from equation 19 in Chapter 3. Table 70 presents the quantities $\lambda_i (d^*_i - d_{i,k})$ from which S_k is determined for each BHC by summing across all ratios for each firm.

Table 70

1989 $\lambda_i (d^*_i - d_{i,k})$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT	S_k
AM	.011	.000	.000	.011	.479	.501
BA	.000	.073	.050	.065	.534	.722
BS	.068	.040	.038	.007	.000	.153
NY	.068	.003	.087	.087	.516	.761
PT	.047	.056	.002	.000	.507	.612
SB	.120	.096	.042	.007	.527	.792
US	.084	.117	.030	.024	.535	.790

In 1989 Bell South continued to enjoy the lowest total entropy measurement at .153 while Southwestern Bell had the highest at .792. Thus during 1989 Bell South has the overall best set of ratios while Southwestern Bell has the worst set of ratios.

The final step in the entropy calculations is to determine where the greatest potential for improvement exists for each firm. Table 71 presents the quantities, $\pi_{i,k} = [\ \lambda_i (d^*_i - d_{i,k}) / S_k\ ] * 100$, computed for each ratio for each BHC.

Table 71

1989 $\pi_{i,k}$ Values

BHC	REMP	ASTURN	ROE	PRMARG	DEBT
AM	2.2	0.0	0.0	2.2	95.6*
BA	0.0	10.1	6.9	9.0	74.0*
BS	44.4*	26.1	24.8	4.6	0.0
NY	8.9	0.4	11.4	11.4	67.8*
PT	7.7	9.2	0.3	0.0	82.8*
SB	15.2	12.1	5.3	0.9	66.5*
US	10.6	14.8	3.8	3.0	67.7*

In table 71 once again the dominance of the debt ratio is obvious. Bell South's continuing much lower, and hence much superior, debt ratio continues to cause the entropy computations to signal the inadequacy of the other BHCs debt ratios. Bell South's primary shortcoming is in its average revenue per employee ratio.

Summary

In this chapter the DEA and entropy calculations for the BHCs between 1985 and 1989 have been presented. It has been shown that these analytical procedures can be applied to the financial and operational data of competitive firms in pursuit of the displaced ideal.

In the following chapter an extensive analysis of these results will be presented. This analysis will include observations on how specific management actions that the BHCs took affected these results. After that

presentation Chapter 6 will discuss future potential research directions.

Chapter 5

ANALYSIS OF RESULTS

In the previous chapter the results of the DEA and entropy calculations when applied to the Bell Holding Companies were presented. In this chapter those results will be reviewed and an extended analysis of them will be undertaken. This analysis will focus on the results of these firms had they of been in pursuit of the displaced ideal. Additionally, based upon the entropy analysis, rationale for decisions these firms could have made based upon this procedure will be presented. Thus, a basis for the firm's management to explain its actions, as the firm pursues the displaced ideal, is provided.

When reviewing this analysis it is important to remember that the purpose of this study was to establish the procedure and to illustrate its application. The inputs, outputs, and ratios employed in this study provide the foundation for these findings. It is likely that alternative or additional data would impact these findings. Thus, one should view these findings as illustrative of the procedure and not

necessarily a final judgement regarding the performance of the BHC's.

DEA Analysis

In this section the results of the five computer runs, presented in Chapter 4, evaluating firm efficiency with DEA will be discussed. This discussion will focus on the success of the BHC's as they may have endeavored to become the ideal firm.

Same Year Evaluations

The following four tables, tables 72 to 75, present the DEA efficiencies for the same year as the window size varied. For example, table 72 presents the DEA efficiency estimates for the seven BHC's in each of the five computer runs where set of 1985 data was included.

Table 72

1985 DEA Efficiencies by Computer Run

	Computer Run				
Company	1	2	3	4	5
Ameritech	.952	.952	.952	.952	.946
Bell Atlantic	.873	.874	.858	.848	.841
Bell South	.754	.756	.742	.740	.736
Nynex	.791	.793	.778	.770	.757
Pacific Telesis	.908	.908	.899	.884	.878
Southwestern Bell	.953	.953	.941	.934	.930
US West	.975	.975	.975	.975	.975

Table 73

1986 DEA Efficiencies by Computer Run

Company	Computer Run 2	3	4	5
Ameritech	.976	.976	.976	.961
Bell Atlantic	.893	.874	.864	.849
Bell South	.769	.769	.769	.769
Nynex	.824	.808	.799	.785
Pacific Telesis	.943	.923	.911	.895
Southwestern Bell	.940	.920	.912	.892
US West	.964	.955	.937	.931

Table 74

1987 DEA Efficiencies by Computer Run

Company	Computer Run 3	4	5
Ameritech	.945	.935	.926
Bell Atlantic	.858	.848	.833
Bell South	.729	.729	.729
Nynex	.800	.788	.774
Pacific Telesis	.890	.879	.864
Southwestern Bell	.939	.933	.919
US West	.929	.917	.900

Table 75

1988 DEA Efficiencies by Computer Run

Company	Computer Run 4	5
Ameritech	.929	.921
Bell Atlantic	.844	.830
Bell South	.713	.701
Nynex	.755	.742
Pacific Telesis	.894	.878
Southwestern Bell	.917	.901
US West	.915	.898

In tables 72 to 75 no firm saw its efficiencies improve between the first time they were included and the last time. To illustrate this consider Bell Atlantic in table 74. The first time the results of Bell Atlantic's 1987 operations were analyzed was in computer run four and the last time those same 1987 results were analyzed was in computer run five. Thus, we see that no firm's performance, relative to the ideal, improves when it is viewed in years subsequent to the first time it was evaluated.

It is notable that the results of US West's 1985 operations in Table 72 were unchanged. Also Bell South's 1986 and 1987 operations in tables 73 and 74, respectively, were unchanged. Thus, the performance of those firms remained constant despite the displacement occurring to the ideal firm. Otherwise, for all of the other firms, the efficiency estimates decreased between

the time they were initially included in the computer runs and the final computer run.

In table 72 the DEA results for Bell Atlantic, Bell South and Nynex increased slightly between computer runs one and two for the 1985 data. This slight increase, the largest change was .002, may be more attributable to rounding error from the small initial data set than any actual increase.

From tables 72 to 75 the following conclusion seems justified. The characteristics of the ideal firm are indeed being displaced. This is based upon the shifting of the BHC's efficiencies as new years are entered into the database. That is, for example, when only the 1985 data is evaluated the DEA results are higher than when the other years, 1986 to 1989, are incorporated into the analysis.

The deterioration of these same year efficiencies as new years operational results are incorporated into the analysis suggests that the ideal firm is becoming a more efficient firm. Hence, credence is given to the fact that the ideal firm is being displaced, becoming more efficient, over time.

Five Year Pursuit

Table 76 presents the efficiencies for each of the seven firms across all five years.

Table 76

BHC's DEA Results Across All Years

Company	Year 1985	1986	1987	1988	1989
Ameritech	.946	.961	.926	.921	.910
Bell Atlantic	.841	.849	.833	.830	.794
Bell South	.736	.769	.729	.701	.686
Nynex	.757	.785	.774	.742	.713
Pacific Telesis	.878	.895	.864	.878	.894
Southwestern Bell	.930	.892	.919	.901	.930
US West	.975	.931	.900	.898	.874

To determine the changes in a firms DEA efficiencies the difference between the estimates are taken. For example US West's DEA efficiency deteriorated by .044 ,(.975 - .931), between 1985 and 1986. In table 77 the 28 differences between successive years efficiencies are presented. For example in the column headed 1986 the 1985 efficiency estimates are subtracted from the 1986 estimates for each of the BHC's. Where the change is negative, a deterioration in DEA efficiency, the results are in parenthesis.

Table 77

BHC's Changes in Annual DEA Estimates

Company	Year 1986	1987	1988	1989
Ameritech	.015	(.035)	(.005)	(.011)
Bell Atlantic	.008	(.016)	(.003)	(.036)
Bell South	.033	(.040)	(.028)	(.015)
Nynex	.028	(.011)	(.032)	(.029)
Pacific Telesis	.017	(.031)	.014	.016
Southwestern Bell	(.038)	.027	(.018)	.029
US West	(.044)	(.031)	(.002)	(.024)

As table 77 reveals these firms have, on a year to year basis, not been very successful in their pursuit of the displaced ideal. In 19 of the 28 changes, 67.9%, in the estimated DEA efficiencies the movement has been negative. During the last three years 17 of the 21 changes, 81.0%, have been negative.

In table 78 the total change in the BHC's efficiency estimates over the five year study period are provided. These changes are computed by subtracting the 1985 efficiencies from the 1989 efficiencies presented in table 76. Thus, a summary view is provided on how the BHC's have advanced as they pursued the displaced ideal.

Table 78

BHC's Changes in Cumulative DEA Estimates

Company	Change
Ameritech	(.036)
Bell Atlantic	(.047)
Bell South	(.050)
Nynex	(.044)
Pacific Telesis	.016
Southwestern Bell	.000
US West	(.101)

Table 78 conforms to the findings in table 85. Only Pacific Telesis experienced a positive growth towards the displaced ideal during the last five years while Southwestern Bell had no change.

All five of the other BHC's lost ground in comparison to the gains in efficiency enjoyed by the mythical ideal firm. US West suffered the greatest slippage going down over 10% from 97.5% to 87.4% in its relative efficiency rating. Bell South which had the lowest initial efficiency rating of 73.6% saw its rating decline 5% to 68.6% from 73.6%.

DEA Summary

If the goal of the BHC's had been to become more efficient over the past five years, based upon the data selected for inclusion in this study, in comparison to the efficiency of the ideal firm then only one

conclusion is possible. On the whole they would have failed in their attempt.

Only Pacific Telesis has been able to improve its efficiency relative to that of the mythical ideal firm. While Southwestern Bell maintained its efficiency rating all five of the other BHC's saw reductions in their relative efficiencies with US West experiencing the largest decline.

Entropy Analysis

Any or all of the firms in the competitive set may formally engage in pursuing the displaced ideal. However, it would not be enough for management to say that they are trying to follow such a program. Management must present to its various stakeholders an action plan providing a sufficient level of detail on how it plans to pursue its goal.

In this section the discussion is based upon the entropy results of Chapter 4. This discussion focuses on how management could have created a context to aid in the explicability of its actions. Thus, the pursuit of the ideal is linked with a mechanism that allows management to explain its actions. This procedure is built upon the widespread acceptance of financial ratios.

For each of the seven BHC's a discussion is presented on explanations possible for each firm's

potential actions based upon the entropy calculations. However, it still must be kept in mind that the ratios utilized in this study where selected as representing a wide set of available ratios. Individual firms may feel that other or additional ratios should be included in the analysis.

Ameritech Entropy Analysis

In table 79 the percentage improvement potential, the $\pi_{i,k}$, generated in Chapter 4, for each Ameritech ratio are presented. The ratios and the $\pi_{i,k}$ values are as they were defined in Chapter 3 and have been rounded to the nearest whole percent.

Table 79

Ameritech $\pi_{i,k}$ Values in Percent

Year	REMP	ASTURN	ROE	PRMARG	DEBT
1985	0	0	0	100	0
1986	0	2	0	11	87
1987	0	1	0	3	96
1988	0	0	0	0	100
1989	2	0	0	2	96

Taken as a whole it is clear from table 79 that Ameritech's ratios are very good. A zero $\pi_{i,k}$ value indicates the highest relative performance relative to the other BHC's. With 14 of the 25 $\pi_{i,k}$ having a zero value, 56%, Ameritech's over all performance across all ratios was the best.

In 1985 Ameritech outperformed all of the other BHC's with the exception of the profit margin ratio which is net income to revenue. Here it would have been possible to explain that the firm's primary objective would become one of improving the profit margins performance. Perhaps the strategy of th firm would be to focus on expense control to address this ratios shortcoming. Alternatively, the firm could set out to explain to the various stakeholders why this occurred and what steps were going to be taken in the future to improve its performance.

In 1986 through 1989 Ameritech's primary area of opportunity to improve its performance has been with respect to its debt ratio. The debt ratio has been of such a nature that with the exception of its profit margin in 1986 no other ratio measure exceeded a 10 % improvement potential. Clearly, the reason why there is so little room for improvement is due to Ameritech's superior performance in its ratios with the exception of the debt ratio.

As Ameritech strove in pursuit of the displaced ideal during the years 1986 through 1989 the debt ratio would have provided it with an opportunity to explain its actions. With the debt ratio being the measurement of liabilities to total assets Ameritech was in position to develop strategies aimed at improving the

performance of this ratio. The most obvious of the actions would have involved reducing the overall level of the firm's liabilities.

In table 76 it was shown that Ameritech's overall DEA efficiency rating had deteriorated from .946 to .910 during the study. However, at .910 it was still the second highest among the BHC's. The entropy results suggest that had Ameritech focused on its debt ratio to a somewhat higher degree the overall efficiency may have improved.

Bell Atlantic Entropy Analysis

In table 80 the $\pi_{i,k}$ generated in Chapter 4, rounded to the nearest percent, for Bell Atlantic are presented. The ratios and $\pi_{i,k}$ are as they were defined in Chapter 3.

From table 80 it is determined that the debt ratio provides the greatest area for potential improvement across all five years. However, as opposed to the Ameritech findings, there is room for improvement in the performance of all ratios with the exception of the revenue per employee ratios in 1987 and 1989.

Table 80

Bell Atlantic $\pi_{i,k}$ Values in Percent

Year	REMP	ASTURN	ROE	PRMARG	DEBT
1985	19	16	12	21	31
1986	5	5	6	13	73
1987	0	1	3	6	90
1988	8	14	6	4	67
1989	0	10	7	9	74

The entropy analysis suggests that Bell Atlantic's greatest area for improvement was in the performance of the debt ratio. However, there would have been opportunities to explain managements actions through other ratios where ten percent or greater improvements were possible. This was particularly true in 1985 where significant opportunities existed for greater than ten percent improvement in the performance of all ratios at Bell Atlantic.

Between 1985 and 1989 table 76 revealed that the overall efficiency of Bell Atlantic as it pursued the displaced ideal fell from .841 to .794 for a fall of .047. Table 78 shows that this was the third largest deterioration for all of the BHC's.

Had the management of Bell Atlantic utilized this procedure and had the variables and ratios utilized in this procedure been pertinent to Bell Atlantic's operations much could have been gained from its

application. In most years the management at Bell Atlantic could have selected from multiple ratios upon which to improve its performance. While the debt ratio was the one area with the greatest area for potential improvement all of the ratios at one point in time or another had room for improvement.

Bell South Entropy Analysis

In table 81 the $\pi_{i,k}$ generated in Chapter 4, rounded to the nearest percent, for Bell South are presented. The ratios and $\pi_{i,k}$ are as they were defined in Chapter 3.

Table 81

Bell South $\pi_{i,k}$ Values in Percent

Year	REMP	ASTURN	ROE	PRMARG	DEBT
1985	26	44	13	0	18
1986	40	43	17	0	0
1987	39	38	23	0	0
1988	18	29	44	9	0
1989	44	26	25	5	0

In table 81 it is possible to determine that while year-by-year variances occur the revenue per employee, asset turnover and return on equity ratios offer the greatest areas for improvement. Across all five years Bell South could have sought to improve its performance in all three of these ratios.

Relative to the performance of the other BHC's the profit margin and debt ratios hold up quite well. From

1986 onward Bell South had the best debt ratio. Also between 1985 and 1987 it had the best profit margin and there was only slight room for improvement in the profit margin during 1988 and 1989.

In table 76 it is shown that the overall DEA efficiency of Bell South deteriorated from .736 to .686 between 1985 and 1989. The DEA rating of .686 was the lowest rating of any of the BHC's across all of the years in the study. Table 78 shows that the decline of .050 was the second largest decline of all of the BHC's during the study period.

The variables and ratios utilized in this procedure suggest that Bell South is trailing the BHC group of companies in the pursuit of the ideal. The entropy analysis suggests that Bell South management could have been addressing the revenue per employee, asset turnover and return on equity ratios as areas in need of improvement.

Nynex Entropy Analysis

In table 82 the $\pi_{i,k}$ generated in Chapter 4, rounded to the nearest percent, for Nynex are presented. The ratios and $\pi_{i,k}$ are as they were defined in Chapter 3.

Table 82

Nynex $\pi_{i,k}$ Values in Percent

Year	REMP	ASTURN	ROE	PRMARG	DEBT
1985	16	0	26	39	19
1986	4	0	8	18	71
1987	4	0	3	7	86
1988	16	2	8	14	61
1989	9	0	11	11	68

Table 82 shows that across nearly all years the asset turnover enjoyed by Nynex was superior to all of the other BHC's. With respect to all of the other ratios, however, at one point-in-time or another Nynex had the opportunity for significant improvement.

Specifically, from table 82 it is determined that in 1985 Nynex's profit margin offered the greatest room for improvement closely followed by the return on equity. From 1986 to 1989 the performance of Nynex with respect to the debt ratio offers the greatest area of opportunity for improvement.

However, table 82 also shows that Nynex had double digit opportunities for improvement of its revenue per employee in 1985 and 1988; its return on equity in 1985 and 1989; and its profit margins performance in 1986, 1988 and 1989.

From table 76 it is determined that the DEA efficiency estimates of Nynex deteriorated from .757 to

.713 between 1985 to 1989. The .713 is next to the lowest, behind Bell South, by 1989.

The entropy calculations could have provided Nynex management with an ability to develop an explainable course of action had it been formally in pursuit of the ideal with the given sets of variables and ratios. The debt ratio was the one area for the greatest potential for improvement after 1985. However, there were also other areas for potentially significant increases in performance during all of the years in the study period.

Pacific Telesis Entropy Analysis

In table 83 the $\pi_{i,k}$ generated in Chapter 4, rounded to the nearest percent, for Pacific Telesis are presented. The ratios and $\pi_{i,k}$ are as they were defined in Chapter 3.

Table 83

Pacific Telesis $\pi_{i,k}$ Values in Percent

Year	REMP	ASTURN	ROE	PRMARG	DEBT
1985	6	17	23	26	27
1986	9	10	6	8	67
1987	3	5	6	6	79
1988	5	16	6	0	74
1989	8	9	0	0	83

During the period covered by the study, Pacific Telesis' greatest opportunity for improvement was consistently to be found in the performance of its debt

ratio. During 1985 the debt margin was in the same neighborhood as the profit margin and the return on equity ratios with the asset turnover ratio not too far behind as an area of potential improvement. However, after 1985 the only other potential areas of double digit improvement for Pacific Telesis were in the asset turnover ratio in 1986 and again in 1988.

Between 1986 and 1989 inclusively Pacific Telesis' performance of the revenue per employee, return on equity and profit margin ratios were consistently under ten percent behind the performance of the best companies with respect to those three ratios.

In table 76 the DEA efficiency estimates for Pacific Telesis rise by .016 from .878 to .894 between 1985 and 1989. While the DEA estimate of .894 is the median value for all of the BHC's in 1989 Pacific Telesis is the only BHC to have gained ground in its pursuit of the ideal during the time frame of the study.

While Pacific Telesis improved its DEA efficiency estimate during over the course of the study the entropy analysis suggests additional area for improvement. The performance of Pacific Telesis' debt ratio offers management the opportunity for additional gains in the firm's pursuit of the ideal.

Southwestern Bell Entropy Analysis

In table 84 the $\pi_{i,k}$ generated in Chapter 4, rounded to the nearest percent, for Southwestern Bell are presented. The ratios and $\pi_{i,k}$ are as they were defined in Chapter 3.

Table 84

Southwestern Bell $\pi_{i,k}$ Values in Percent

Year	REMP	ASTURN	ROE	PRMARG	DEBT
1985	16	23	12	23	25
1986	10	15	11	3	62
1987	7	8	5	1	79
1988	20	22	17	0	41
1989	15	12	5	1	67

As was the case with Bell Atlantic and Pacific Telesis, Southwestern Bell's largest opportunity for improvement in each year is in the performance of the debt ratio. However, Southwestern Bell has many more areas for double digit improvements than did Atlantic and Pacific Telesis. In 1985 Southwestern Bell had opportunities for double digit improvement in the revenue per employee, asset turnover, return on equity, profit margin and debt ratios. In 1986 and again in 1988 it had room for double digit improvement in all ratios except the profit margin ratio. In 1989 double digit opportunities for improvement were possible in all ratios except the return on equity and profit margin ratios.

After 1985 Southwestern Bell's profit margin ratio was always the best or close to the best of the BHC's. In 1987 only the debt margin was a candidate for significant improvement.

In table 76 it is shown that the DEA estimate for Southwestern Bell's efficiency was the same in 1989 at .930 as it was in 1985. Southwestern Bell was the only BHC to experience no change and had the highest DEA efficiency rating at the end of the study period in 1989.

Had Southwestern Bell utilized this strategy of pursuing the ideal firm in their strategic planning, the entropy analysis reveals a wide number of possible ratios to target for improvement. Such a strategy may have resulted in Southwestern Bell improving its performance in pursuit of the ideal.

US West Entropy Analysis

In table 85 the $\pi_{i,k}$ generated in Chapter 4, rounded to the nearest percent, for US West are presented. The ratios and $\pi_{i,k}$ are as they were defined in Chapter 3.

Table 85

US West $\pi_{i,k}$ Values in Percent

Year	REMP	ASTURN	ROE	PRMARG	DEBT
1985	18	21	17	17	28
1986	7	12	12	12	58
1987	3	7	4	4	82
1988	12	17	5	2	64
1989	11	15	4	3	68

Once again as was the case with Bell Atlantic, Pacific Telesis and Southwestern Bell the debt ratio dominates all other ratios when it comes to opportunities for improvement. As was the case with Southwestern Bell, US West had a considerable number of ratios where double digit opportunities for improvement exist.

In 1985 all five ratios offered considerable room for improvement and hence explicability for management actions at US West. By 1986 and especially in 1987 the debt ratio was dominating the entropy results. However, in 1986 the asset turnover, return on equity and profit margins could have provided opportunities for double digit improvement in overall improvement. In 1988 and again in 1989 the revenue per employee and asset turnover ratios were potential sources of improvement.

From table 76 it is determined that the DEA efficiency estimates for US West declined from .975 in

1985 to .874 in 1989. From table 78 it is shown that US West suffered a decline of .101 in the DEA efficiency which was the largest decline of any BHC. In 1985 the .975 efficiency rating was the highest of any BHC while its 1989 rating of .874 was the median valued rating of the seven BHC's.

One interesting observation concerning the US West findings is that US West never possessed the best ratio value for any of the ratios in any of the years included in this study.

Had US West utilized this procedure as an aid in their pursuit of the displaced ideal, numerous opportunities were available to them to use the ratios in the entropy analysis to explain their managerial decisions. While the debt ratio was the greatest source of potential improvement many of the other ratios previously cited could have been candidates for explaining the companies' strategies.

Entropy Summary

It has been shown that entropy can be used as a basis upon which explicability arguments can be developed as the firm pursues the displaced ideal.

The DEA portion of the procedure allows for the capability of management to track the firm's progress in pursuit of the ideal firm. Entropy allows the firm to identify well accepted financial and operational

ratios to explain to the firm's stakeholder groups what the firm is going to do to improve its performance in the future.

Through entropy analysis the firm is able to determine which ratios could provide the greatest opportunities for improvement. The ratios are not viewed individually but as a group and the firm's group of ratios is compared to the firm's competitive set. Thus, the firm has a rationale for explaining the future actions of the firm as it pursues the displaced ideal firm.

Summary

In this chapter a detailed discussion of the DEA and entropy results, as calculated in Chapter 4, for each BHC has been conducted. These discussions illustrate the interpretation of the methodology as it relates to the companies included in this study.

The discussions presented illustrate that the linkage of DEA and entropy can be viewed as a management decision aide as the firm pursues the displaced ideal. DEA allows a firm to chart its progress as it pursues the ideal. Entropy allows management to develop plans and explain its actions to its various stakeholders as it pursues the ideal.

In the next chapter several illustrations will be presented comparing actual management actions and the potential integration of those actions to this methodology.

CHAPTER 6

ANALYSIS OF MANAGERIAL DECISIONS

In this study the application of DEA and entropy has provided a basis from which a firm may pursue the displaced ideal. In this pursuit the firm is able to link the efficiency of its operations with the ability to explain its actions, thus yielding a more effective firm as it conducts its business.

The BHCs evaluated utilizing this procedure were, in all probability, not explicitly in pursuit of the displaced ideal. However, it does seem reasonable that indirectly they would have been in pursuit of it. Beyond this the inputs, outputs and ratios employed in this analysis may not be the same ones that the BHCs would consider to be relevant.

However, in this study five of the seven firms fell further behind the ideal firm over the five years covered by this study. Thus, in an effort to gain insight into this phenomenon the analysis will be extended. A limited qualitative review of some of the more significant managerial actions undertaken by the BHCs will be reviewed in this chapter.

In conducting a qualitative examination such as this one a wide variety of resources are available beyond the company's annual report. Independent research reports such as those by Benson, et. al.(1990) and by the Market Intelligence Research Company (1990) can be purchased to gain insights. Other sources such as the Wall Street Journal, New York Times, and Fortune can contribute towards gaining insight into the results of managements actions.

Despite the availability of the information sources cited above it is still extremely difficult, if not impossible, to obtain absolute cause and effect type of information. That is unless one is privy to the books of the corporations. Thus, what follows in this qualitative phase should be thought of as reasonable conjecture based upon the sources consulted in the course of this study. In this chapter most of the information presented comes from the BHCs annual reports. When additional sources are consulted they are cited in the text of this chapter.

In this review the focus will be on the firm's actions outside of their regulated telephone operations. It is areas other than the telephone operations where management had the greatest opportunity to be innovative and respond quickly and decisively. However, a review of some of the telephone

company issues will be presented in summary form later in this chapter.

Finally, in this review a long term view should be maintained. While management is in a position to be the firm's major change agent, decisions and the impact of those decisions evolve over time and as such are difficult to evaluate on a year-by-year basis.

Ameritech Review

In Chapter 5 it was discussed that Ameritech's DEA efficiency rating decreased from .946 to .910 between 1985 and 1989. However, the .910 was still the second highest for all seven BHCs in 1989. Thus, while the decline is significant the company is still in a relatively good position.

In reviewing the Ameritech annual reports it appears as if the nature of the companies' actions have been quite conservative. That is, by and large, Ameritech primarily focused on developing its core operations.

While Ameritech is the primary provider of cellular services in its traditional territory, the states where it provides telephone operations, it has not aggressively entered the cellular market outside of this territory. By the end of 1989 Ameritech had 242,000 cellular customers. With respect to the paging

market Ameritech entered this market in 1988 through its cellular subsidiary and had 110,000 customers by the end of 1988 with an expected annual growth rate of 20%.

From an international perspective Ameritech produced English-language directories in Japan during 1988 and 1989. In 1985 it provided directory consulting in Thailand. However, beyond these limited endeavors no other international publishing activity was detected (Sims 1989). Here, once again, is an illustration that with respect to Ameritech's international activities inputs such as assets, liabilities and people produced little in the way of outputs such as net income and revenue. This contributed, in all likelihood, to a further deterioration of the DEA ratings.

In 1986 Ameritech acquired a computer software company called Applied Data Research or ADR (Blankenhorn 1987). Despite revenue increase at ADR of 30% in 1987 ADR was sold in 1988 for $170 million which produced an after tax loss of $8.1 million (Page 1988).

One of the areas where Ameritech appears to have staked out a position is in the voice messaging area. In 1988 Ameritech acquired The Tigon Corporation to serve customers in the United States, United Kingdom and Japan (Eckerson 1988). While in 1989 Ameritech reported expanded results from Tigon it did not report

specific results of Tigon operations. Hence, in all likelihood the voice messaging impact at Ameritech was minimal.

In its publishing line of business Ameritech acquired Old Heritage Advertising and Publishing in 1986. By 1989 the number of states where Old Heritage provided Yellow Pages services grew from eight to sixteen. Thus, it appears as if Ameritech has made a serious commitment to compete in the Yellow Pages market outside of its traditional markets. However, a review of the literature reveals that the competition encountered by the BHCs as they ventured outside of their traditional regions is fierce (Graham 1988). As a result it may be that this effort contributed to the decrease in the Ameritech DEA rating from .946 to .910. Thus, Ameritech became less efficient, relative to the displaced ideal, during the course of this study.

The following conclusions, based upon a review of the sources cited in the introduction to this chapter, seem in order. Ameritech began its operations as a highly efficient firm in 1985 and, it appears, executed minimal effort to expand beyond its traditional lines of business (Bermar 1987). When efforts were made to expand an informed estimate would be that they purchased overpriced assets and these assets have yet

to begin to significantly contribute to the revenue and net income at Ameritech.

Conversely they were able to keep labor size down relative to revenues, effectively utilize their assets and maintain relatively high levels of return on equity and profit margins.

Bell Atlantic Review

Bell Atlantic had its efficiency estimates, relative to the ideal, decrease by .047 from .841 to .794 between 1985 and 1989. This decline was the third worst of the BHCs and the ending efficiency was second from the worst.

In the United States one of the key areas that Bell Atlantic has aggressively entered is computer maintenance. In 1985 Sorbus, an IBM computer maintenance company, was acquired. However, by 1987 Bell Atlantic was selling significant portions of it back to MAI Basic Four, the company it purchased Sorbus from originally (LaGanga 1987). Thus, it appears that this diversification effort failed to contribute to increased efficiencies at Bell Atlantic.

Some of the earlier attempts at diversification included the acquisition of CompuShop, a computer distributer (Bermar 1987), and a national paging company called A Beeper Company (Gibson 1986). However,

by 1987 Bell Atlantic had sold these companies, except the paging operations in its traditional territory, stating that they weren't achieving the results that had been expected.

In reviewing the results of the management discussions it appears as if Bell Atlantic has decided to hinge its future opportunities in the international marketplace (Page 1988). By 1989 Bell Atlantic had established a European headquarters in Brussels, Belgium. From this location it oversees the activities of 700 employees in eight countries. Additional opportunities are being pursued in Asia and the Pacific rim by Bell Atlantic.

However, it appears as if these efforts are probably positioning activities for future opportunities. While Bell Atlantic cites several projects currently under way in Spain and Germany it does not appear that these are making any significant contribution to current financial and operational results (Sims 1989).

In Bell Atlantic's traditional region, including the states of New Jersey, Pennsylvania, Delaware etc., Bell Atlantic has enjoyed the gain in cellular communications growth. However, Bell Atlantic apparently decided not to enter into the cellular business outside of its traditional markets. Thus, Bell

Atlantic was not in a position to fully participate in the explosive growth of the cellular industry during the study period.

With respect to Bell Atlantic's publishing, Yellow Pages, products the strategy has been similar to the cellular business. That is to focus on the traditional region, offer some product enhancements and form some partnerships where synergies can be gained. However, once again the end effect is a predictably consistent product.

In conclusion it appears that between 1985 and 1989 Bell Atlantic did not enjoy any significant success in its development of new business. It also appears as if Bell Atlantic is focusing on potential future opportunities in the international marketplace.

Thus, the finding of the DEA efficiencies seems to be quite consistent with the management messages being communicated in the firm's annual reports and in the citations mentioned in this chapter. That is the decrease of the DEA efficiency from .841 in 1985 to .794 by 1989 is supported by the lack of any new lines of business that contributed significantly to Bell Atlantic during the study period.

Bell South Review

Bell South consistently received the lowest DEA efficiency ratings. In table 76 of Chapter 5 Bell South's efficiency deteriorated from a .736 in 1985 to .686 in 1989. This deterioration of .05 was also the second largest deterioration as was shown in table 78 of Chapter 5.

In reviewing the annual reports of Bell South it stands out that Bell South seems to be aggressively entering myriad different areas in the telecommunications arena (Gannes 1989). As early as the 1985 annual report Bell South had formed seven separate corporations, in addition to its telephone operations. These companies ranged from international operations in the Pacific Basin and Europe, to a joint venture that designs and installs fiber optic local area networks, to its cellular telephone operations.

By 1986 the number of separate whole and partially owned companies, once again excluding telephone operations, had climbed to fourteen. Examples of new and expanded areas of operations at Bell South included paging, directories outside of its traditional region and a subsidiary dedicated to Government Systems.

In the annual report for 1987 eighteen separate companies are reported to exist beyond the telephone operations. Growth is continued in the areas of

communications systems, mobile systems, international and publishing.

Through 1988 and 1989 significant increase in Bell South's international and cellular operations are reported. However, these are not mutually exclusive areas. The establishment of a consortium headed by Bell South in Argentina to provide cellular service in Buenos Aires attests to this (Gannes 1989).

While all of the BHCs engage in taking advantage of the public relations aspect of the annual report Bell South appears to be exceedingly successful at it. However, in the review of the annual reports one result does appear to be absent. With Bell South starting all of these new lines of business it is difficult to find any information regarding the contributions of these companies to the net income of the corporation.

Thus, it may be that Bell South is continuing to develop its new lines of business even though the current contribution by any of them, with the exception of its cellular operations (Ballen 1988), may be minimal. However, it may also be that Bell South is slow to admit when it has acquired or created a poor performing company.

Nynex Review

Nynex saw its DEA efficiency rating drop from .757 to .713 between 1985 and 1989. This decrease of .044 was the median change of the seven BHCs. This data is presented in tables 76 and 78 in Chapter Five.

Nynex had established by 1985 a presence in the retail selling of computers via acquisitions and expansion. It was operating 11 stores, named Datago, throughout the northeaster states. These stores marketed computers from suppliers such as Apple and Compaq as well as telephone systems. Additionally, these stores began carrying cellular telephones.

In 1986 Nynex acquired IBM's Business centers and was operating 94 centers in 33 states (Bermar 1987). They also changed the name from Datago to Nynex Business Centers. However, by 1988 it was reported that the number of centers had been reduced to 80. Thus, while Nynex was still operating these stores it would seem as if the initial enthusiasm and attractiveness of this business had faded (Schultz 1988).

Nynex also initially entered the paging market and in 1986 acquired the assets of Page Boy, Inc. which served paging markets in the northeast. However, in 1989 Nynex abandoned its paging subsidiary by selling it to the PageAmerica Group.

In the publishing arena Nynex introduced several new products during the first years of this study. However, it appears that Nynex also experienced increased competition and limited success in the publishing business (Graham 1988 and Wilke 1986).

In 1985 it introduced Spanish Yellow Pages in New Jersey and New York. In 1986 it began publishing a magazine called "Changing Homes" for the segment of the households across the U.S. that relocate each year. In 1987 a directory, called "NYNEX BOATERS" was introduced at several maritime locations in the northeast, southeast, northwest and western coasts of the United States. However, that same year Nynex began to discuss a need to restructure its publishing operations. By 1988 and 1989 most of the new products mentioned in the earlier reports had disappeared (Krasilovsky 1990).

Another area Nynex advocated for growth in 1985 and 1986 was in the provision of procurement and storage services to other companies through its new Material Enterprises Company. However, by 1987 it is apparent that this company will serve other Nynex subsidiaries only. Even with this limitation the company has been plagued with operational and regulatory problems (Coy 1990).

In this review of the Nynex results a pattern of relatively quick entry and exit into a number of lines

of business becomes apparent. While this pattern appears to be the antithesis of Bell South's actions the results appear to be consistent. That is, Bell South and Nynex had the two lowest efficiency estimates in all years of the study, see table 76 in Chapter Five, and reductions of .05 and .044, respectively, between 1985 and 1989 in those efficiency estimates.

Thus, the Nynex strategy of rapid entry and exit from new lines of business apparently did not contribute to improvements in the firm's efficiency as it pursued the ideal. Indeed, the deterioration of the DEA efficiency rating from .757 in 1985 to .713 in 1989, suggests that the approach by Nynex was detrimental to the firm as it pursued the displaced ideal.

Pacific Telesis Review

Tables 76 and 78 in Chapter five reveal that Pacific Telesis was the only firm to move closer to the ideal firm between 1985 and 1989. Overall, its DEA efficiency rating improved by .016 from .878 to .894 during the course of this study.

Pacific Telesis enjoys an intangible benefit of only providing regulated telephone service in the two states of California and Nevada. In so doing Pacific Telesis only has to concentrate on two public service

commissions as opposed to the other six BHCs having a minimum of five each. This allows for less distraction of senior managers attention from growing the business.

Pacific Telesis also had significant senior management transition occur late in 1987 and 1988 (Feder,1988). At that time four of the companies most senior officers, including its Chairman and Chief Executive Officer, retired. This transition is noteworthy in that at the time the four officers ranged between 55 to 59 years of age. However, the annual reports don't report any motivation behind this change. In Chapter three of this study the potential positive impact that this action can have on the firm was developed. Miller (1991) provides evidence that the longer the tenure of the CEO, the greater is the reluctance of management to improve the organization's performance.

Pacific Telesis began to aggressively enter into the cellular marketplace, on a national basis, as early as 1985 (Feder 1988). Through acquisitions it moved into Atlanta, Tampa Bay, Detroit and other markets across the United States. In the 1988 annual report Pacific Telesis is reporting that it is the largest cellular service provider in the country with over 262,000 customers, by 1989 that figure had grown to 381,000.

During this time Pacific Telesis was also entering the paging market through construction and acquisition. However, it appears that by 1989 the strategy of the paging operations is to have them where it has cellular operations. With the cost of cellular service being high many customers link paging service with cellular service so the cellular user can control the cellular usage. However, it appears Pacific Telesis has been exiting selected paging markets where it doesn't have cellular operations (Ballen 1988).

In the publishing area it appears that early on Pacific Telesis brought some specialty directories to market. These included directories aimed at architects, hotel executives and interior designers in 1985. By 1987 the company has introduced "SMART Yellow Pages" which are the yellow pages designed to provide ease of use by the consumer. Through market research the wants and needs of the consumers are used to select and organize the contents of the directory in the different markets served.

However, not all areas entered into by Pacific Telesis appeared to have done so well. PacTel InfoSystems was built via internal growth and acquisitions starting with 13 stores in the Pacific Northwest and California in 1985 (Keppel 1986). By 1986 the chain, which sold products from Apple, IBM, Compaq

and others, had grown to 25 stores (Bermar,1987). By 1988 PacTel InfoSystems is has changed its focus to meeting the microcomputer and local area network needs of Fortune 1,000 companies on the west coast. Finally, by 1989 PacTel Infosystems is no longer mentioned.

In conclusion it appears that while not all actions taken by Pacific Telesis were successful it did, nevertheless experience progress in pursuit of the displaced ideal. It appears that the business errors it committed, e.g. PacTel InfoSystems, were minor in comparison to the success it enjoyed in areas such as its position in the cellular marketplace. As the only company to see its DEA rating improve, from .878 in 1985 to .894 in 1989, it appears as if this qualitative review supports the quantitative finding.

Southwestern Bell Review

While the DEA efficiency estimates of Southwestern Bell varied across the years of the study they were the same at .930 in 1985 and 1989. However, examination of table 76 in Chapter Five reveals that Southwestern Bell went from being in the third position in 1985 to being the BHC with the highest efficiency rating, relative to the ideal firm, in 1989.

In 1985 Southwestern Bell began to aggressively develop its publishing operations through the

acquisition of three firms in the marketing and publishing of Yellow Pages across the United States (Page 1988). They also started up new operations in selected markets across the country to compete in the Yellow Pages arena (Wilke 1986).

In 1984 they had announced a new product called "Silver Pages" as a discount based directory aimed at the senior citizen market across the United States. By 1985 this product was in 46 markets and the stated goal was to achieve profitability by 1988.

In the 1986 and 1987 annual reports production records and sales achievements are prominently mentioned in both the national Yellow and Silver Pages operations. However, in 1988 it is reported that the decision was made to cease the entire Silver Pages operation and the vast majority of Yellow Pages operations outside of their traditional regional markets (Graham 1988). This action was taken since the companies failed to achieve business expectations (Krasilovsky 1990). Clearly the expense associated with the startup and shutdown of such a large product resulted in a reduction of the efficient utilization of resources at Southwestern Bell.

Contrary to this appears to be Southwestern Bell's cellular and paging operations. The company was developing cellular operations in its traditional

region. Then in 1986 it offered to purchase the cellular and paging operations of Metromedia, Inc. and in 1987 it received permission to do so.

The company paid 1.65 billion dollars for the cellular operations in 6 cities and the paging operations in 28 markets. The major cellular markets it gained access to were Baltimore/Washington, D.C., Boston and Chicago (Feder 1988 and Gibson 1986).

By 1989 it was being reported that the cellular operations had grown to a total of 382,000 customers. While the customer growth was significant, of even greater significance was the 1989 announcement that the cellular operations had turned profitable ahead of schedule (Poole 1990). This was accomplished despite the price paid for the Metromedia properties. Additionally, it was announced in 1989 that the paging operations had grown to be the largest in the country with over 800,000 pagers in operation in 32 markets across the United States (Poole 1990). This allowed the company the ability to overcome the negative impact of the Silver Pages experience.

While Southwestern Bell entered other lines of business, such as communications equipment and cable television in the United Kingdom, the Yellow Pages and cellular lines are apparently the most significant events in the company's evolution. As Southwestern

pursued the ideal the failure of the publishing was offset by the success of the cellular operations. Thus, the same DEA efficiency rating of .930 in 1985 and 1989 seems reasonable.

US West Review

In table 76 of Chapter Five US West experiences the largest decrease in efficiency of any of the BHCs. In 1985 it had the highest DEA rating at .975 and saw that deteriorate by .101 to .874 by the end of the study period. The .874 was the median efficiency rating of the seven BHCs in 1989.

One of the external factors that may relate to the loss of efficiency at US West is the scope of its regulated telephone operations. As opposed to Pacific Telesis, US West has the largest geographical coverage of any BHC (Ballen 1988). Its regulated telephone operations cover 14 states. So that where Pacific Telesis has only two public service commissions to maintain relations with, US West has 14. This, in all probability, requires more attention by senior management in conducting their telephone operations (Ivey 1988).

In reviewing the US West reports, US West early on began an aggressive acquisition program of directory operations and publishing outside of its traditional

region. In 1985 US West acquired six publishing related companies and in 1986 it acquired twelve additional firms. However, this rapid growth slowed to three in 1987 and two in 1988. Thus, it may be that the results of these expansions may be the greatest addition to the US West portfolio of operations.

With respect to the cellular operations the only major acquisition outside of its traditional region was the acquisition of the San Diego property in 1986. Considerable activity took place in the paging markets with a possible strategy being to offer paging in those markets where it offers cellular service. By 1989 US West had 135,000 cellular customers and 134,00 pagers in service.

One interesting development was that in 1988 US West held an initial public offering in its paging and cellular subsidiary, US West NewVector Group. It sold 19 percent, 9.7 million shares, of the common stock it held in the company. This allowed US West to recoup its total investment in the subsidiary. However, by 1991 US West paid a premium of $45,000,000 to buy back those shares (Lindstrom 1991,). Thus, it may be that the effort to recoup its investment was not prudent.

Early on US West entered the financial services, leasing and commercial real estate businesses. However, by 1989 it was reporting on changing the focus of its

financial services and divesting itself of its real estate development operations. Certainly the cooling off of the real estate markets in the 1980s contributed to this divestiture (McMahon 1990). Once again this would likely contribute to the decrease in DEA efficiency estimates.

In international operations US West was aggressive in the cable television and cellular industries. By 1989 it had cable television operations in Hong Kong, England and France and was building a cellular system in Hungary. However, it was most likely that at that time those operations were contributing little, if any, to the revenues and net income of the company.

This review seems to indicate that US West attempted to enter quite a number of new areas during the study period while finding little success. Additionally, it appears that towards the end of the study US West was removing capital from several of these operations, including cellular operations in the United States, and redirecting it towards its international operations. Thus, the decrease in efficiency that the DEA revealed during the study period seems warranted.

Regulated Telephone Review

Operations at the telephone companies owned by the firms are quite similar. Exogenous variables such as the local economies, state regulators and even harsh weather events clearly impact operations. However, this study focused on the areas where management could take meaningful and decisive action.

The BHCs continue to lobby at both the federal and state levels for regulatory reform. While the long term efforts of these actions may prove to be rewarding the ability to translate these actions into meaningful impact of current operations is minimal at best.

The BHCs through their common telephone technology research company, Bellcore, maintain a common set of telecommunications standards and shared research results. This sharing coupled with a ban on their ability to design and manufacture products makes the likelihood of one firm gaining superiority in their telephone operations unlikely.

In the introduction of new products and services, in association with their telephone network, that all can offer the same products and services. Clearly, competition from outside competitors can occur in an ever increasing number of areas. However, during the course of this study it doesn't appear as if any BHC

was able to gain technological superiority over another BHC in its telephone operations.

To illustrate the impact of telephone operations on the firms revenue and net income one needs only to look at the growths in the BHCs telephone customer base. This growth, referred to as access line growth, can have a significant impact on the firm.

Between 1985 and 1989 the annual reports reveal that Pacific Telesis had the highest cumulative growth rate (CGR) of 5.1% annually between 1985 and 1989 with access lines climbing from 11.6 million to 13.6 million. This addition of two million lines is consistent with Pacific Telesis having the only increase in its DEA rating.

US West reported the smallest CGR at 1.5% annually, and this is in line with its DEA rating experiencing the largest decrease. With a CGR of 1.5% US West added one million access lines to its network.

However, beyond these two extremes the relationship between access line growth and DEA rating change is mixed. For example Southwestern Bell had the next to lowest access line CGR at 1.9% while experiencing no decline in its DEA rating. Additionally, while Bell South Had the second largest access line CGR at 3.9% it also had the next to worst deterioration in its DEA rating.

Thus, while it may be that extreme swings in the BHCs access line CGR's are quite relevant they do not appear to be the sole impact on the firm's overall efficiency ratings under DEA.

Summary

In this qualitative examination and discussion a review of some of the managerial decisions at the BHCs supports the DEA efficiency findings in Chapter Five. Specifically, that during the five year time span of this study the companies were searching to diversify away from their core regulated telephone businesses.

The explosive growth that the cellular business has enjoyed appears to have provided a basis for increased DEA efficiencies at some of the BHCs. Conversely, the aggressive entry into expanded Yellow Pages publication seems to have negatively impacted most of them.

Beyond the current operations the BHCs all continue to report on future directions of the companies. They all are pursuing the avenues of removing the restrictions placed on them at divestiture. These limitations regard what lines of business they are prohibited from entering and restrictions on how they compete in current markets.

The companies by and large feel that in the immediate future international ventures will provide the greatest opportunities. These ventures seem to be in the provision of cable television, cellular communications and taking equity positions in foreign telephone operations.

Clearly the senior management at the BHCs has an obligation to its stakeholders to grow the business. However, the data from this qualitative examination seem to support two findings. First, as these firms branch out they should not venture too far away from the communications business. Secondly, they should be prepared to exit poorly performing ventures fairly rapidly and not continue to hold out hope for future success.

CHAPTER 7

SUMMARY AND CONCLUSIONS

In this chapter a review will be conducted on the purpose and results of this study. As part of that review the normative procedure, as developed in this study, will be formalized into seven distinct steps. Beyond this, some suggestions are offered on where additional research could be conducted based upon the findings of this study.

Summary

The fundamental purpose of this study was to develop a normative procedure, utilizing Data Envelopment Analysis and entropy, to assist a firm in pursuit of the displaced ideal. In such a procedure, a linkage between operational management (efficiency); tactical management (effectiveness); and strategic management (explicability) needs to be achieved.

The findings of this digest suggest that the establishment of such a procedure appears to be quite feasible. Beyond being feasible, given that a firm carefully adapted the procedure to its own structure and environment, the procedure has the potential to be

quite rewarding in aiding the firm as it pursues the displaced ideal.

Steps of the Normative Procedure

The normative procedure, as developed in this study, consists of the following seven steps:

1. Identify those companies to be included in the competitive set. These companies are selected at management's discretion; however, it is reasonable to assume that this set will be fairly homogeneous.

2. Determine the appropriate input and output variables relative to the competitive set. These variables are selected by the firm's management and as such reflect management values on the importance of these variables.

3. Establish the performance characteristics of an ideal company based upon the best values of the input and output variables in the competitive set. At different points-in-time, known as windows, determine the properties of the new ideal firm.

4. Evaluate the efficiency rating of the company and all other companies in the competitive set relative the ideal company. This evaluation is conducted utilizing data envelopment analysis.

5. Select the financial, operational, and managerial ratios that are managements indicators of firm effectiveness. The ratios are strongly linked to

the input and output variables selected in step two of this procedure. Should specific ratios be required in this analysis then every measure should be taken to ensure that the variables in those ratios are selected in step two of this procedure.

6. Through the application of entropy analysis determine those ratios where the firm has the potential for the greatest improvement in its performance. This potential is relative to all of the other firms in the competitive set.

7. Management links the results of the DEA and entropy analysis to target selected specific areas for improvement. In this step management links tactical, operational and strategic management as the firm pursues the displaced ideal. That is, management develops action plans to explain to the firm's stakeholders its objectives relative to the firm's effectiveness and efficiency goals.

Through the implementation of this seven step procedure a firm would be in a position to formally pursue the displaced ideal.

Findings of the Study

The Bell Holding Companies, which served as the empirical data utilized in this study, were only used to illustrate the potential of the normative procedures approach. It should be recalled that the variables used

in this study would not necessarily be the same ones selected at any or all of the firms included in this study. However, even with this caveat on the limitations of the data utilized in this study the following observations are made:

1. The procedure did provide a basis for management to develop action plans at all of the BHCs during each year of analysis. This appears to be the first application of DEA in the evaluation of competitive firms. The findings suggest that DEA can be an effective managerial aid in decision making.

2. The deterioration of DEA ratings for the same year as new years were added to the database strongly suggests that the ideal firm is becoming a more efficient firm across time. Thus, the concept of the "displaced ideal", as discussed in this study, seems to be applicable.

3. The finding that only one firm, Pacific Telesis, improved its DEA rating during the study suggests that, relative to the inputs and outputs utilized, the firms were not successful in pursuit of the displaced ideal.

4. The entropy analysis provided an ability to simultaneously view the performance of the firms on a number of ratios. Also an ability to identify, on a

firm by firm basis, where the greatest opportunity for possible improvement is gained.

5. In the entropy analysis the debt ratio tended to be the most dominant candidate for improvement. This was the case for all companies except Bell South from 1986 to the end of the study period. This dominance of a single ratio suggests that the performance by the BHCs on the other ratios evaluated in this study were more consistent.

6. Through the review of past management actions in Chapter 6 it appears as if supporting qualitative evidence exists to support the findings of the quantitative section. That is, the procedure developed in this study appears to be supported by observations reported in both the firm's annual reports and in public newspapers and business magazines.

7. Since the AT&T divestiture in 1984, this study provides comprehensive insight into the performance of the Bell Holding Companies on the variables included in this study.

8. The procedure can provide a source of information to financial analysts, stockholders and other firm stakeholders upon which management can be evaluated. Both past performance and future firm goals could be determined through the application of this procedure.

Future Research Topics

The research presented in this digest while suggesting that the application of the normative procedure has the potential for being quite rewarding is open to many avenues of additional research. Future areas would include:

1. Determining the impact of utilizing other variables in this analysis. This could be done using data independent of the variables utilized in this study or as variables augmented to the current data set. This augmentation would have to followed within the restrictions imposed by the DEA degrees-of-freedom constraint.

2. The data set utilized in the development of this procedure should be extended to other industries. The extension to industrial sectors that have an information database across a longer time horizon, such as steel makers or auto makers, would allow for additional testing of the validity of this approach. This longer time frame would allow for the consideration of different environmental and economic factors present in the markets. For example, the relevance of efficiency in bull and bear markets would be worth further examination.

3. In a similar vein the ability to have firms enter and exit the competitive set over time needs to

be developed. As time progresses, a company may find itself exiting one sector and entering another. The ability to make this transformation should prove interesting.

4. An extensive testing of the DEA procedures performance against actual marketplace performance in several sectors should be conducted. In such a way it would be possible to provided an extended benchmark of the estimates versus market performance.

5. The testing of the procedure when the homogeneous industry constraint is eliminated would be of interest and potentially valuable. What impact the elimination of this constraint would have on the information generated by the consideration of firms engaged in different lines of business would be of interest.

6. Another area worthy of investigation is in what happens when the time intervals are shortened. In the present procedure the data is annual in nature. It would be interesting to see the impact when the data is quarterly.

7. Finally, based upon the procedure developed here it may be possible to enhance management compensation plans incorporating the DEA based measures. With the DEA measures incorporating short, intermediate, and long term performance research to tie

these ratings into managers short and long term performance bonuses may be worthwhile.

Conclusion

This normative procedure, based upon the utilization of Data Envelopment Analysis and entropy, was applied in an evaluation of the seven Bell Holding Companies between 1985 and 1989 inclusive. This application suggests that DEA and entropy when linked together have the potential to contribute to the decision making process at the firm.

This decision making process incorporates the strategic, tactical and operational management functions of the firm. This linkage is accomplished through the application of data envelopment analysis and entropy in the context of the firm being in pursuit of the displaced ideal.

APPENDIX 1

COMPUTER PROGRAM INPUT FILES

COMPUTER RUN ONE

INPUT DATA

1985 DATA ENVELOPMENT ANALYSIS DATA FILE FOR THE RBOCs

```
    8     2     3
REVENUE   NETPCT     TOTAS       EMP        TLIAB
        1.         1.         1.         1.         1.

         9058.0                11.9          17635.0
74100.0 10547.0
         9084.0                12.0          18684.0
82800.0 11175.0
        10664.0                13.3          23673.0
96000.0 14258.0
        10314.0                10.6          19853.0
94900.0 11999.0
         8498.0                10.9          18433.0
76900.0 11951.0
         7925.0                12.6          18042.0
71900.0 11047.0
         7819.0                11.8          17100.0
70800.0 10452.0
        10664.0                13.3          17100.0
70800.0 10452.0


AM85
BA85
BS85
NY85
PA85
SB85
US85
ID85
```

COMPUTER RUN TWO
INPUT DATA

1986 DATA ENVELOPMENT ANALYSIS DATA FILE FOR THE RBOCs

```
   16     2     3
REVENUE    NETINC     TOTAS       EMP        TLIAB
         1.         1.         1.         1.         1.

          9058.0                11.9           17635.0
74100.0  10547.0
          9385.0                12.1           18149.0
70900.0  10699.0
          9084.0                12.0           18684.0
82800.0  11175.0
         10054.0                11.6           19788.0
79300.0  11867.0
         10664.0                13.3           23673.0
96000.0  14258.0
         11401.0                13.9           25008.0
92500.0  14810.0
         10314.0                10.6           19853.0
94900.0  11999.0
         11341.0                10.7           20682.0
89600.0  12333.0
          8498.0                10.9           18433.0
76900.0  11951.0
          8977.0                12.0           19538.0
71500.0  12221.0
          7925.0                12.6           18042.0
71900.0  11047.0
          7902.0                12.9           19291.0
71400.0  11894.0
          7819.0                11.8           17100.0
70800.0  10452.0
          8381.0                11.0           18422.0
70200.0  11478.0
         10664.0                13.3           17100.0
70800.0  10452.0
         11401.0                13.9           18149.0
70200.0  10699.0

AM85
AM86
BA85
BA86
BS85
BS86
NY85
NY86
PA85
PA86
```

SB85
SB86
US85
US86
ID85
ID86

COMPUTER RUN THREE

INPUT DATA

1987 DATA ENVELOPMENT ANALYSIS DATA FILE FOR THE RBOCs

24 REVENUE	2 NETINC	3 TOTAS	EMP	TLIAB
	1.	1.	1.	1.
	9058.0	11.9		17635.0
74100.0	10547.0			
	9385.0	12.1		18149.0
70900.0	10699.0			
	9548.0	12.4		18739.0
71200.0	11130.0			
	9084.0	12.0		18684.0
82800.0	11175.0			
	10054.0	11.6		19788.0
79300.0	11867.0			
	10747.0	11.5		21091.0
80200.0	12770.0			
	10664.0	13.3		23673.0
96000.0	14258.0			
	11401.0	13.9		25008.0
92500.0	14810.0			
	12230.0	13.6		26218.0
96900.0	14956.0			
	10314.0	10.6		19853.0
94900.0	11999.0			
	11341.0	10.7		20682.0
89600.0	12333.0			
	12084.0	10.6		22032.0
90200.0	13164.0			
	8498.0	10.9		18433.0
76900.0	11951.0			
	8977.0	12.0		19538.0
71500.0	12221.0			
	9156.0	10.4		20321.0
74900.0	12568.0			
	7925.0	12.6		18042.0
71900.0	11047.0			
	7902.0	12.9		19291.0
71400.0	11894.0			
	8003.0	13.1		20300.0
67500.0	12482.0			
	7819.0	11.8		17100.0
70800.0	10452.0			
	8381.0	11.0		18422.0
70200.0	11478.0			
	8697.0	11.6		20048.0
69400.0	12769.0			

	10664.0	13.3	17100.0
70800.0	10452.0		
	11401.0	13.9	18149.0
70200.0	10699.0		
	12230.0	13.6	18739.0
67500.0	11130.0		

AM85
AM86
AM87
BA85
BA86
BA87
BS85
BS86
BS87
NY85
NY86
NY87
PA85
PA86
PA87
SB85
SB86
SB87
US85
US86
US87
ID85
ID86
ID87

COMPUTER RUN FOUR

INPUT DATA

1988 DATA ENVELOPMENT ANALYSIS DATA FILE FOR THE RBOCs

32	2	3			
REVENUE	NETINC	TOTAS	EMP	TLIAB	
	1.	1.	1.	1.	1.
		9058.0	11.9	17635.0	
74100.0	10547.0				
		9385.0	12.1	18149.0	
70900.0	10699.0				
		9548.0	12.4	18739.0	
71200.0	11130.0				
		9903.0	12.5	18780.0	
71900.0	11170.0				
		9084.0	12.0	18684.0	
82800.0	11175.0				
		10054.0	11.6	19788.0	
79300.0	11867.0				
		10747.0	11.5	21091.0	
80200.0	12770.0				
		10880.0	12.1	21245.0	
81000.0	12503.0				
		10664.0	13.3	23673.0	
96000.0	14258.0				
		11401.0	13.9	25008.0	
92500.0	14810.0				
		12230.0	13.6	26218.0	
96900.0	14956.0				
		13597.0	12.3	27417.0	
98700.0	15438.0				
		10314.0	10.6	19853.0	
94900.0	11999.0				
		11341.0	10.7	20682.0	
89600.0	12333.0				
		12084.0	10.6	22032.0	
90200.0	13164.0				
		12661.0	10.4	23006.0	
95300.0	13809.0				
		8498.0	10.9	18433.0	
76900.0	11951.0				
		8977.0	12.0	19538.0	
71500.0	12221.0				
		9156.0	10.4	20321.0	
74900.0	12568.0				
		9483.0	12.5	21056.0	
71900.0	13166.0				
		7925.0	12.6	18042.0	
71900.0	11047.0				

	7902.0	12.9	19291.0
71400.0	11894.0		
	8003.0	13.1	20300.0
67500.0	12482.0		
	8453.0	12.5	21500.0
67100.0	13309.0		
	7819.0	11.8	17100.0
70800.0	10452.0		
	8381.0	11.0	18422.0
70200.0	11478.0		
	8697.0	11.6	20048.0
69400.0	12769.0		
	9221.0	12.3	20981.0
68500.0	13525.0		
	10664.0	13.3	17100.0
70800.0	10452.0		
	11401.0	13.9	18149.0
70200.0	10699.0		
	12230.0	13.6	18739.0
67500.0	11130.0		
	13597.0	12.5	18780.0
67100.0	11170.0		

AM85
AM86
AM87
AM88
BA85
BA86
BA87
BA88
BS85
BS86
BS87
BS88
NY85
NY86
NY87
NY88
PA85
PA86
PA87
PA88
SB85
SB86
SB87
SB88
US85
US86
US87
US88

ID85
ID86
ID87
ID88

COMPUTER RUN FIVE

INPUT DATA

1989 DATA ENVELOPMENT ANALYSIS DATA FILE FOR THE RBOCs

```
   40     2     3
REVENUE    NETINC     TOTAS       EMP        TLIAB
        1.         1.          1.         1.         1.

           9058.0          11.9         17635.0
 74100.0 10547.0
           9385.0          12.1         18149.0
 70900.0 10699.0
           9548.0          12.4         18739.0
 71200.0 11130.0
           9903.0          12.5         18780.0
 71900.0 11170.0
          10211.0          12.1         19163.0
 71900.0 11319.0
           9084.0          12.0         18684.0
 82800.0 11175.0
          10054.0          11.6         19788.0
 79300.0 11867.0
          10747.0          11.5         21091.0
 80200.0 12770.0
          10880.0          12.1         21245.0
 81000.0 12503.0
          11449.0           9.4         24729.0
 81000.0 15552.0
          10664.0          13.3         23673.0
 96000.0 14258.0
          11401.0          13.9         25008.0
 92500.0 14810.0
          12230.0          13.6         26218.0
 96900.0 14956.0
          13597.0          12.3         27417.0
 98700.0 15438.0
          13996.0          12.4         28472.0
100300.0 16633.0
          10314.0          10.6         19853.0
 94900.0 11999.0
          11341.0          10.7         20682.0
 89600.0 12333.0
          12084.0          10.6         22032.0
 90200.0 13164.0
          12661.0          10.4         23006.0
 95300.0 13809.0
          13211.0           6.1         25362.0
 97400.0 15942.0
           8498.0          10.9         18433.0
```

76900.0	11951.0 8977.0	12.0	19538.0
71500.0	12221.0 9156.0	10.4	20321.0
74900.0	12568.0 9483.0	12.5	21056.0
71900.0	13166.0 9593.0	12.9	21191.0
69700.0	13106.0 7925.0	12.6	18042.0
71900.0	11047.0 7902.0	12.9	19291.0
71400.0	11894.0 8003.0	13.1	20300.0
67500.0	12482.0 8453.0	12.5	21500.0
67100.0	13309.0 8730.0	12.5	20985.0
64900.0	12481.0 7819.0	11.8	17100.0
70800.0	10452.0 8381.0	11.0	18422.0
70200.0	11478.0 8697.0	11.6	20048.0
69400.0	12769.0 9221.0	12.3	20981.0
68500.0	13525.0 9691.0	11.5	22416.0
69800.0	14630.0 10664.0	13.3	17100.0
70800.0	10452.0 11401.0	13.9	18149.0
70200.0	10699.0 12230.0	13.6	18739.0
67500.0	11130.0 13597.0	12.5	18780.0
67100.0	11170.0 13996.0	12.9	19163.0
64900.0	11319.0		

AM85
AM86
AM87
AM88
AM89
BA85
BA86
BA87
BA88
BA89
BS85

BS86
BS87
BS88
BS89
NY85
NY86
NY87
NY88
NY89
PA85
PA86
PA87
PA88
PA89
SB85
SB86
SB87
SB88
SB89
US85
US86
US87
US88
US89
ID85
ID86
ID87
ID88
ID89

APPENDIX 2

COMPUTER OUTPUT REPORTS

COMPUTER RUN ONE

COMPUTER OUTPUT FOR 1985

```
   1-AM85                                                    .9517
1  DMUS IN FACET
     8
  1.00
   2-BA85                                                    .8728
1  DMUS IN FACET
     8
  1.00
   3-BS85                                                    .7540
1  DMUS IN FACET
     8
  1.00
   4-NY85                                                    .7913
1  DMUS IN FACET
     8
  1.00
   5-PA85                                                    .9076
1  DMUS IN FACET
     8
  1.00
   6-SB85                                                    .9530
1  DMUS IN FACET
     8
  1.00
   7-US85                                                    .9746
1  DMUS IN FACET
     8
  1.00
   8-ID85                                                   1.0000
1  DMUS IN FACET
     8
  1.00
```

COMPUTER RUN TWO

COMPUTER OUTPUT FOR 1985 AND 1986

```
   1-AM85                                                .9518
2  DMUS IN FACET
    16    15
   .38   .62
   2-AM86                                                .9760
1  DMUS IN FACET
    16
  1.00
   3-BA85                                                .8740
1  DMUS IN FACET
    16
  1.00
   4-BA86                                                .8929
1  DMUS IN FACET
    16
  1.00
   5-BS85                                                .7562
1  DMUS IN FACET
    16
  1.00
   6-BS86                                                .7685
1  DMUS IN FACET
    16
  1.00
   7-NY85                                                .7932
1  DMUS IN FACET
    16
  1.00
   8-NY86                                                .8238
1  DMUS IN FACET
    16
  1.00
   9-PA85                                                .9084
1  DMUS IN FACET
    16
  1.00
   10-PA86                                               .9433
1  DMUS IN FACET
    16
  1.00
   11-SB85                                               .9532
2  DMUS IN FACET
    16    15
   .90   .10
```

```
  12-SB86                                                    .9401
1  DMUS IN FACET
    16
  1.00
  13-US85                                                    .9746
2  DMUS IN FACET
    16    15
   .00  1.00
  14-US86                                                    .9644
1  DMUS IN FACET
    16
  1.00
  15-ID85                                                   1.0000
2  DMUS IN FACET
    16    15
   .00  1.00
  16-ID86                                                   1.0000
1  DMUS IN FACET
    16
  1.00
```

COMPUTER RUN THREE

COMPUTER OUTPUT FOR 1985 TO 1987

```
   1-AM85                                                .9518
2  DMUS IN FACET
    23     22
   .38    .62
   2-AM86                                                .9760
2  DMUS IN FACET
    22     23
   .00   1.00
   3-AM87                                                .9450
1  DMUS IN FACET
    24
  1.00
   4-BA85                                                .8577
2  DMUS IN FACET
    24     23
   .91    .09
   5-BA86                                                .8743
1  DMUS IN FACET
    24
  1.00
   6-BA87                                                .8578
1  DMUS IN FACET
    24
  1.00
   7-BS85                                                .7419
1  DMUS IN FACET
    24
  1.00
   8-BS86                                                .7685
2  DMUS IN FACET
    24     23
   .00   1.00
   9-BS87                                                .7292
1  DMUS IN FACET
    24
  1.00
  10-NY85                                                .7779
1  DMUS IN FACET
    24
  1.00
  11-NY86                                                .8075
1  DMUS IN FACET
    24
  1.00
```

```
  12-NY87                                                    .7955
1  DMUS IN FACET
    24
  1.00
  13-PA85                                                    .8991
2  DMUS IN FACET
    24    23
   .48   .52
  14-PA86                                                    .9230
1  DMUS IN FACET
    24
  1.00
  15-PA87                                                    .8904
1  DMUS IN FACET
    24
  1.00
  16-SB85                                                    .9411
2  DMUS IN FACET
    24    22
   .57   .43
  17-SB86                                                    .9199
1  DMUS IN FACET
    24
  1.00
  18-SB87                                                    .9388
1  DMUS IN FACET
    24
  1.00
  19-US85                                                    .9746
2  DMUS IN FACET
    24    22
   .00  1.00
  20-US86                                                    .9546
2  DMUS IN FACET
    24    23
   .46   .54
  21-US87                                                    .9290
1  DMUS IN FACET
    24
  1.00
  22-ID85                                                   1.0000
3  DMUS IN FACET
    23    24    22
   .00   .00  1.00
  23-ID86                                                   1.0000
2  DMUS IN FACET
    24    23
   .00  1.00
  24-ID87                                                   1.0000
1  DMUS IN FACET
    24
```

COMPUTER RUN FOUR

COMPUTER OUTPUT FOR 1985 TO 1988

```
   1-AM85                                          .9518
2  DMUS IN FACET
    30    29
   .38   .62
   2-AM86                                          .9760
3  DMUS IN FACET
    32    29    30
   .00   .00  1.00
   3-AM87                                          .9348
2  DMUS IN FACET
    32    30
   .92   .08
   4-AM88                                          .9287
1  DMUS IN FACET
    32
  1.00
   5-BA85                                          .8476
2  DMUS IN FACET
    32    29
   .94   .06
   6-BA86                                          .8638
1  DMUS IN FACET
    32
  1.00
   7-BA87                                          .8478
1  DMUS IN FACET
    32
  1.00
   8-BA88                                          .8442
1  DMUS IN FACET
    32
  1.00
   9-BS85                                          .7401
2  DMUS IN FACET
    32    31
   .27   .73
  10-BS86                                          .7685
2  DMUS IN FACET
    31    30
   .00  1.00
  11-BS87                                          .7292
2  DMUS IN FACET
    32    31
   .00  1.00
```

```
  12-BS88                                                    .7132
1  DMUS IN FACET
    32
  1.00
  13-NY85                                                    .7704
1  DMUS IN FACET
    32
  1.00
  14-NY86                                                    .7991
1  DMUS IN FACET
    32
  1.00
  15-NY87                                                    .7875
1  DMUS IN FACET
    32
  1.00
  16-NY88                                                    .7545
1  DMUS IN FACET
    32
  1.00
  17-PA85                                                    .8841
2  DMUS IN FACET
    32     29
   .79    .21
  18-PA86                                                    .9109
1  DMUS IN FACET
    32
  1.00
  19-PA87                                                    .8794
1  DMUS IN FACET
    32
  1.00
  20-PA88                                                    .8935
1  DMUS IN FACET
    32
  1.00
  21-SB85                                                    .9341
2  DMUS IN FACET
    32     29
   .56    .44
  22-SB86                                                    .9122
2  DMUS IN FACET
    32     31
   .64    .36
  23-SB87                                                    .9330
2  DMUS IN FACET
    32     31
   .45    .55
  24-SB88                                                    .9171
1  DMUS IN FACET
    32
```

```
  1.00
  25-US85                                                    .9746
2  DMUS IN FACET
    32    29
   .00  1.00
  26-US86                                                    .9374
2  DMUS IN FACET
    32    29
   .79   .21
  27-US87                                                    .9166
1  DMUS IN FACET
    32
  1.00
  28-US88                                                    .9146
1  DMUS IN FACET
    32
  1.00
  29-ID85                                                   1.0000
3  DMUS IN FACET
    32    30    29
   .00   .00  1.00
  30-ID86                                                   1.0000
2  DMUS IN FACET
    31    30
   .00  1.00
  31-ID87                                                   1.0000
2  DMUS IN FACET
    32    31
   .00  1.00
  32-ID88                                                   1.0000
1  DMUS IN FACET
    32
  1.00
```

COMPUTER RUN FIVE

COMPUTER OUTPUT FOR 1985 TO 1989

```
   1-AM85                                          .9460
2  DMUS IN FACET
    40     36
   .11    .89
   2-AM86                                          .9606
2  DMUS IN FACET
    40     36
   .28    .72
   3-AM87                                          .9258
2  DMUS IN FACET
    40     36
   .78    .22
   4-AM88                                          .9209
2  DMUS IN FACET
    40     36
   .81    .19
   5-AM89                                          .9103
1  DMUS IN FACET
    40
  1.00
   6-BA85                                          .8406
2  DMUS IN FACET
    40     36
   .77    .23
   7-BA86                                          .8486
1  DMUS IN FACET
    40
  1.00
   8-BA87                                          .8330
1  DMUS IN FACET
    40
  1.00
   9-BA88                                          .8295
1  DMUS IN FACET
    40
  1.00
  10-BA89                                          .7936
1  DMUS IN FACET
    40
  1.00
  11-BS85                                          .7361
2  DMUS IN FACET
    40     37
   .60    .40
```

```
  12-BS86                                                    .7685
2  DMUS IN FACET
    40    37
   .00  1.00
  13-BS87                                                    .7292
3  DMUS IN FACET
    37    40    38
   .00   .00  1.00
  14-BS88                                                    .7014
1  DMUS IN FACET
    40
  1.00
  15-BS89                                                    .6862
1  DMUS IN FACET
    40
  1.00
  16-NY85                                                    .7573
1  DMUS IN FACET
    40
  1.00
  17-NY86                                                    .7854
1  DMUS IN FACET
    40
  1.00
  18-NY87                                                    .7741
1  DMUS IN FACET
    40
  1.00
  19-NY88                                                    .7418
1  DMUS IN FACET
    40
  1.00
  20-NY89                                                    .7126
1  DMUS IN FACET
    40
  1.00
  21-PA85                                                    .8781
2  DMUS IN FACET
    40    36
   .65   .35
  22-PA86                                                    .8945
1  DMUS IN FACET
    40
  1.00
  23-PA87                                                    .8638
1  DMUS IN FACET
    40
  1.00
  24-PA88                                                    .8776
1  DMUS IN FACET
    40
```

```
  1.00
  25-PA89                                                    .8937
1  DMUS IN FACET
    40
  1.00
  26-SB85                                                    .9297
2  DMUS IN FACET
    40    36
   .46   .54
  27-SB86                                                    .8916
1  DMUS IN FACET
    40
  1.00
  28-SB87                                                    .9192
2  DMUS IN FACET
    40    37
   .80   .20
  29-SB88                                                    .9006
1  DMUS IN FACET
    40
  1.00
  30-SB89                                                    .9299
1  DMUS IN FACET
    40
  1.00
  31-US85                                                    .9746
2  DMUS IN FACET
    40    36
   .00  1.00
  32-US86                                                    .9312
2  DMUS IN FACET
    40    36
   .64   .36
  33-US87                                                    .9001
1  DMUS IN FACET
    40
  1.00
  34-US88                                                    .8982
1  DMUS IN FACET
    40
  1.00
  35-US89                                                    .8740
1  DMUS IN FACET
    40
  1.00
  36-ID85                                                   1.0000
3  DMUS IN FACET
    40    37    36
   .00   .00  1.00
  37-ID86                                                   1.0000
2  DMUS IN FACET
```

```
    40    37
   .00  1.00
  38-ID87                                          1.0000
3  DMUS IN FACET
    37    40    38
   .00   .00  1.00
  39-ID88                                          1.0000
3  DMUS IN FACET
    36    40    39
   .00   .00  1.00
  40-ID89                                          1.0000
1  DMUS IN FACET
    40
  1.00
```

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VITA AUCTORIS

James Michael Velayas was born in Dennison, Texas, on October 18, 1949. He served in the United States Marine Corps and was honorably discharged at the rank of corporal in 1971.

Mr. Velayas earned his B.S. in mathematics from Metropolitan State College in 1975, his M.S. in statistics from Bowling Green State University in 1977, and his M.B.A. degree from Southern Illinois University in 1984.

Between 1977 and 1982 Mr. Velayas was employed by National Steel Corporation. His first assignment was as a Management Scientist at the steel mill in Detroit, Michigan. In 1981 he was named Senior Management Scientist at the steel mill in Granite City, Illinois.

Late in 1982 Mr. Velayas joined Southwestern Bell Telephone Company as Manager of Statistical Research. In 1986 he was named District Manager of Statistical Decision Support. During 1987 he was transferred to the staff at Southwestern Bell Corporation, where he serves as the Associate Director of Corporate Research.

Mr. and Mrs. Velayas reside in Columbia, Illinois.