AN OVERALL AND TECHNICAL EFFICIENCY STUDY OF 25 ELECTRIC UTILITIES IN THE MIDWEST U.S. EXPERIENCING DEREGULATION AND COMPETITION

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A Dissertation
Submitted in Partial Fulfillment of the Requirements for the
Doctor of Philosophy Degree

Department of Business Administration
in the Graduate School
Southern Illinois University
at Carbondale
January 2001

UMI Number: 3021518

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Jan 19, 20 01

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Entitled

Overall and Technical Efficiency Study of Midwest

US Electric Utilities Experiencing Deregulation and Competition

Be accepted in partial fulfillment of the requirements for the

DOCTOR OF PHILOSOPHY degree.

In Charge of Dissertation

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Recommendation concurred in

1.
2.
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5.

Committee
for the
Final Examination

AN ABSTRACT OF THE DISSERTATION OF

David E. Schultz, for the Doctor of Philosophy degree in Business Administration, presented at Southern Illinois University at Carbondale.

TITLE: AN OVERALL AND TECHNICAL EFFICIENCY STUDY OF 25 ELECTRIC UTILITIES IN THE MIDWEST U.S. EXPERIENCING DEREGULATION AND COMPETITION

MAJOR PROFESSOR: Suresh Tadisina

This dissertation identified, measured, and validated the production efficiency of a small sample of electric utilities in the Midwest U. S. The measure of production efficiency selected for this study was the relative efficiency measure defined by the data envelopment analysis (DEA) CCR input-oriented model developed by Charnes, Cooper, and Rhodes (1978, 1981). This model provided a relative measure of overall and technical efficiency of a sample of electric utilities or decision-making units (DMUs) with respect to one another. This model as utilized in this study involved a two-stage process. In the first stage, the relatively efficient and inefficient firms or DMUs were identified as a scalar measure determined for each DMU. In the second stage of this analysis, changes in the input variable mix were identified and measured that enable management of the inefficient DMU to move the respective DMU to the efficient frontier or envelopment surface.

This study has extended the work previously undertaken by other researchers and practitioners observed in the literature. A complete set of thirteen representative input and output variables was selected and identified that account for the transformation process of the electric utility. These variables were incorporated into the production efficiency analyses. A retrospective cross-sectional efficiency analysis for three years (1988, 1992, and 1997) identified the relatively efficient and inefficient electric utilities. In addition to

this, a retrospective longitudinal analysis utilized the DEA CCR model with a three-year moving average window was performed over a ten-year horizon (1988 through 1997). The longitudinal analyses enabled the researcher to determine trends in the relative efficiency performance of individual electric utilities in the sample. An examination of the relative efficiency measures was undertaken and the presence of outliers, shape, and type of frequency distribution was examined. The sample selected consisted of two major types of electric utility organizations: the investor-owned electric utility (IOU) and the rural electric generation and transmission electric utility (G&T). Relative efficiencies were measured and compared for both organization types as a single combined sample and as separate representative electric utility firm types.

A relative efficiency measure was developed for consideration and use in improving the performance of its own firm as well as the competitive marketplace. Through the use of planning and control in the production process, management has the capability to provide for improvement in its firm relative to competition. If implemented on a continuing basis, management has the means to begin a process of continuous improvement and a potential source of competitive advantage to enhance profitability and survival.

ACKNOWLEDGMENTS

I extend my sincere thanks and appreciation to my chairman, Dr. Suresh Tadisina, and my dissertation committee members, Dr. Greg White, Dr. Arkalgud Ramaprasad, Dr. Subhash Sharma, and Dr. Richard Rivers. This committee provided valuable assistance, support, guidance on a timely basis. I am grateful for their dedication and effort in helping to make this dissertation project worthwhile and successful.

I also want to thank my family without whose inspiration, encouragement, support, prayers, and sacrifices this project could not have been accomplished.

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CHAPTER 1

INTRODUCTION

In today's competitive atmosphere, there is much interest in assessing and evaluating firm performance. Many questions arise when contemplating these ideas. Why do firms differ? Why are some firms more successful than others even in the same industry (Carroll, 1994; Nelson, 1994; Williams, 1994)? What accounts for firm differences? What is performance as it relates to a single firm? Can several firms' performances be described by a similar performance criterion? Can these performance criteria be measured? Can they be compared? Will such a comparison yield insights for the researcher or management to utilize in order to improve its own performance and competitive position in its marketplace? Will the added information enable an individual firm to determine its competitors' performances and positions? Will such analyses enable one to determine the best-in-class performers within a single period or throughout a specific horizon? Can key performance insights be gained by identifying the key parameters of those best in class firms? Can similar findings be made with respect to those firms that are relatively inefficient?

This dissertation does not attempt to answer all of these inquiries. However, this dissertation is concerned with postulating a definition of a firm's performance and developing a measure of such performance for the firm over time. It is important for the management of the firm to be able to determine, measure, monitor, track, and evaluate its individual performance. By doing so, management can determine what critical parameters are within its purview and control and develop its business planning, strategies, processes, and decision making on both a short-term and long-term basis to achieve continuous improvement. Continuous improvement is necessary to insure economic prosperity and survival.

Performance

The economic health and well being of a country or nation is dependent heavily on its productivity. Productivity is defined as the "relative measure of output per labor hour or machine hour, and is often expressed as a ratio of output to input" (Lee & Schneiderjans, 1993, p. 18). The greater the productivity ratio, the more efficient the organization or firm. "Efficiency is a measure that shows the relationship between the use of resources (input) and the resulting output" (p. 18). When the nation or country as a whole is producing quality products and services at prices better than those of its competitors, it will enjoy economic health and prosperity. When a nation, for whatever reason, finds that it is lagging behind its competition, it then will suffer economically and its standard of living will drop relative to its competitors. It is in the nation's best interest to encourage and sustain high levels and growth in productivity.

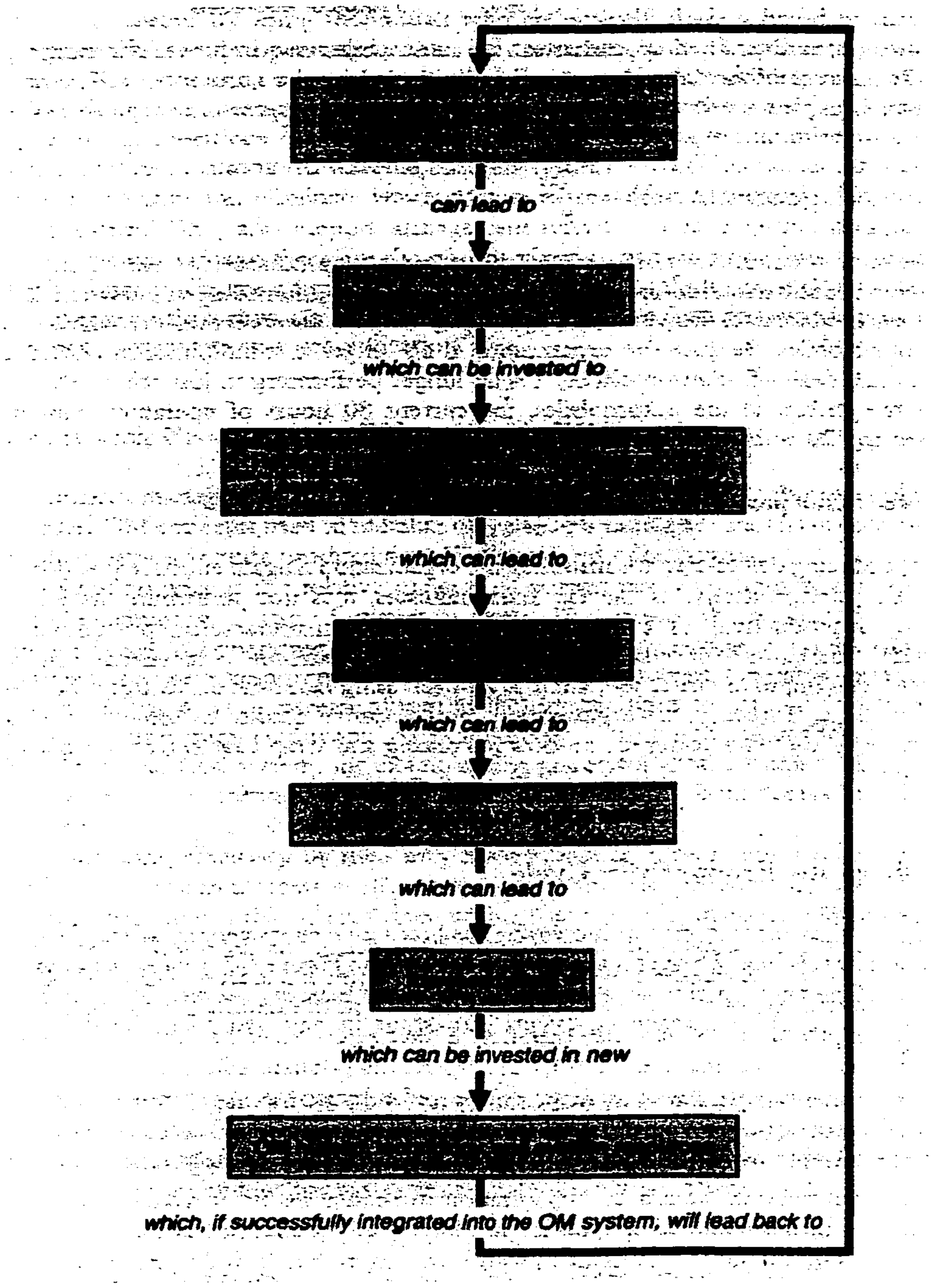
High productivity is not only important and critical for national competitiveness and well-being; it is critical also for the prosperity and well-being of an organization or firm in its own industry and markets. In order to survive and prosper, organizations and firms competing in this fast-paced, changing environment must continue to find ways to be competitive.

Lee and Schneiderjans (1993, p. 20) offer the productivity cycle, shown in Figure 1, as a guide for providing an environment for continuous productivity improvement within an organization. Improvements in flexibility or productivity can lead to reduced operating costs, which may be reinvested in the organization to reduce prices and/or improve the quality of the firm's products and services. These results can lead to competitive advantage for the firm, which in turn may lead to increased sales and increased profit. These profits can be shared with the owners or stakeholders and/or returned to the firm to further improve productivity. The productivity cycle can be initiated at any point in the sequence and the initiatives and results incorporated into the ongoing operation and function of the individual firm. This cycle appears to be a straightforward mechanism for a firm or organization to employ in pursuit of gaining sustainable competitive advantages and achieving success in its markets and industry.

Bitran and Chang (1984) (Eilon, 1985; Markland, Vickery, & Davis, 1998; Troutt, Rai, Tadisina, & Zhang, 1998; Troutt, Zhang, Tadisina, & Rai, 1996; Van Zandt, 1998) also view performance of the firm as an input-output conversion process and consider productivity and efficiency of production as indicators and measures of firm performance. Productivity and efficiency of the firm are to be measured by consideration of a ratio measure of outputs and inputs. Researchers differ as to the consideration of key firm inputs and outputs as well as the weights assigned to those respective variables. Some of these differences are considered elsewhere in this study.

Performance Definition

Performance in this dissertation is concerned primarily with a relative efficiency or productivity ratio developed for each firm using a set of selected inputs and outputs



Source: Lee & Schneiderjans, 1993, p. 20

Figure 1. The productivity cycle

critical to the operation and success of the firm. The ratio of the outputs to the inputs for a particular firm provides a measure of the efficiency of the organization. Comparisons of various firms' efficiency ratios during a single time period provide a means of evaluating their relative efficiencies or performances. Comparing such ratios in this single period allows the researcher an opportunity to determine the most efficient frontier and to determine the relative efficiencies (performances) of the respective firms under consideration or comparison. The most relatively efficient and inefficient firms can be identified through this relative efficiency ratio analysis.

The data envelopment analysis (DEA) CCR input-oriented model developed by Charnes, Cooper, and Rhodes (1978, 1981) defines the methodology for making these relative efficiency determinations. This model provides a relative efficiency measure of overall and technical efficiency of a comparison sample of decision-making units (DMUs) with respect to one another. Furthermore, this model enables one to identify a scalar value measure to determine those firms or DMUs that are efficient and inefficient with respect to one another. The relative efficiency measures range in numerical value in the interval greater than or equal to zero and less than or equal to one. Firms whose scalar value or relative efficiency is equal to one or one hundred percent are most relative efficient. Firms with ratios or scalar values falling within the range less than one are inefficient. This model also has the ability to identify specific changes in the input variable mix for one to consider in improving the relative performance and efficiency, enabling an inefficient DMU to move to the most efficient frontier.

This research study explores firm performance through the DEA model and provides a mechanism for management of the firm to assess and measure the relative efficiency of its own firm and that of its competitive peers. Such an analysis can help management of a firm to develop added insights into the critical areas identified in the input variable mix and provide a way for continuous performance improvement. This research study approach provides the researcher and/or firm management with the means to identify, measure, assess, and evaluate its competitors within the same framework and performance model. This model, in addition to the other performance models, is discussed in more detail in Chapter 2 and Chapter 3 of this dissertation.

The use of DEA performance modeling and analyses has been utilized in many different firms. Seiford (1996) formulated a bibliography of the research studies and applications for the last several years. DEA studies have been performed in agriculture, banking and finance, education, government, health care, manufacturing, transportation, and the utilities industries. The electric utility industry has been selected for the DEA analyses to be performed in this research study.

Industry Selection

The electric utility industry currently is experiencing a dramatic transformation in its business environment. This industry is undergoing deregulation, re-regulation, and a move to a more competitive environment all at the same time. Companies in this industry are seeing the ground shift, markets change, barriers to entry relaxed and shifted, new entrants, new rules, new business options, and dramatic potential shifts in their customer basis. The primary purpose of this study is to evaluate the performance of a select group of electric utilities during the 1988 to 1997 period in order to examine organizational differences under these environmental shifts. In order to gain greater insight into these events, it is necessary to consider what major events and actions are taking place within the environment that are bringing these changes. A brief summary of these major influences and impacts are described as follows. A more detailed treatment of this major legislation and the impacts on the electric utility industry is contained in Appendix A.

The electric utility industry has experienced many changes in its regulatory environment over the past century. In fat, the United States Congress has enacted six major laws concerning the electric utility industry, as shown in Table A1 (see Appendix A). These regulations have a significant impact on the manner in which electric utilities conduct their business and operations.

There exists within the U.S. a wide variation in the prices for electricity. Deregulation is intended to promote competition for the supply, transportation, and delivery of electricity throughout the country. The move to competition should reduce barriers to entry and provide an open competitive market where supply and demand will enable market-based prices to prevail. Large industrial customers are attempting to become involved in the wholesale electric supply market. Such customers who are located in high-cost states are lobbying and seeking competitively priced power to meet their requirements. International global competition is putting tension on all major suppliers to lower their costs in order to compete and maintain market share.

Electricity, as a product that is virtually sightless, tasteless, and indistinguishable across suppliers, is readily achieving recognition as a commodity. Electricity can be purchased, sold, and transacted much like wheat, barley, corn, and other commodities. The birth of this commodity market has created new classes of competitors vying for the traditional electric utility company's customers, business, and markets.

Individual Firm Alternatives

In order to cope, companies experiencing the uncertainty within the electric industry may strive to make changes, or they may simply consider the changes as a fad and do nothing. As one surveys the field, there are companies embracing differing strategies. Weiner et al. (1997) conclude:

> The existing regulatory framework in the U.S. electric utility industry is increasingly at odds with market and technological forces. While the pressure for change may vary from state to state depending on existing electricity rates and the political ideology of local regulators, one thing is certain: restructuring may occur at a different pace in each state, but it will be faster and more dramatic than most utility executives expect. (p. 22)

What strategies should an electric utility adopt to cope with this environment? An electric utility operating within this new competitive and deregulated environment has the opportunity to select from several different generic strategies in order to successfully compete and survive.

With the emphasis on competition and a move to encourage many entrants into the market by changing industry structure, rules, and deregulation, the primary push is to lower prices and makes availability, adequacy, quality, and reliability transparent to the ultimate consumer through development of a commodity product market. Cost leadership strategy is a method in which the firm rigorously and vigilantly reduces its costs in every competitive area. The primary goal is to achieve low-cost position by gaining a competitive advantage relative to its competitors. Porter identifies the efforts to control and reduce costs as those involved in "tight cost and overhead control, avoidance of marginal customer accounts, and cost minimization in areas like R&D, service, sales force, advertising, and so on. A great deal of managerial attention to cost control is necessary to achieve these aims" (Porter, 1980, p. 35). Porter suggests that firms that have a low-cost strategy enjoy above-average returns in the industry as compared to their competitors. He also believes that this strategy yields important advantages with respect to suppliers and buyers.

Differentiation of a product or service is a second generic strategy available to the firm. Differentiation of a product or service involves "creating something that is perceived industrywide as being unique" (Porter, 1980, p. 37). Porter offers design, brand image, technology, product or service features, and dealer network as potential areas for differentiation.

Focus, a third generic strategy, is concerned with a firm specializing and directing its product or service at specific market segments or entities. These market segments may be special customers, geographic areas, customized products, services or combinations. Focus provides distinct advantages for the firm:

> Although the low cost and differentiation strategies are aimed at achieving their objectives industrywide, the entire focus strategy is built around serving a particular target very well, and each functional policy is developed with this in mind. The strategy rests on the premise that the firm is thus able to serve its narrow strategic target more effectively or efficiently than competitors who are competing more broadly. As a result, the firm achieves either differentiation from better meeting the needs of the particular target or lower costs in serving this target, or both. Even though the focus strategy does not achieve low cost or

> differentiation from the perspective of the market as a whole, it does achieve one or both of these positions vis-à-vis its narrow market target. (Porter, 1980, pp. 40-41)

In order to gain competitive advantage and survive, some firms may find it desirable and necessary to combine two or more of these strategies in their arsenal. "Research has shown that the generic strategies of differentiation and cost are not mutually exclusive — a company can pursue them simultaneously. The consensus is that generic strategies are actually dimensions along which a company can score high or low" (Markland et al., 1998, p. 85).

In an editorial entitled "IOUs expected to dwindle down to 80 by year 2000," presented in the September 1996 issue of Electric Light & Power, it was stated:

> By the year 2000, mergers will reduce the number of investor-owned electric utilities (IOU) from 101 to 80. This according to a new Resource Data International (RDI) report, will be the ultimate result of U.S. IOUs merging at a rate of four to six companies per year. (Beaty, 1996, p. 5)

Weiner et al. (1997) also discuss firm efficiency and suggest the primary area for attention that a successful firm should pursue. "The most efficient operators in the future will, in fact, be able to operate at a variable cost lower than the current best in class. Thus cost management and operating efficiency will be the core capabilities of the survivors in generation" (p. 27).

Unit of Analysis

The unit of analysis for this study is the individual electric utility company. The firm-level analysis as proposed will consider the electric aspect of the company. For firms that limit business or products to electrical power and energy, the data collected will be directly relevant to this analysis. For firms that are combination electricity-and-gas providers, the data will require special attention to develop and separate the electric business from the combination.

Sample Selection

Some researchers selected comparative firms or organization structures for their investigations that are all IOUs (Goto & Tsutsui, 1998; Haeri, Khawaja, & Perussi, 1997; Taylor & Thompson, 1995); other utility researchers chose all cooperatives (Charnes, Cooper, Divine, Ruefli, & Thomas, 1989). The similar class organizations were undertaken to eliminate relative competitive advantages and disadvantages across the sample firms from influencing the analysis. While this may be valuable and useful from a research perspective, such imbalances and distortions exist in the industrial competitive environment. In spite of the unbalanced or unleveled playing fields, firms still must compete with one another.

This study is different in that all organizations thought to be in a particular firm's competitive group have been included in defining the relatively efficient frontier and the opportunities available for exploration by the various firms. A firm is somewhat limited by its past decisions with respect to its plant, facilities, service area, capacity mix, investment, and short- and long-term contract flexibility. However, in spite of these unique circumstances and situations, firms in a turbulent environment under tension must compete with one another, declare bankruptcy, cease to exist, merge, or be acquired by a competitor in a competitive market.

This sample was selected for a specific purpose and cannot be considered a statistically random sample. Babbie (1994) refers to this type of nonprobability sampling as purposive or judgmental sampling. The implication in this study is that whatever findings result can only be attributed to those utilities in the study and are not able to be generalized across the industry as a whole. Even with this limitation, the study was deemed to be worthwhile. The sample could be considered a population in that it was selected to represent all companies that the specific utility deemed as its competitors. It is important to mention that the top-level management in the specific utility and its consultants were directly involved in the selection of these firms and this sample mix.

Twenty-five electric utilities were selected for this sample. Twenty-one of the electric utilities were within two electric systems of the specific utility system. Management and consultants selected four other utilities in addition to these for inclusion in the sample. These four other electric utilities were electric utilities similar in nature to the specific utility. They were generation-and-transmission rural electric cooperatives located in the northern United States, the southern United States, and in the southeastern United States. Fourteen (56%) of the electric utilities were investor-owned electric utilities, and the other 11 (44%) were generation-and-transmission electric cooperative utilities.

Why study this small sample size of 25 electric utilities located in the midwestern U.S.? These electric utilities are situated in the heart of one of the largest coal reserves in the United States. Many of these utilities have built fossil-fuel power plants designed to burn the abundant, relatively low-cost coal available in this region. Building plants at the source of the fuel supply enhances the efficiency and competitiveness of these utilities as a result of a reduction in transportation and delivery costs. Many of the utilities included in this sample are among the lowest-cost producers in the nation; they pass these relative low costs to their customers. These same utilities are subject to the environmental regulations, deregulation actions, and a more competitive environment as discussed previously. While these utilities are low cost, changes in the competitive environment may have dramatic impact on the cost position and viability of these firms.

This research study evaluated nine key input variables and four key output variables for each firm from 1988 through 1997. The input and output variables are summarized as listed below.

1. Input Variables:

    Fixed Expenses

        Taxes

        Interest

        Depreciation

        Administrative and General

    Variable Expenses

        Fuel and Purchased Power

        Non-Fuel Production and Operations and Maintenance

    Full-Time Electric Employees

    Net Installed Generating Capacity in Kilowatts

    Transmission Line Circuit Miles Installed

2. Output Variables:

    Total Kilowatt-hours Sold

    Maximum Kilowatt Demand

Total Electric Revenue

Net Generation in Kilowatt-hours

The CCR model was utilized to determine a relative efficiency performance measure for each firm or DMU for each year of the study horizon. This study focused on the estimation of the most productive scale size for the various DMUs examined in the sample. "The CCR measure captures not only the productive inefficiency due to its actual scale size, but also any inefficiencies due to its actual scale size being different from the mpss" (Banker, 1984, p. 37). The results of this analysis identified the most relatively efficient firms and the most efficient frontier for each period. The performance of the inefficient firms also were determined and measured. Additionally, this model identified changes in the input variable mix for the researcher to consider, enabling the inefficient firms to move to the most efficient frontier and become efficient. Study and evaluation of these firms over the horizon enabled the researcher to determine which firms are the most efficient over the full time horizon and which are inefficient over the same horizon. Once these measures were determined, trends in firm performance could be assessed.

In order to consider and assess changes in firm performance through time, DEA windows analyses were performed using a three-year-window, moving average technique. This technique afforded the ability to evaluate individual firm performance and efficiency patterns over the time horizon. By observing and measuring these patterns and the specific firms involved in the patterns, the researcher was able to identify the most successful firms, the key input and output parameter changes, and corresponding actions accounting for such performance changes. Once these performance measures and trends were examined and studied, the researcher could formulate reasons and justifications that help to explain and support the findings which result. The primary purpose for this endeavor was to learn more about efficiency measurement and performance evaluation for the individual firm and its operating environment. The identification of key patterns and the key variables that influence and account for sustained superior performance can help researchers and firm management. Similar benefits also can be derived for those firms that prove to be inefficient through this same time horizon. It was hoped that by studying and examining past history and firm performance, important observations, insights, and findings could be utilized to provide guidance and direction for firm's management and researchers. The success of the individual firm and its future viability may well be determined by the ability of its management to measure, monitor, assess, evaluate, plan and control its performance in the face of an uncertain and turbulent environment.

Research Questions

The research questions contemplated in this research effort were:

Why do electric utilities in the sample of midwestern U.S. electric utilities differ?

Why are some electric utilities more successful than others even in the same industry?

What firms are the best performers and which are the poorest-performing firms?

These research questions are more formally stated as follows.

Static or Cross-sectional Comparison and Analyses

Research Question 1: What firms are operating at the most efficient scale size and are situated on the most efficient frontier for the firms in the sample?

It was expected that the relative efficiency measure (i.e., overall technical and scale efficiency) of large electric utilities would be greater than the relative efficiency measure of small electric utilities. For purposes of this study, the utilities in the sample are considered to be in one of two categories, that is, either large utilities or small utilities. Large electric utilities were defined as electric utilities with input variables measured in quantity or volume equal to or above the median value of the sample. Those electric utilities with input variable quantity or volume below the median of the sample were referred to as small electric utilities.

Research Question 2: What firms are not operating at the most productive scale size (i.e., inefficient firms) and are not operating on the most efficient frontier?

It was further expected that the relatively inefficient electric utilities in the sample would be those of small size. A secondary outcome from this study was expected to provide insights into determining what inefficient firms may do to move to the efficient frontier or to achieve most productive scale size.

Longitudinal Comparison and Analyses

Research Question 3: Using the relative efficiency measures for determining overall most productive scale size, are firm relative efficiencies improving, remaining the same, or declining over the full study horizon?

It was expected that the relative efficiencies of the midwestern electric utility sample would be improving over the full study horizon. Several secondary outcomes of this study were expected to provide insights to determine: (a) the firms that are relatively most efficient and inefficient over this horizon and (b) what the relatively inefficient firms may do to improve their performance over the horizon.

This study is organized and arranged with the following chapter headings and topics. Chapter 2, entitled "Literature Review," contains a review of the various data envelopment analysis models and approaches as well as reviews of other prior utility efficiency and performance studies in the field. Chapter 3 reviews the methodology and specific approaches performed in the conduct of this study. The results of the detailed DEA CCR (input-oriented) and MER models for the retrospective cross-sectional and longitudinal analyses are presented in Chapter 4. The major results are reviewed, compared, and presented in Chapter 5. The conclusions reached in the study are presented in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

Researchers from various fields and perspectives have developed different theories that have been offered as explanations for the subsequent research questions. Why do firms differ? Why are some firms more successful than others even in the same industry (Carroll, 1994; Nelson, 1994; Williams, 1994)? Important related issues concern which firms are the best performers and which are the poorest. Seiford (1996) prepared a detailed bibliography of research studies and publications that include over 700 different analyses utilizing data envelopment analysis and other methods of evaluating firm performance. Figure 3 shows the publication activity over the period 1978 through 1996. It is interesting to observe that the interest in firm and organizational performance was growing through this period. By reviewing the titles of the various research publications, one can gain insight into the industries under examination. Table 1 lists alphabetically the industries that are identified in this bibliography. Research studies and analyses of organizations involved in 16 different industries are represented. The industry analyses are concerned with 300 of the over 700 citations contained in this listing. Seventy-seven percent of these industry studies and analyses involve five industries: banking and finance, education, government, health care, and transportation.

Approximately 376 of the 700 research studies and analyses were published in

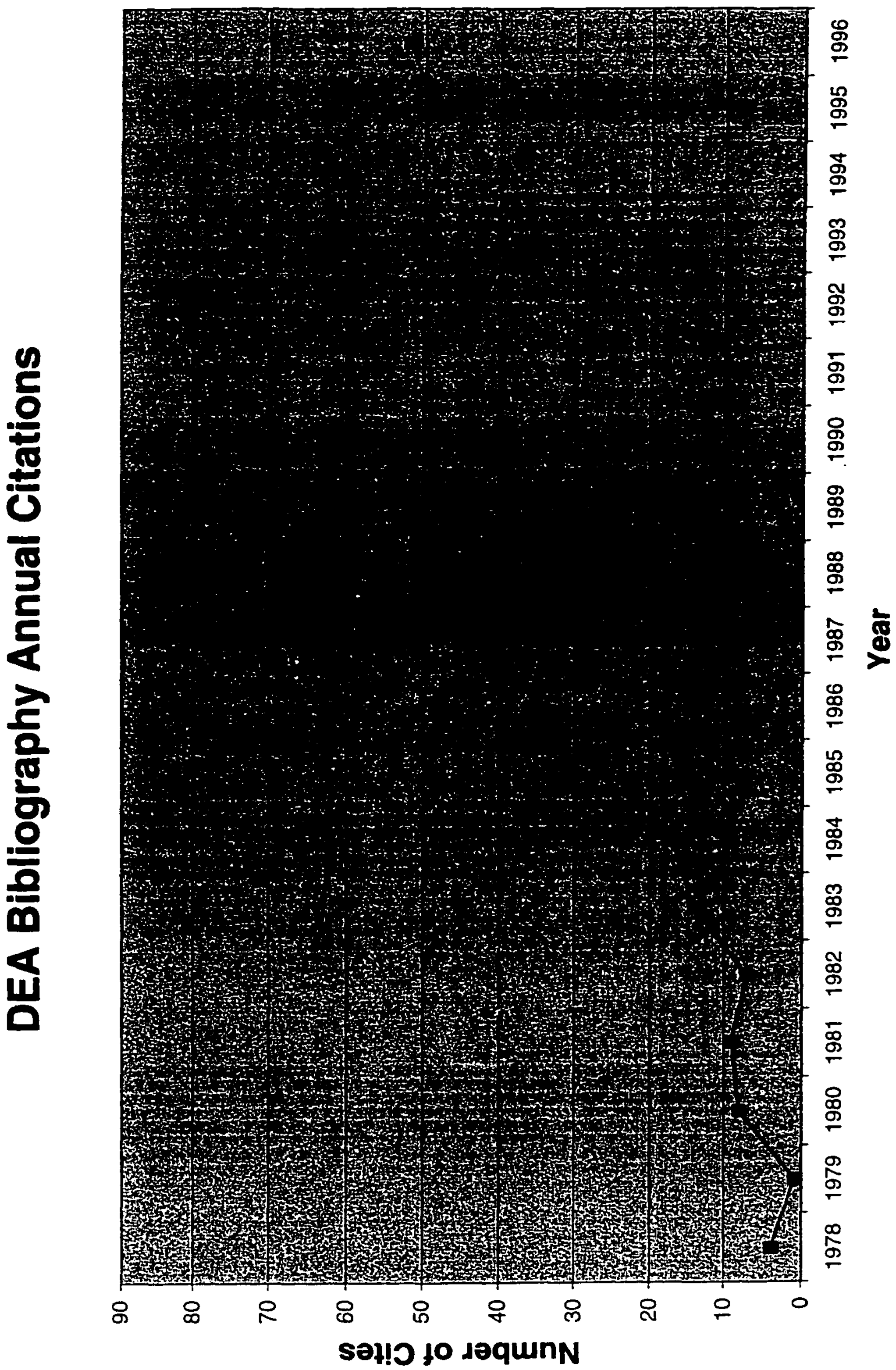


Figure 2. DEA bibliography annual citations.

Table 1

Industry Studies and Publications

Industry	Number	Percentage
Agriculture	10	3.3
Airlines	8	2.7
Banking and finance	38	12.7
Beverage	6	2.0
Coal and mining	3	1.0
Computer	3	1.0
Education	56	18.7
Government	29	9.7
Health care	76	25.3
Insurance	1	0.3
Manufacturing	10	3.3
Oil and natural gas	2	0.7
Sports	8	2.7
Telecommunications	2	0.7
Transportation	29	9.7
Utilities	19	6.3

Source: Seiford, 1996.

major research journals and periodicals of interest to those engaged in the study of business management. Table 2 shows a summary listing of the sources of those publications. Approximately 82% of these research studies and analyses were published in the following journals and periodicals:

1. Annals of Operations Research
2. Computers and Operations Research
3. Dissertations
4. European Journal of Operational Research
5. Journal of Operational Research Society
6. Journal of Productivity Analysis

Table 2

Research and Study Publications of Interest

Publication	Number
Academy of Management Journal	1
Accounting, Auditing, and Accountability Journal	1
Annals of Operations Research	28
Computers and Operations Research	21
Decision Sciences	3
Dissertations	104
Econometrica	2
European Journal of Operational Research	45
Interfaces	9
International Journal of Management Science	1
International Journal of Operations and Production Management	1
Journal of Econometrics	12
Journal of Operational Research Society	33
Journal of Operational Research Society in Japan	1
Journal of Operations Management	2
Journal of Productivity Analysis	42
Management Science	36
Omega	16
Operations Research	4
Operations Research Letters	7
Theses	9
Total	376

Source: Seiford, 1996.

7. Management Science

A review of the titles of the various publications revealed that there is much interest in the behavior of organizations and industries with respect to performance. The behaviors or interests most frequently cited are summarized in Table 3. Efficiency was the most-cited issue, accounting for approximately 70% of those reviewed. Performance and productivity were also found to be of major interest, accounting for approximately 21% of the publications noted in Table 3.

Table 3

Research and Study Topic of Interest

Class	Number
Effectiveness	15
Effectiveness and performance	1
Effectiveness and productivity	1
Efficiency	317
Efficiency and effectiveness	7
Efficiency and performance	3
Efficiency and productivity	10
Efficiency, performance, and effectiveness	1
Performance	55
Productivity	42
Productivity and performance	1
Total	453

Source: Seiford, 1996.

Performance

The economic health and well-being of a country or nation are dependent heavily on its productivity. Productivity is defined as the "relative measure of output per labor hour or machine hour, and is often expressed as a ratio of output to input" (Lee & Schniederjans, 1993, p. 18). The greater the productivity ratio, the more efficient the organization or firm. "Efficiency is a measure that shows the relationship between the use of resources (input) and the resulting output" (Lee & Schneiderjans, 1993, p. 18). When the nation or country as a whole is producing quality products and services at prices better than that of its competitors, it will enjoy economic health and prosperity. When a nation, for whatever reason, finds that it is lagging behind its competition, it will then suffer economically and its standard of living will drop relatively to its competitors. Therefore, it is in the nation's best interest to encourage and sustain high levels and growth in productivity. There are several trends that are putting pressure on a nation to boost its national productivity. Lee and Schniederjans offer these four trends:

> 1. The era of the domestic economic system has given way to the age of the global economic system.
> 2. The industrial age has transcended to the intelligence age.
> 3. The rate of increase in productivity in the United States has declined.
> 4. The U.S. economy has shifted dramatically from the goods-producing manufacturing sector to the service-producing sector. (1993, pp. 4-5)

These trends are changing the character and market base for the nation to an international market wherein all countries with the abilities can vie for the economic markets and customers across the street. The customers' preferences with respect to quality, availability, safety, and price are key with respect to how, when, where, and why they place their business and allegiances. With the advance of Internet, smart banking and shopping, and world-wide access, the customer is king. In order for a nation and its people to prosper, it is imperative that a nation pays heed to these changes and positions itself to compete at high productivity.

High productivity is not only important and critical for international competitiveness and well- being, it is critical also for the prosperity and well-being of an organization or firm in its own industry and markets. Organizations and firms competing in this fast-paced and changing international environment must continue to find ways to be competitive in order to survive and prosper. There are three primary needs that an organization must address to succeed: the need for improved productivity; the need for improved flexibility; and the need to develop competitive advantages (Lee & Schneiderjans, 1993, pp. 5-6). Lee and Schneiderjans (p. 20) offer the productivity cycle (Figure 1) as a guide for providing an environment for continuous productivity improvement within an organization. Improvements in flexibility or productivity can lead to reduced operating costs, which may be reinvested in the organization to reduce prices and/or improve quality of the firm's products and services. These results can lead to competitive advantage for the firm that may in turn lead to increased sales and increased profit. These profits can be shared with the owners or stockholders and also returned to the firm to further improve productivity. The productivity cycle can be initiated at any point in the sequence and the initiatives and results incorporated into the ongoing operation and function of the individual firm. This cycle appears to be a straightforward mechanism for a firm or organization to employ in pursuit of gaining sustainable competitive advantages and achieving success in its markets and industry.

Bitran and Chang (1984, pp. 29-31) define productivity as follows:

> Performance is a measure of production efficiency. Here, we use the word "production" in a broad sense and define it as an activity which converts a basket of goods and services (inputs) into another basket of goods and services (outputs). From the viewpoint of economics, all production activities are intended to create utility, which is the subjective satisfaction individuals can derive from consuming a basket of goods and services. Within the definition, purchasing raw materials, manufacturing, transporting, stocking, and retailing goods are all production

activities. Other production activities include advertising, research and development (R&D), financial investments, financing activities. . . . Productivity measures the efficiency with which a production activity converts inputs into outputs. Ideally, productivity should measure the efficiency in terms of input and output utilities since a production activity is intended to create utility. However, it is difficult in practice to either quantify the utility individuals derive from consumable goods and services or assign it to those inconsumable in a satisfactory manner. Because of this difficulty productivity is commonly defined in terms of input and output quantities because these quantities are measurable in most cases. (1984, pp. 29-31)

Bitran and Chang (1984) also view performance of the firm as an input-output conversion process and consider productivity and efficiency of production as indicators and measures of firm performance. Much of the literature follows this view (Eilon, 1985; Markland et al., 1998; Troutt et al., 1998; Troutt et al., 1996; Van Zandt, 1998). Productivity and efficiency of the firm are measured by consideration of a ratio measure of outputs to inputs. Researchers differ in the literature as to the consideration of key firm inputs and outputs as well as the weights assigned to those respective variables. Some of these differences are considered elsewhere in this study proposal.

Performance Measurement

Evolution of Data Envelopment Analysis (DEA)

Farrell (1957) also was concerned with firm performance and its measurement. In a simple production process, he considered an analysis of firms producing a common single output from two similar inputs. He constructed a simple plot of the output as a function of the combined inputs and developed isoquants to describe the production function representative for all firms by using constant returns-to-scale. Each firm's respective output and inputs could be located as a point on this plot, and its relative technical efficiency measured. The actual respective firm production level or point could be located on the plot using its particular output and inputs. By using a graphical solution method, a line drawn from the origin (zero intercept) through the isoquant to the actual firm production point on the plot formed the basis of relative efficiency measurement for a particular firm. The length or magnitude of the first segment of this line as formed from the origin to the intersection point on the isoquant would form the numerator of a measure of relative efficiency. The length or magnitude of the second segment formed as measured from the origin through the isoquant to the actual production point of the particular firm would form the denominator of the measure of relative technical efficiency for this same firm. Relative technical efficiency is found graphically by a ratio formed by dividing the numerator by the denominator, as described previously. This ratio of relative efficiency is a measure of the firm's output divided by its respective inputs. This efficiency ratio as specified would be constrained to fall within the limits of an interval equal to or greater than zero or less than or equal to one. Maximum relative technical efficiency is equal to one (or 100%) and represents maximum production with minimum inputs and no waste. A zero value (0% as a percentage) shows that a given firm is producing no useful output while using all of its resources and generating much waste. Values of this measure that fall within these interval limits indicate a firm is operating at a level where improvements in its production function are possible. Such improvements in the use of its resources or inputs can be made to achieve the same output level with fewer resource inputs or where more output could be achieved with better utilization of resource inputs, resulting in greater relative technical efficiency.

Several assumptions were introduced in order to make this analysis feasible. The shape of the isoquants was constrained to be negative slope; the inputs and output levels were constrained to be greater than or equal to zero; and the isoquants considered were such that all respective firm production functions would be greater than or equal to the isoquants. Using this model, it was possible to measure the relative technical efficiency of each firm considered in this analysis and to determine which firms were operating at maximum efficiency. Those firms found to be operating at maximum relative technical efficiency would be operating at production function points on the respective isoquant. Those firms operating at less-than-maximum relative technical efficiency could be identified and measured. It also would be possible to determine what input and/or output adjustments should be considered to improve the relative technical efficiency levels.

In an effort to ease the solution of such ratio problems encountered in firm performance analysis, Charnes and Cooper (1962) developed a methodology to convert the fractional linear programming problem into two separate linear programming (LP) formulations. One such LP model would be representative of the numerator or output(s), and the other LP model would be representative of the denominator or input(s). As long as the function could be treated as consisting of linear piecewise segments, the two respective LP models could be evaluated either by maximizing the numerator in order to optimize the ratio or by minimizing the denominator in order to maximize the ratio or efficiency under consideration. Either maximizing the efficiency so as to provide a maximum output with the given input resources or attaining the same output level with a minimum of input resources results in maximizing the overall efficiency of the given firm or group of firms described by the linear fractional programming problem.

The field of nonparametric relative efficiency analysis and measurement continued to grow (Banker & Maindiratta, 1988; Sengupta, Sfeir, & Phillips, 1987) and developed into the area known as Data Envelopment Analysis (DEA). Development of DEA as a field of analysis and inquiry is well documented by Charnes, Cooper, Lewin, and Seiford (1994). The various DEA models and approaches to relative efficiency analyses follow the solution of a linear fractional programming problem or ratio form described in this reference as follows (1994, pp. 40-41):

Fractional DEA Model

Maximize

$$_o = \frac{\sum_r u_r y_r}{\sum_i v_i x_i}$$

Subject to

$$\frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1 \quad \text{, for j = 0,1,...,n}$$

$$\frac{u_r}{\sum_i v_i x_{io}} \geq \varepsilon \quad \text{, for r = 1,...,s}$$

$$\frac{u_r}{\sum_i v_i x_{io}} \geq \varepsilon \quad \text{, for i = 1,...,m}$$

$$u_r \geq \varepsilon, \; v_i \geq \varepsilon$$

where y_{rj} = output variables for r = 1,...,s outputs for the jth DMU

x_{ij} = input variables for i = 1,...,m inputs for the jth DMU

u_r = output variable weights, such as dollar benefit per unit of output y_r

v_i = input variable weights, such as dollar cost per unit of input x_i

j = DMU reference for j = 1,...,n DMUs

ε = infinitesimal, usually equal to the value one millionth.

(Charnes, Cooper, Lewin, & Seiford, 1994, p. 40)

The four most popular nonparametric DEA models according to the literature are the CCR ratio model (Charnes, Cooper, & Rhodes, 1978), the BCC ratio model (Banker, Charnes, & Cooper, 1984), the additive model, and the multiplicative models. Each of these models uses a nonparametric approach in estimating the efficiencies of one or more Decision-Making Units (DMUs) in the sample or group under study. "In summary, the choice of a particular DEA model determines (1) the implicit returns-to-scale properties; (2) the geometry of the envelopment surface (with respect to which efficiency measurements will be made); and (3) the efficient projection, i.e., the inefficient DMU's path to the efficient frontier" (Charnes, Cooper, Lewin, & Seiford, 1994, pp. 45-46). The CCR ratio model results in a piecewise linear, constant returns-to-scale (i.e., a convex conical hull) envelopment surface or efficient frontier. The BCC ratio and additive models result in a piecewise linear, variable returns-to-scale (i.e., a convex hull) envelopment surface. The multiplicative models result in the development of a Cobb-Douglas or a piecewise log-linear envelopment surface. Both the BCC and CCR ratio models can be specified with input and/or output orientations. The input orientations provide the ability to evaluate reductions in the various input resources to move an inefficient DMU to the efficient envelopment surface while maintaining or achieving the same outputs. The output orientations permit the opportunity to evaluate optimum output augmentation in moving the inefficient DMU to the efficient envelopment surface by adjusting the input resource levels.

Charnes et al. (1978), in the formulation of the CCR ratio model, specified a new definition of optimal efficiency. A DMU is considered as optimally efficient only if the value of its objective function in its linear programming transformation equivalent is equal in value to one and the slack variables are all zero. This condition classifies the particular DMU as Pareto or Pareto-Koopmans efficient (Charnes, Cooper, Golany, Seiford, & Stutz, 1985). This model also enables one to identify which DMUs are inefficient and to determine alternatives for management or decision-makers to consider in order to move the respective inefficient DMU into the optimal efficient frontier or envelopment surface (Charnes, Cooper, & Thrall, 1986).

In further analysis of public (not-for-profit sectors) educational Program Follow Through, Charnes et al. (1981) were able to evaluate program efficiency and managerial efficiency for the public sector DMUs involved in the study. The ability to distinguish and separate these two efficiencies with respect to one another enabled managers of the respective DMUs to begin to provide a way to measure and evaluate managerial efficiency as well as technical or program efficiency.

Bessent, Bessent, Elam, and Long (1984) studied 25 independent school districts in Texas utilizing the CCR ratio model to determine those districts that were efficient and those that were inefficient. The results of their study provided a benchmark for the decision-makers of inefficient districts to examine as a guide, enabling them to find alternatives in improving their districts and inefficiencies. School managers found that they could use the results of these analyses to improve the education and quality of their respective schools.

> It is far better to compare performances with the best actually achieved than with some unattainable ideal. . . . Some CEOs like Eli Douglas, Superintendent of

> Garland Independent School District, emphasize the motivating use of the information. He says, "It's a motivating factor for us. We meet with principals as a group and go over the results." (p. 4)

The CCR ratio model also was found to be useful in determining the most productive scale size for a group or sample of DMUs. Banker (1984) defined most productive scale size (mpss):

> For a single-input single-output case, the most productive scale size is simply that scale for which the average productivity measured by the ratio of total output to total input is maximized. On the other hand, at the optimal scale size, the marginal productivity is equal to the ratio of the output price to the input price. The concept of average productivity is commonly extended to the case of multiple inputs by the use of input prices to aggregate the multiple inputs, and by the estimation of the correspondence between the total input cost and the output. But input prices are affected by many factors other than the pure technological correspondence between the inputs and the outputs that characterize the production process. Prices are likely to be more volatile than the pure technological characteristics, and therefore, estimation of merely the cost function is likely to retain its relevance for managerial and policy decisions for a shorter period than the estimation of the purely technological relation between the physical quantities of inputs and outputs. (p. 35)

Banker also identified a relationship between mpss and returns-to-scale for multiple-input multiple-output analysis. This analysis also made it possible for a manager or decision-maker to measure and compare each DMU's efficiency with respect to the mpss and to identify each DMU and its distance or path to achieve mpss itself.

Banker et al. (1984) relaxed the constraint in the CCR ratio model to incorporate the non-Archimedean, resulting in extending the geometry of the efficient envelopment surface. The authors also modified this model to incorporate consideration of variable returns-to-scale. This BCC ratio model enables one to determine the technical efficiency of each DMU in the analysis with respect to whether it is Pareto efficient or inefficient. In exploring the various alternatives available to make improvements in the respective DMU in order to move to the efficient frontier, one is able to measure its scale inefficiencies with respect to other similar scale efficient firms. The relationship between efficient and inefficient DMUs or firms and the DEA relatively efficient envelopment surface was described and illustrated graphically by Charnes et al. (1986). Other researchers also have examined and evaluated returns to scale in their DEA studies (Banker & Thrall, 1992; Seiford & Zhu, 1998; Sueyoshi, 1997).

Extensions to Data Envelopment Analysis (DEA) Models

In the development and use of DEA models, Banker and Morey (1986b) presented several additional refinements for use in all of the four basic DEA models in order to take into account important differences and their impacts on relative efficiency of various firms or organizations under study. Their efforts enable one to introduce categorical variables into the analysis (Kamakura, 1987; Rousseau & Semple, 1993) as either additional input or output variables. In one such study of branch banking, Banker and Morey (1986b) were able to take into account the presence of drive-in service windows as a variable in service efficiency analysis. In some cases, the type of organizations to be studied are not controllable or changeable by the researcher, such as the analysis and comparison of public and private ownership. Such differences in DMU classifications, characteristics, or typology can be considered as categorical variables and their impacts determined.

In some instances, one encounters variables that are beyond the control of the managers or organization and are bounded or determined outside of the organization. Exogenous variables can be observed as input and/or output variables for the DMU being analyzed. Banker and Morey (1986b) formulated a modification to incorporate exogenous variables into the respective DEA models and efficiency analyses. They suggested that advertising expenditures set by corporate headquarters management for each restaurant in a fast-food chain were examples of an exogenous input variable. These expenditures were not controllable by the individual restaurant manager or the restaurant. Check-cashing transactions rendered by a bank gratis as a part of its banking services were offered as an example of an exogenous output variable. These transactions are not under the control of the manager or bank. Incorporation of these exogenous variables into the respective DEA analysis enables one to fine-tune the relative efficiency measures and to determine their impacts on the results. It also serves to help reduce various inconsistencies found in the empirical setting.

Window Analysis

DEA can be used in studies of the various reference sets and individual firms over time. In longitudinal analysis, DEA can be performed for each particular period of interest throughout the study horizon. Comparison of DEA cross-sectional results can be evaluated by the researcher from period to period for those firms included in the analysis and in the reference set(s). Day, Lewin, Li, and Salazar (1994) point out several problems with this approach.

> . . . One approach to performing the longitudinal analysis is to compare cross-sectional runs across the number of time periods in the study. This approach introduces variability into the analysis because it treats the performance of a DMU in each time period as independent from performance in the previous period. Also, with this approach it is not feasible to ascertain trends in performance or to observe persistence of efficiency or inefficiency, the window analysis approach corrects for some of these problems. The underlying assumption is that of a moving-average analysis, except that each DMUs score is represented in the window n times (where n represents the number of time periods in window) instead of being represented by a single summary score. Charnes, Clark, Cooper, and Golany (1985) discuss the trend analysis of the efficiency scores and their managerial applications. It should be noted, however, that choosing the number of time periods to be included in the window is at present a matter of judgment. (p. 217)

Charnes, Clark, et al. (1985) used DEA and also applied window analysis to evaluate the operational maintenance efficiency of aircraft in the U.S. Air Force. Aircraft maintenance efficiencies were considered for 14 tactical fighter wings in the U.S. Air Force. The study looked at maintenance performance over a seven-month period. Window analysis was performed using the monthly data available for each fighter wing. The authors selected different period lengths for the window width and conducted DEA window analysis. A comparison of the various window widths and relative maintenance efficiency scores was undertaken. Such an analysis enabled the researcher to evaluate the performance of each fighter wing in the window over time using the moving-window-average technique for each fighter wing. Trends (improvement, constant, or decrement) in efficiency levels can be detected and examined. The performance of each of the fighter wings can be assessed across fighter wing groups. Overall performance of all 14 fighter wings also can be examined. This work demonstrated that window analysis provides several advantages in using DEA in a longitudinal analysis framework. These advantages are cited as follows:

> 1. facilitates identification of trends in performance;
> 2. evaluates the stability of reference sets;
> 3. incorporates measures of central tendency and dispersion for each firm or subunits relative stability for each entity in the set or subset;
> 4. constructs a facet participation table which shows the number of times an efficient DMU appears in the efficient reference sets for other DMUs;
> 5. trial and error sensitivity assessments can be made with varying window widths to determine the optimum size window. (Charnes, Cooper, Lewin, & Seiford, 1994, pp. 57-61)

This window analysis technique was selected by Charnes, Cooper, Golany, Learner, Phillips, and Rousseau (1994) in their longitudinal analysis of market segments and brand efficiency study of the competitive carbonated beverage industry. The use of DEA and window analysis enabled these researchers to study this industry during the spring of 1982 to the fall of 1983. In their study, they reported that these methodologies enabled them to realize the following benefits:

1. determine most appropriate window length and number of windows;
2. test stability of efficiency ratings;

3. detect trends and seasonal effects in the efficiency performance of individual RUs;
4. analyze time-lagged effects of specific variables, e.g., previous periods' advertising;
5. allow for variable number of RUs in a market, e.g., as a result of new market entries or discontinued brands;
6. increase the sample size by replicating RUs across quarters;
7. flag possible errors in the data;
8. further distinguish efficient RUs by their consistency of efficiency as revealed in the window table (see table 8-1); and
9. create the facet participation table (see table 8-5 below). (p. 153)

Day et al. (1994) utilized DEA and window analysis to study strategic group formation in the U.S. brewing industry from 1960 through 1974. This study considered seven different models for performing the DEA and window analysis - barrels produced (barrels); operating income (OPINC); rate of return on equity (ROE); rate of return on assets (ROA); Barrels and OPINC; Barrels and ROE; and Barrels and ROA. While the results did not lead to significant findings with respect to strategic group formation, the authors did cite several benefits as a result of implementing DEA and window analysis techniques:

> The findings do illustrate that by use of another methodology, contrary results may be obtained, thus redirecting the discussion of strategic groups. The DEA window analysis makes it possible to evaluate the homogeneity and mobility-barrier criteria. It also demonstrates the possibility of firms defining their own strategic groups and

that the membership of a strategic group is a function of the model specified. Ideally, the model for each firm should correspond to the actual strategy of that firm. (p. 234)

Statistical Regression and Data Envelopment Analyses

Haeri et al. (1997) identified two families of efficiency measurement techniques: mathematical programming and statistical regression techniques. Data Envelopment Analysis (DEA) is a mathematical programming technique that enables one to analyze relative firm performance cross-sectionally and/or longitudinally.

DEA has the following significant advantages with respect to determination of the best-practice frontier of firms and development of new managerial and theoretical insights into relative firm performance. Charnes, Cooper, Lewin, and Seiford (1994) cite that DEA calculation:

1. focus on individual observations in contrast to population averages;
2. produce a single aggregate measure for each DMU in terms of its utilization of input factors (independent variables) to produce desired outputs (dependent variables);
3. can simultaneously utilize multiple outputs and multiple inputs with each being stated in different units of measurement;
4. can adjust for exogenous variables;
5. can incorporate categorical (dummy) variables;
6. are value free and do not require specification or knowledge of a priori weights or prices for the inputs or outputs;
7. place no restriction on the functional form of the production relationship;

8. can accommodate judgment when desired;
9. produce specific estimates for desired changes in inputs and/or outputs for projecting DMUs below the efficient frontier onto the efficient frontier;
10. are Pareto optimal;
11. focus on revealed best-practice frontiers rather than on central-tendency properties of frontiers; and
12. satisfy strict equity criteria in the relative evaluation of each DMU. (p. 8)

Cooper (1997) contends that new methods and techniques for the evaluation of the historical data of organizations with respect to their behavior and performance are important. These new methods enable the researcher to extend the application of the field of operations research and management science (OR/MS) into the management of organizations. The study and assessment of firm performance is important to the planning functions of the organization and in diagnosing and determining what managers should do to improve performance. Cooper points out that a manager's influence and control of firm performance can be enhanced as a result of these inquiries and efforts (Epstein & Henderson, 1989). Cooper (1997) cites the use and development of Diagnosis Related Groups (DRG) in the administration of hospital health care costs as a major contribution:

> Very few (if any) OR/MS projects can claim as much of an <u>impact</u> on practice as this one, for, as Fetter (1991, p. 19) notes, "a remarkable change in the method of financing health care was affected by the U.S. Congress in a very short period of time (based on DRG analyses) and with virtually no dissent." The <u>results</u> have been equally remarkable as documented in the independently conducted evaluation which is reported in the Brookings Institution study undertaken by Russell (1989)

> – which concludes that the system has more than fulfilled original expectations. (p. 21)

In further elaboration on the role of OR/MS, use of DEA, and the emphasis on management planning and control, Cooper (1997) points out the following:

> Having concentrated on this DRG research and use, it seems appropriate to conclude this section with some thoughts suggested by the following quotation from Fetter: "Once one has a means of measuring performance, one can develop a system for understanding, predicting and ultimately controlling the process of production (of even so complex a phenomenon as medical services)." It might also be added that once one has such a system, it becomes possible to build upon and improve it. One way to do this is to introduce more flexibility into both DEA and the statistical approaches that underlie these cluster analyses and regression approaches. (p. 23)

Cooper (1997) mentions specifically that DEA can be used along with statistical analysis methods to support this research agenda:

> Although the two approaches differ in important responses, they need not be mutually exclusive. One approach might use DEA to identify "what is happening" after which a statistical regression could be used to sharpen these results by identifying which variables are significant and which contribute most strongly to the results secured. An early example of this kind of approach is the paper by Rhodes and Southwick (1987) which studied the relative efficiency of private and public universities. Their first stage finding that private universities were more efficient, as determined by DEA, was followed by a second-stage statistical

> approach using "Tobit regressions" (a) to check for consistency and (b) to identify possible explanatory variables. In particular, quality considerations were used in this second stage analysis to sharpen results by regressing DEA scores against data on SAT (Scholastic Aptitude test) scores, faculty salaries and government grants for research – as well as "outside factors" such as the state of the economy and the degrees of competition to which individual universities were subjected. The results were consistent with the DEA finding that private universities were more efficient. Indeed, the disparity widened with competition playing an especially significant role for private universities. (pp. 16-17)

Others within the research community (Rhodes, 1986; Sexton, 1986; Sexton, Silkman, & Hogan, 1986) also have advocated the use of DEA along with other measures and methods of analyses. Sexton (1986) suggests the application of DEA, efficiency ratio analysis, and multiple regression analysis as a means of comparing the relative efficiencies and inefficiencies of the DMUs in a specific efficiency analysis. These three methodologies allow one to analyze and compare the various results with each other in an effort to further enhance the interpretation and understanding of the relative efficiency positions of the respective DMUs and the efficient production frontier. The researcher or manager also will be able to consider various alternatives available to move the inefficient DMUs to the efficient frontier and to rank the efficient DMUs relative to one another.

Data Envelopment Analysis (DEA) Limitations

DEA offers many new and exciting opportunities in the evaluation and measurement of relative efficiency for DMUs in their competitive markets and respective industry. A review of the literature shows that while DEA has many advantages in its applications, there are several disadvantages or limitations that the researcher and manager should consider (Dyson & Thanassoulis, 1988; Fare & Hunsaker, 1986; Nunamaker, 1985; Pettypool, 1989; Troutt et al., 1996; Troutt et al., 1998; Troutt & Zhang, 1993).

Van Zandt (1998) lists four such deficiencies:

1. The virtual multipliers have no verifiable, economic meaning.
2. The multipliers do not necessarily indicate the relative worth of the various inputs and outputs.
3. While providing insights as to how inefficient DMUs may improve, no suggestion is available as to the optimal direction for such improvement.
4. Limited information is available as to how a fully efficient DMU can further improve. (pp. 20-21)

In addition to these deficiencies, Troutt and Zhang (1993) also state that a particular DMU may be considered efficient if it has a favorable ratio for some particular input and output (Pettypool, 1989). They further state that DMUs with extremal (high and/or low values of inputs and/or outputs) are by definition efficient. The existence of these extremal values may have an inconsequential or disastrous impact on the model (Epstein & Henderson, 1989). These extremes can influence the shape and existence of the relatively efficient frontier as well as influence the relatively efficient subset and the efficiency measurements of all the DMUs under evaluation. They also advise that separate linear programming models must be solved for each DMU and that this added computational burden complicates the efficiency determination process (Sexton, 1986; Sexton et al., 1986). Sexton (1986) further stresses the importance of variable selection as a possible DEA limitation. The inclusion of an invalid variable or the omission of a key valid variable in the DEA specification can bias the efficiency results, leading to misclassification of efficient DMUs as efficient and inefficient DMUs as efficient. DEA is directed primarily at providing measures of technical and scale efficiency. It cannot be used to analyze or comment on a particular DMU's price efficiency. This inability to advise on DMU price efficiency limits its use for economic pricing matters (Sexton, 1986; Sexton et al., 1986).

Since DEA is an extremal common weights model, it is important to realize that it treats all inputs and outputs of all the DMUs in the specification as the same. It is not possible to take into account differences in the quality levels of inputs and/or outputs of the individual DMUs within the full set of DMUs in the model specification (Sexton et al., 1986). Sexton et al. (1986) further point out that there are also problems in DEA with misspecification. Data errors can occur primarily in two ways - as misreported data and as miscoded data. These data errors can have similar effects on the envelopment surface and the determination of efficient and inefficient DMUs as those encountered in extremal values of inputs and/or outputs. DEA lacks robustness with respect to these error types (Epstein & Henderson, 1989). Nunamaker (1985) also points out a primary weakness of DEA when used in a non-cooperative environment:

> Since DMUs are evaluated along their best dimensions (variables), ample opportunity exists for DMUs to increase their efficiency score through manipulation of reported data. The Pareto criterion employed by DEA exacerbates the data variation problem by enabling DMUs to successfully increase their efficiency ratings without actually improving productivity or reducing costs. (p. 57)

There is no way of assessing the relative strengths of the various DEA models with respect to one another in terms of the efficient and inefficient DMU subsets (Sexton et al., 1986). While each model generates both subsets, each model as constructed is complete within itself, and comparison across models is difficult. In other words, different DEA models yield different efficient and inefficient subsets. The alternatives for the respective DMU to move to the envelopment surface may also be different.

Epstein and Henderson (1989) advise that there is a need for exploratory data analysis and post-optimality analysis with graphical support. There is also a need to provide additional insight into the issues and impacts of data value variation and selection of the data variable set and DMU field. They further advise that there is a possibility of misinterpretation of the DEA results for the managers in the application of the DEA efficiency results. There is a tendency for the manager or managers of inefficient DMUs to move to the efficient frontier in the shortest and fastest way possible at the expense of the respective DMU's business strategy and goals. Managers must understand the measurement system by which they are evaluated and the impact of efficiency movements relative to the business goals and strategies of the firm.

Efficiency Ratio Models

Maximum decisional efficiency measures. A new approach was proposed by Troutt (1995b) and Troutt et al. (1996) that sought a solution to the performance measurement issue for managers and organizations. It was conjectured that managers and organizations act to maximize their overall performance or efficiency through conscious deliberate choices of the respective various input-and-output mixes to yield maximum efficiency. It was assumed that the goal of maximizing overall efficiency was known and common to all managers and firms in competition with one another; the concept was noted as intuitively appealing. It also was assumed that the managers and firms all had access to the common sets of inputs and outputs and that these sets readily were capable of being substituted and measured across firms. The idea was that achievement by a firm or DMU of excellent performance, with overall efficiency scores of unity or 100%, was attributable to excellent management and not a random chance occurrence or expectation. This approach was referred to as a maximum decision efficiency (MDE) methodology. This methodology further assumed that historical data were available of the key inputs and outputs for each of the various DMUs for which overall efficiency was to be measured. This approach was applicable to situations in which measures of inputs and outputs are available either longitudinally for one organization or cross-sectionally for multiple organizations.

These MDE models are true ratio productivity measures commonly referred to as efficiency ratio models (Troutt et al., 1998, pp. 202-203). The primary advantages of the MDE approach are cited below:

> The methodology may be regarded as an alternative to regression, canonical correlation, and DEA methods. The essential features of the methodology are: (1) emphasis on purposeful rather than random behavior, (2) meaningful weights on inputs and outputs, (3) direction of improvement for both efficient and inefficient units, (4) dollar value imputation for outputs of efficient units or periods, and (5) ease of handling the estimation of input amortizations or carry-over effects. (p. 221)

<u>Maximin efficiency ratio model (MER).</u> Troutt (1993, 1995a) developed a maximin efficiency ratio model (MER):

Maximin Efficiency Ratio Model

Maximize (u_r, v_i)

$$[\ Minimum\ (j)\ \frac{\sum_r u_r y_{ri}}{\sum_i v_i x_{ij}}\ ]$$

Subject to

$$\frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1 \text{ , for all } j$$

$$\sum_r u_r = 1$$

$$u_r,\ v_i \geq 0 \text{ , for all } r \text{ and } j$$

where u_r = nonnegative output multipliers

v_i = nonnegative input multipliers

x_{ij} = input vectors for i = 1, ..., m

y_{rj} = output vectors for r = 1, ..., s

j = 1, ..., N DMUs. (Troutt & Zhang, 1993, pp. 2-3; Troutt, 1995a, pp. 2-3)

Note that the model formulation and description are of the same form and type as that utilized by Charnes et al. in the DEA models. The MER model can be solved by Bolzano search (Troutt, 1987). This MER model originally was developed as an extension of DEA to provide a way for ranking of the most efficient DMUs in the DEA efficiency analysis problem setting.

The present approach differs from those approaches by supposing the existence of a ratio form objective function common to all the DMUs, which is not necessarily technical or frontier efficiency oriented. In addition, the multipliers for the present models are determined by maximum likelihood considerations. Thus, the present

> paper seeks to extend the frontiers of DEA by considering a common objective that is not necessarily the same as technical efficiency. However, as may be expected, DMUs declared fully efficient by the present approach are noted below to also be technically efficient. (Troutt, 1995a, p. 2)

This model seeks to find the maximum of the minimum efficiencies of the *j* DMUs considered in the cross-sectional analysis for a specific period in time. This time period may be weeks, months, quarters, or an annual period. While this method was originally proposed as a way to rank most efficient DMUs in DEA analysis, Troutt and Zhang (1993) offered this model as an alternative to DEA analysis as a single-step ranking device. MER model enables one to assess and measure performance of both efficient and inefficient DMUs in a DEA data set with very comparable results with minimum effort using a single linear programming formulation and solution.

This model technique was benchmarked with two other modified DEA analyses. In Charnes et al.'s (1981) Program Follow Through (PFT) in evaluation of 49 PFT sites and 21 Non-Program Follow Through (NFT) sites, the results of the MER model matched favorably with those of the modified DEA analysis, strongly supporting the superiority of the NFT sites. The MER model also was tested against the modified DEA data in Dyson and Thanassoulis' (1988) evaluation of 62 British rate authorities. Again, the MER model found the same three most excellent DMUs and the same low inefficient DMU as the modified DEA model. The MER model required solution of a single linear programming problem formulation.

There are two possible disadvantages with the MER model (Troutt & Zhang, 1993). The first is concerned with the concept of fairness. A manager or DMU may feel that it has been ranked too low since the lowest or most inefficient DMU provides the start of the minimum efficiency search of the maximization process. A second concern is that selection of the weights will unfairly rank the particular DMU low in the full data set. With respect to the concept of the fairness issue, Troutt and Zhang state:

> Using the maximin principle, each DMU can be assured that, even in the unlikely event that it should be rated lowest, its rating will nevertheless be as high as possible consistent with the performance of the other DMUs. Among all such principles, the maximin principle will give those declared as least efficient the highest possible rating. (p. 4)

The maximin principle works to the maximization of the average and at the same time to the minimization of the variance of the efficiency scores. Troutt and Zhang (1993) point out that the MER model results in efficiency evaluations which are more conservative than the modified DEA scores in the Charnes et al.'s (1981) Program Follow Through and Dyson and Thanassoulis' (1988) British rate authorities studies.

Prior Utility Studies

Several previous studies have been conducted with respect to evaluating utility performance. These studies have utilized historical firm-specific input and output variables in various DEA models and statistical regression models. Table 4 shows a summary comparison of the respective input and output variables considered in each of these prior utility studies. These studies considered various key input variables for the respective organizations utilized in their respective samples. However, the input variables selected did not represent a complete selection of the critical inputs utilized by the firm required to explain the transformation process of the firm. The input variables for the proposed study shown in Table 4 account for the total costs of the firm. The expense components necessary to track and explain both the fixed and variable expenses of the firm on an annual basis are tracked. Such treatment enables the researcher to assess fixed costs as well as variable costs of production and operation. Key system characteristics also are included in the proposed study that allow the researcher to evaluate and assess the size and investment capacity of the respective firms with respect to both its generation mix and transmission delivery system. It is important also to note that the database collection efforts in the study enable the researcher to make comparisons of various sizes and types of generating capacity. The type and sizes of various capacity, that is, coal-fired, gas-fired, oil-fired, pumped storage, and/or nuclear generation capacity and the requisite additions and/or retirements can be monitored and tracked on an annual basis.

Key output variables considered in prior studies are not adequate to account for the key outputs for electric utilities. This study considers total kilowatthours of energy sold, maximum kilowatt system demand, total electric revenue, and net generation in kilowatthours for each respective firm on an annual basis. Use of the total revenue as a key output with the total expenses as inputs enabled the researcher to determine net margins and various component unit costs and revenues or rates among the sample sets. Such measures and capability provided additional checks within the model framework on the study results. The database collection gathered information on maximum electric system demands that allowed the researcher the opportunity to determine when the maximum demands on the individual systems occur. The ability to determine whether a firm is winter-peaking or summer-peaking can provide additional insights to the nature of

Table 4

Study Input and Output Variable Comparison

Study	Input Variables	Output Variables
1.	Charnes, Cooper, Divine, Ruefli, & Thomas (1989)	
	Operations expense Maintenance expense Consumer accounts expense Administrative and general expenses Miles per consumer Line loss (system efficiency) Average hours outage per customer Percent system unload (load factor) Total plant (system size) Other management items (salaries and inventories)	Net margin (before power and transmission expenses) Total KWh sales Total revenue received from sales of electricity
2.	Fare, Grosskopf, & Logan (1985)	
	Labor (full-time equivalent) Fuel usage (installed generating capacity) Prices (rental price of capital; labor price from total labor expenditures; fuel prices calculated as weighted averages of the prices per BTU of coal, oil, and gas)	KWh (generated by each plant)
3.	Taylor & Thompson (1995)	
	Labor (total employees) Capital (total assets)	Profit (gross profit)
4.	Haeri, Khawaja, & Perussi (1997)	
	Labor Capital Fuel (total outlays for all fuels in real dollars) Operating expenses (sum of all expense accounts and included	Total output (total physical production in MWH sold)

table continues

Table 4 (continued)

	operation, maintenance, depreciation, depletion, amortization and property losses, excluding local taxes) Load factor (account for effect of idle capacity) Time trend (capture time-varying effect of technology) Error function	
5.	Goto & Tsutsui (1998)	
	Nameplate generation capacity (proxy for total assets in MWH) Total fuel consumed (coal, petroleum, gas, and nuclear measured in Kilocalories) Total number of employees Purchased power (measured in GWH)	Energy sold to residential consumers in GWH Energy sold to non-residential consumers (industrial, others and wholesale customers in GWH)
6.	This study	
	Fixed expenses Taxes Interest Depreciation Administrative and general Variable expenses Fuel and purchased power Non-fuel production and transmission operations and maintenance Full-time electric employees Net installed generation capacity Transmission line circuit miles installed	Total Kilowatt-hours sold Maximum Kilowatt demand Total electric revenue Net generation

the electric systems under study and review. In a similar manner, it also was possible to determine the annual system load factor based on the system peak demand experienced by each firm. The load factor provided a measure of how intensively the firm's electric load is utilizing its own system and infrastructure.

Furthermore, the firms included in the sample consisted of both the electric production and transmission delivery system side of the business for investor-owned utilities and rural electric G&T firms. The other studies are concerned primarily with the study and evaluation of organizations of like kind. While this is commendable for research, the inclusion of mixed organizations in the sample served to provide representative sample organizations that a firm will likely encounter as its competitors in its marketplace under open competition and deregulation. Similar findings can be observed in considering the various output variables in each of the respective studies.

In addition, this study is more pervasive and inclusive than prior studies. This study performed detailed DEA cross-sectional analysis for each period in the 1988 through 1997 horizon. Additionally, longitudinal DEA windows analyses using a three-year moving average window were performed throughout the horizon to determine performance trends within the sample. These trends assessed performance for each utility separately as well as for the IOUs, the G&Ts, and the sample as a whole. The methods used in other studies did not provide as robust analyses as the methods employed in this study. An assessment was undertaken considering large as well as small size firms throughout this horizon. In order to provide reliability and validity checks on these DEA analyses, it was further proposed that a separate maximal decision efficiency model, the MER model, be implemented to test and compare to the DEA CCR model results. Other studies did not utilize this type of verification and validation analyses in their approaches. The study also evaluated the best in class and the inefficient firms to determine rationales for the conduct of the various firm performances. Such information and insights should prove valuable for management and the organization for continuous improvement in performance to insure its success and survival.

The prior utility studies are each discussed and reviewed as follows.

Charnes, Cooper, Divine, Ruefli, and Thomas (1989)

Charnes et al. (1989) used the CCR ratio form of Data Envelopment Analysis (DEA) to study 75 rural electric distribution cooperatives (co-ops) regulated by the Public Utility Commission (PUC) in Texas. The Texas PUC is charged with the legal mandate to audit each of the co-ops at least once every ten years. Previously, these audits have been performed by PUC staff and outside consultants incorporating various operating and financial data in ratio and regression analyses. The data required for these analyses was co-op specific data provided to the PUC and other data provided by lenders, that is, the Rural Electrification Administration of the U.S. Department of Agriculture (REA) and the Cooperative Finance Corporation (CFC). The authors cite:

> Evidently, there is a plethora of information but inadequate guidance is supplied on how to choose between the behavior of the different ratios. This often includes conflicting indicators, as illustrated in the above discussion of the TIER ratio values for San Patricio. In addition, the use of averages of ratios as in the Average TIER makes it difficult to allow for variations in individual cooperatives. (p. 190)

The authors selected three output variables, eleven input variables, and two management audit variables for consideration. These variables were formulated from expert discussions with the PUC staff, consultants, and co-op staff. These variables are as follows:

1. Output Variables, including:

Net Margin (before power and transmission expenses)

Total KWh Sales

Total Revenue Received From Sales of Electricity

2. Input Variables, including:

Operations Expense

Maintenance Expense

Consumer Accounts Expense

Administrative and General Expense

(System Characteristics)

Miles Per Consumer

Line Loss (system efficiency)

Average Hours Outage Per Customer (reliability)

Percent System Unload (load factor)

Total Plant (system size)

Other Management Items (Salaries and Inventory). (Charnes et al., 1989, pp. 199-200)

Charnes et al. (1989) considered the identification and measurement of technical inefficiency of the respective cooperative DMUS. The authors did not report the overall results of the 75 DMUs as to the number and identification of those found to be efficient and inefficient, respectively. The authors advised that these 75 DMUs are cooperatives in Texas. The authors did not make the distinction that these DMUs are distribution cooperatives and not generation-and-transmission cooperatives. REA has two different types of cooperatives or borrowers that it lends money and also provides management oversight. These are defined as generation-and-transmission (G&T) cooperatives and distribution cooperatives. The G&T cooperatives usually provide wholesale power and energy for resale to their respective distribution cooperatives. Apparently, the authors assumed that the reader would be knowledgeable of this fact and distinction. This clarification or assumption should have been recognized in this study.

The validation efforts discussed were limited to comparison of the DEA model with ratio and regression model results and discussions with the individual cooperative DMU management and the PUC staff. This study appears to have been a cross-sectional DEA analysis for the year 1983 using readily available input and output annual data. Several different information and data sources were cited for gathering the specific data, but no discussion was offered with respect to how misreported data or data coding errors were treated and considered. There was no discussion of comparison efforts of individual data variables between data sources or data preparation and gathering efforts. Many of the references previously cited in the DEA limitations discussion earlier in this proposal stressed the critical importance of data, error checks, misspecification of variables, and the examination of extremal variable values. There appears to be no discussion of these important validation efforts in the study as cited. No additional extremal variable analyses, sensitivity or stability analyses were discussed. It is also possible that some of the respective DMU management may be in an uncooperative environment as referenced by Nunamaker (1985) and tried in some way to "game" or bias its performance and the other DMUs in the study. There is no mention or discussion of these possible influences and any measures taken to detect and consider these possible influences.

The results of the Charnes et al. (1989) study showed that:

> DEA outperforms other current (ratio and regression based) electric cooperative efficiency evaluation systems for purposes of (1) selecting audit candidates, (2) targeting problem areas which merit examination, and (3) providing a basis for selecting comparison organizations to help in securing efficiency evaluations. (p. 188)

As a result of this study, the PUC of Texas adopted the use of DEA analyses as a part of its management audit process along with ratio analysis, regression analysis, and field audits. The three primary areas for incorporating DEA into the audit process are stated below:

> 1. Determine which cooperative might best be audited.
> 2. Provide reference DMUs which can be used to supplement or replace those suggested by a cooperative under audit.
> 3. Supply clues as to sources and magnitudes of any inefficiencies that might be present. (Charnes et al., 1989, p. 208)

Fare, Grosskopf, and Logan (1985)

Fare, Grosskopf, and Logan (1985) cite several other studies (Atkinson & Halvorsen, 1980; Meyer, 1975; Neuberg, 1977; Pescatrice & Trapani, 1980) that found evidence that public-owned firms have lower costs than investor-owned utilities. These studies were all based on cost function analysis.

> Meyer (1975) estimated a simple, single equation model, which cannot be called a cost function due to the lack of input price variables. Neuberg (1977) estimated Cobb-Douglas cost functions, but focused on the distribution rather than generation of electric power. Both Pescatrice and Trapani (1980) and Atkinson

and Halvorsen (1984) estimated a more general translog cost function simultaneously with the cost share functions. These two studies differ, however, in that Pescatrice and Trapani (1977) allow for effects of regulation (i.e., use of shadow rather than market input prices) for the privately-owned firms only. Atkinson and Halvorsen (1984) argue that publicly-owned utilities may also be subject to regulation. The two studies also use different techniques to compare the two types of ownership. Pescatrice and Trapani (1977) compare costs of the two types of firms under the assumption of no regulatory constraint. Atkinson and Halvorsen (1984) compare actual costs and explicitly test whether firms achieve relative efficiency (cost minimization) and absolute price efficiency (input price equal to output price times marginal product). (Fare, Grosskopf, & Logan, 1985, p. 89)

Fare, Grosskopf, and Logan (1985) used a nonparametric, linear programming approach to calculate six different efficiency measures to compare public and private performances of electric utilities. These six efficiency measures are overall efficiency, allocative efficiency, overall technical efficiency, purely technical efficiency, congestion, and scale efficiency. They selected a sample of 123 private and 30 public electric utilities operating in the U.S. for the year 1970. The variables selected for their analysis are shown below:

1. Output Variables

   KWh in millions (generated by each plant)

2. Input Variables

   Labor (full-time equivalent employees)

Fuel Usage (BTUs)

Capital (installed generating capacity)

Prices (rental price of capital; labor price from total labor expenditures; fuel prices calculated as weighted averages of the prices per BTU of coal, oil, and gas). (pp. 96-97).

The data for these variables were obtained from Atkinson and Halvorsen (1985, p. 96), who collected the data from the following publicly available sources for 1970 from the U.S. Federal Power Commission:

Statistics of Privately Owned Electric Utilities in the United States: 1970

Statistics of Publicly Owned Electric Utilities in the United States: 1970

Steam Electric Plant Construction Cost and Annual Production Expense: Twenty-Third Annual Supplement: 1970

Fare, Grosskopf, and Logan (1985) summarized their findings as follows:

> We find that the mean efficiency values of four of the six measures are slightly higher for publicly-owned utilities, including the efficiency measure which is closest to that used in earlier studies (namely, efficiency defined in terms of cost minimization which is called overall efficiency, or O(u, p, x) in this paper). Based on a battery of nonparametric tests, we find that the publicly- and privately-owned utilities are not significantly different in terms of the overall allocative and overall technical efficiency measures. On the other hand, we find that publicly-owned utilities have better ratings in terms of purely technical efficiency, but are worse than privately-owned utilities in terms of congestion and scale efficiency. In terms of sources of inefficiency, we find that deviations from allocative (price) efficiency

> are the greatest source of inefficiency for both publicly-and privately-owned electric utilities. Congestion is more of a problem for public utilities than it is for private utilities. Public utilities, in general, are operating at a scale less than the long-run optimum, whereas most of those private utilities which are scale inefficient, exhibit decreasing returns to scale. (p. 100)

While these authors are to be commended for their work in further defining and measuring efficiencies to include pricing, allocation, and congestion, there are several areas that merit additional comment. First of all, the input and output variables are presented without any discussion as to their importance or relevance. Operationalization of each variable also is stated without any discussion or rationale as to their validity. Without some review of the variables to be examined, or the possible inclusion of variable(s) that are not critical, or the omission of critical variable(s), the model specification easily can be in error as well as produce erroneous efficiency measures for the individual DMUs. It is recognized in the literature that nonparametric analysis depends heavily upon the data and information relied upon in making the mathematical analysis. No discussion of the search for misreported data or error-coded data was mentioned in this study. Without such safeguards and checks, it is possible that such errors occurred in the study. The authors did find an extremal DMU. This DMU was considered an outlier, and further sensitivity analysis was performed. The authors did not present any means or discussion as to how a utility, public or private, should improve its performance. There does not appear to be any rank order or preference as to which of the six efficiency measures a DMU or its management should employ in making such performance improvements.

While the authors compared their results with other studies, no effort was made to compare their results with other experts outside of those involved in academic studies, that is, experts in the various consulting field(s), within the regulatory agencies, or within the utilities themselves. Such a comparison would add valuable insight, credibility, and possible validity to the study effort.

Taylor and Thompson (1995)

Taylor and Thompson (1995) compared the profit potential and efficiency of 19 investor-owned electric utilities (IOUs) in the southern air-conditioning belt of the United States using DEA analysis techniques. They utilized the following input and output variables in their analysis:

1. Output Variables

   Profit (Gross Profit)

2. Input Variables

   Labor (Total Employees)

   Capital (Total Assets)

Federal Energy Regulatory Commission (FERC) Form 1 provided the source of this data and information. Data were collected for 1990 to 1993. Data for the years 1990 and 1991 were averaged as well as for 1992 and 1993. With the enactment of the Energy Policy Act of 1992 (EPACT), structuring the data in this manner provided one with the capability to look at efficiencies of the sample before and after the regulation. The two input variables were normalized with the output variable and plotted for both time periods. The plots then were utilized to show the most efficient production frontier and each company's location with respect to it. The most efficient firms were identified readily as well as the inefficient ones. The authors then compared the efficient and inefficient firms across the periods. Tradeoffs between labor and capital could be viewed and evaluated. It was observed that some of the firms within those four years had already made adjustments to their labor and capital positions and had improved their respective efficiency levels. However, no efficiency values were stated within the study for any firm in the sample. The analysis appeared to be a CCR ratio model formulation even though the authors did not state which model or models they employed in their analysis. A DEA Best Practice Economic Situation Matrix for the sample of utilities was constructed for the 1992-93 period (p. 28). This matrix was based on expressing the profit ratios and efficiency measures into a two by two classification matrix or plot. The x-axis and y-axis of this matrix are efficiency and profit ratios, respectively. The four classifications or cells that result are highlighted below:

1. Low Profit Ratio – Low Efficiency

   (Targets for Independent Power Producers)

2. High Profit Ratio – High Efficiency

   (Best Practice, Good Cost and Revenue Management)

3. High Profit Ratio – Low Efficiency

   (Good Revenue Management, Poor Cost Management

4. Low Profit Ratio – High Efficiency

   (Good Cost Management, Weak Revenue Management, or Poor Frontier Position)

This classification scheme or matrix is offered by the authors as a means for a particular utility to assess its position and begin to find ways to improve its performance and overall efficiency levels.

Taylor and Thompson (1995) stated:

> Nearly all of the 19 IOUs studied could make more efficient use of their capital and labor. Most of them appear poorly positioned to compete in the forthcoming competitive arena. Several large and prominent utilities must change appreciably to become well-positioned. Otherwise, they may well represent attractive targets for independent power producers (IPPs), since significant profit potential exists. (p. 25)

It is interesting to note that the authors advise that those firms finding themselves in cell one are likely takeover targets.

There is no discussion in the study regarding screening or checking against misreported data or coding errors in the analysis. Without mention of such safeguards, it is possible that data errors did occur, casting question on the analysis and results. No mention was made whether the data and results were discussed with outside experts or specific firm management. Such efforts would enhance the credibility and validity of the study and its results. Efforts were made to discuss in general how an inefficient firm could improve its position, but no specific solutions for optimality were offered. Additionally, no mention was made as to what the efficient firms for the 1992-1993 period should do to continue to improve their respective positions and to remain efficient.

After comparing the before and after result for 1992, the authors attributed the improvements in efficiency to the passage of the EPACT. However, there were many other factors that might have been a motivation for these utilities to make changes. The Clean Air Act Amendments of 1990 required significant changes in operation and technology, both with respect to SO_2 and Nox emissions for all affected fossil-fired power generating utilities over two phases. Phase I covered the period 1990 to 1995, and Phase II covers the period 2000 and beyond. These rules require affected utilities to make changes that may take several years to complete. Such changes may involve obtaining federal and state regulatory approval, financing and turn key design, construction, and implementation. These changes would affect labor, capital, and profit. The passage of EPACT left FERC with the responsibility to carry out and implement the EPACT to provide for open access transmission. It took many months for FERC to issue Orders 888 and 889 to determine the structure and the protocol for implementing the provisions of EPACT, which are still underway at this time. Thus, it would be very difficult to attribute the utility changes just to EPACT. During this same time period, many industrial customers throughout the U.S. were lobbying with their utilities and state public service commissions for reduced rates. Rate reductions were requested by these industrial customers as competitive priorities to enable them to remain in business and survive.

Morey and Hiebert (1996)

Morey and Hiebert (1996) take issue with Taylor and Thompson's (1995) study of 19 sunbelt utilities. Taylor and Thompson utilized Farrell's (1957) framework that is a deterministic frontier model to evaluate firm performance. Morey and Hiebert contend that this model has several deficiencies. It assumes that any deviation from the efficiency frontier is a result of the firm's inefficiency. Such deviations may also arise as a result of random exogenous factors, such as weather, which are not controllable by the firm or its management. These deterministic models also are sensitive to extreme observations that can arise from measurement errors. Extreme observations can have a significant impact on sample efficiency measures as well as the particular firm's performance or efficiency. These authors recommend a stochastic approach to efficiency measurement rather than a deterministic one. An advantage of this approach is that it allows for exogenous shocks to be considered as explanations for firm deviation from the efficient frontier as well as its own inefficiency (p. 7).

Morey and Hiebert (1996) also express concern over the selection and measurement of each of the variables within Taylor and Thompson's (1995) DEA specification. With respect to the input variables, they point out that using profit rather than physical production as a measure of a firm's output produced by labor and capital services ignores the impact and uncontrollability of input factor prices. There are concerns with the way that the variables are measured. Capital should not be measured by the book value of the total assets; using this measure distorts the efficiency measure by inclusion of cash and investments in associated or subsidiary companies that are not the focus of the utility performance study. They suggest that total utility plant value be used as the proxy for capital. The total number of utility employees also distorts the efficiency measure in that there is no recognition of the impact of part-time employees and their labor effort. The presence of part-time labor and/or the treatment of outsourcing as part-time labor can bias the analysis and results. Two important input variables omitted from consideration were the fuel consumed in the production process and the impact of purchased power. Each of these variables can have a significant influence on the cost and performance of a utility. The authors also cite that there is no way to distinguish between short-run and long-run efficiency where capital stock can be varied. These authors further suggest that net generation rather than profit is the output variable for total production (pp. 7-8).

Taylor and Thompson responded to the deficiencies cited by Morey and Hiebert. The debate over deterministic (mathematical programming) versus stochastic (statistical regression) approaches in the literature by researchers and experts is ongoing. Deterministic methods can handle multiple input-output problems; however, stochastic methods can handle only single-output problems. "Stochastic frontier methods provide an average, as do virtually all statistical techniques. DEA Best Practice, in contrast, reveals the best-in-class performers. No known statistical technique provides such revelations" (Morey & Hiebert, 1996, p. 8).

The justifications for the use of the input and output variables and DEA methodology used by Taylor and Thompson (1995) are based on several issues. These concerns are stated as follows:

1. Standard definitions in accordance with FERC Form 1 financial and accounting reports developed for utilities exclusively need to be used. Such reporting practices provide for the separation of regulated from non-regulated financial and accounting reporting.

2. There continues to be wide disagreement among the measurement experts as to the proper variables to consider as well as the appropriate means of their measurement.

3. DEA methodologies can be specified with multiple inputs and outputs. Stochastic frontier methodologies are limited to a single output.

4. DEA provides use of real world data and simple tools as a guide for use by utilities and their management. (Morey & Hiebert, 1996, p. 8)

Haeri, Khawaja, and Perussi (1997)

During the period 1990 to 1995, Haeri et al. (1997) used statistical regression analysis to explore the competitive efficiency of 94 U.S. investor-owned electric utilities. Their study developed a Cobb-Douglas production function using input and output variables specific to each firm and measured overall efficiency.

1. Output Variable

   Total Output (Total Physical Production in MWH Sold)

2. Input variables

   Labor

   Capital

   Fuel (Total outlays for all fuels in real dollars)

   Operating Expenses (sum of all expense accounts and included operation, maintenance, depreciation, depletion, amortization and property losses, excluding local taxes)

   Load Factor (account for effect of idle capacity)

   Time Trend (capture time-varying effect of technology)

   Error Function

The data source for each of the variables for 1990 through 1995 was provided from Edison Electric Institute's Uniform Statistical Reports. The Bureau of Labor Statistics provided the Producer Price Index, which was used to deflate all monetary variables in real terms. The individual holding company rather than the individual operating utility was the unit of analysis in this study. The authors reported that the statistical analysis shows that the variables selected and utilized in this study explain 99%

of the production function variations.

A distribution in overall relative efficiency across all firms ranging from 78% to 100% resulted. A number of significant patterns and findings were highlighted in this study:

> Close examination of utility efficiency scores reveal several important patterns, as shown in Table 3. Size of the operation is a significant determinant of efficiency and matters considerably in overall rankings. It shows a strong relationship with efficiencies due to economies of scale. The results suggest as much as a 5-percent difference in efficiency between utilities in the largest group.
>
> Contributions of economies of scale to efficiency are also apparent when we consider company structure (individual operating company vs. holding company). For example, holding companies show slightly higher efficiencies than individual operating companies. More important, five of the six holding companies resulting from mergers during 1990-1995 show above-average efficiency gains. The one-half of the utilities in the sample that are combined operations show slightly higher efficiencies, resulting possibly from economies of joint production.
>
> Northwest utilities lead in overall efficiency. Southeastern, Southern and North-Central utilities follow the Northwest by a high 5-percent margin. A utility's reliance on nuclear fuel outlays, also shows a strong negative correlation with efficiency; the higher the share of nuclear fuel costs, the lower the operational efficiency. Inversely, we find a strong relationship between operational efficiency and the share of hydroelectric power in a utility's generation mix. (Haeri et al., 1997, pp. 31-32)

Statistical regression studies are subject to limitations and deficiencies noted throughout this document. Since this study was limited to a single output, inclusion of other important output parameters (winter and/or summer demand, further classification of total MWH sold by customer class or type, and purchased power) cannot be included in this specific formulation. The efficiency measures are based on averages and the vagaries associated with the application of averages with such measures. No mention is made as to the distribution of the efficiency measures themselves. Are these efficiency distributions normally distributed to fit the independence and normal distribution assumptions? Are these efficiency distributions of the shape offered by Troutt et al. negatively skewed to account for rational, purposeful decision making by the utility and its management?

Goto and Tsutsui (1998)

Goto and Tsutsui (1998) performed a longitudinal study comparing the performance of 23 investor-owned utilities (i.e., nine fully vertically integrated utilities in Japan and 14 fully vertically integrated utilities in the United States). The study was based on the historical period 1984 to 1993. The Japanese utilities were selected from a list of the major 10 utilities within Japan. One utility was eliminated from the study due to unavailability of complete data. Fourteen large utilities in the United States were selected that match the scale of the Japanese utility sample. It is interesting to note that the utilities in both Japan and the United States were being encouraged by their respective governments and large industrial customers to lower prices through deregulation and competition. Goto and Tsutsui also recognized that their study ending in 1993 did not include the effects or impacts of deregulation in Japan or the United States. FERC Orders 888 and 889 implementing the Energy Policy Act of 1992 had not been fully enacted (p.

184).

Goto and Tsutsui's (1998) study utilized an input-oriented DEA model incorporating eight efficiency measures. Sueyoshi (1997) had introduced these measures in a study of efficiency measurement in production and cost analyses of Nippon Telephone and Telegraph. Sueyoshi utilized the CCR DEA model and a unit- price function to develop three efficiency measures: technical efficiency (TE), overall efficiency (OE), and allocative (price) efficiency (AE). No assumption was made regarding returns to scale with respect to these measures. He also utilized Banker et al. (1984) BCC DEA model (and its associated efficient frontier) with unit prices to develop three more efficiency measures assuming constant returns to scale. These three efficiency measures were technical and scale efficiency (TSE), overall and scale efficiency (OSE), and allocative and scale efficiency (ASE). The latter three measures enable one to compare the possible impact of scale effects with the former three efficiency measures assuming unit price functions or information is available a priori. Two other efficiency measures were developed using the six previous measures. These measures were production and scale efficiency (PSE) and cost and scale efficiency (CSE). Goto and Tsutsui (1998) used the efficiency measures developed by Sueyoshi and incorporated the Malmquist index in order to incorporate intertemporal changes in the efficiency technology frontier and utility efficiency performance over time.

The authors selected two output variables and four input variables for their analysis. These variables and their measures are identified as follows:

1. Output Variables

   Energy Sold To Residential Customers (GWh)

Energy Sold To Non-Residential Customers (industrial, others, and wholesale customers in GWh)

2. Input Variables

Nameplate Generation Capacity (Proxy for Total Assets in MWh)

Total Fuel Consumed (coal, petroleum, gas and nuclear measured in Kilocalories)

Total Number of Employees

Purchased Power (measured in GWh)

The Japanese utility data source was provided by the Handbook of Electric Power Industry (1983-1993) published by the Federation of Electric Power Companies (FEPC) in Japan. The United States utility data sources were provided from Energy Information Administration (EIA) publications (1983-1993).

The currencies for both countries were expressed on a common basis using two different indices. Exchange rates and Purchasing Power Parities were both utilized to convert all monies (prices and costs) to U.S. dollars. This was necessary to take into account the differences in currency value between countries as well as for inflation impacts in both countries. The authors noted that utility efficiency measure results are the same with either method.

The major findings of this study as cited by the authors are as follows:

> Our empirical results find that: (1) the overall cost efficiency of the Japanese electric utilities was consistently higher than that of the US electric utilities for the period from 1984 to 1993; (2) Japanese utilities are more efficient than US utilities in terms of technical, allocative and scale efficiencies; (3) allocative inefficiency is

> the largest source of overall cost inefficiency for Japanese utilities; and (4) Japanese utilities have a clear trend of overuse of capital and underuse of power purchase for cost-minimized production under the current relative prices of inputs. These results indicate that the high prices of electricity in Japan are due to an excessive amount of capital input that leads to allocative inefficiency, and to high input prices such as capital. This finding may imply that the electricity prices of the Japanese utilities can be reduced by creating a free market where these utilities can increase inexpensive power purchase, instead of the investment of assets for their own production, from independent power producers through competitive bidding, and procuring inexpensive equipment. (Goto & Tsutsui, 1998, p. 192)

There are several concerns that need to be addressed regarding this study. Within this study there is no discussion or rationale as to the U.S. utilities selected for the comparison tests. The identities of the U.S. utilities were not disclosed. The size, generation mix, geographic location, customer mix, and load factor can have a significant impact on the respective efficiency measures and study results. Without such a description or discussion, a bias or set of biases could have been introduced.

It is further interesting to note that during the 1983 to 1993 time period several external environmental factors occurred within the United States that were not recognized in this study. First, a dramatic shift occurred in average annual energy and demand growth rates from that experienced in the 1960 to 1970s. Growth in the 1960 to 1970s was in the range of 7% to 10%. However, in the 1980s, this rate fell to one to three percent. Many utilities had planned capacity additions in the 1970s, anticipating huge demand in the early to late 1980s that did not materialize. This resulted in over-capacity and added costs for capital and fuel. As a condition for securing financing of these plants, many firms were required to have long-term fuel contracts in place.

Second, discussion and debate were underway with respect to tightening of the environmental laws concerning air and water quality. The passage of the Clean Air Act Amendments in 1990 significantly reduced SO_2 and Nox emission limits for all fossil-fired boilers in the U.S. The reduced emission levels were targeted for implementation in Phase I (1995-1999) and Phase II (2000 and beyond). The Environmental Protection Agency (EPA) provided incentives for utilities that sought early compliance by investing in scrubber technologies and fuel mix choices earlier than required. The results of this regulation increased capital investment, fuel costs, lime and reagent costs, and labor costs. These components all act to increase input costs without increasing energy and demand or revenues as outputs. Performance of utilities affected by such structural change during this period is predictable and understandable; however, there is no mention of these environmental factors in this study. It is not known whether Japanese utilities were experiencing similar external environmental structural changes. If they were not, then these factors alone could account for a significant difference in utility and country performance. Merger activity and bankruptcy also began to be seen in the utility industry in the U.S. in the late 1980s and early 1990s. This is an indication of changing utility industry structure and performance.

Transmission and distribution assets or proxies should be included as input variables. This would account, to an extent, for the differences in vertical integration mix as well as provide a stronger agreement with the residential and non-residential energy consumption output variables.

The total employees input variable includes full-time and part-time employees. Many firms supplement their labor force with part-time employees or with external supplementary services through outsourcing. Such part-time labor and outsource services are masked in this study. Changing this variable to total full-time employees would overcome this difficulty.

The comparisons of performance between the two countries are made using the eight efficiency measures. The averages of the countries are subject to bias, depending upon the extreme individual firm values, either high or low, included in the average calculation. There is no discussion of the extreme values or outliers within the data sets for either country. Sensitivity analyses of efficient and/or inefficient firms in any of the eight measures are not performed nor discussed. DEA analyses depend heavily on historical data. Errors in the data through inclusion of misreported data or in coding of the data can have significant impact and potential bias on individual firm performance as well as group performance. There is no discussion of special screening or data checking of either of the data sets within the study. Checking of the data set with experts or with particular firm management is not discussed or mentioned. Without such checks, one is left with the suspicion that there are errors.

It is of interest to point out that each of the country's performance averages is compared annually with the other throughout the full horizon 1983 through 1993. These trend comparisons would be more meaningful if windows analysis had been performed for all 23 firms throughout the analysis (Charnes, Clark, et al., 1985). Treating each firm in an annual period as a separate DMU and utilizing each DMU in a moving average window would provide a better measure of efficiency changes as noted in Charnes, Clark, et al.

(1985) and overcome disadvantages noted therein.

In addition to this, incorporation of an industry aggregate (IA) measure as suggested by Troutt et al. (1998) would help in validation of this model and study. This IA could be performed for all 23 utilities as the whole sample to develop an industry aggregate performance measure for the combined countries. Furthermore, this measure also could be used to develop industry aggregate performance measures for Japan and the U.S. separately. Such an aggregate measure would enable one to compare industry profiles and performance with respect to one another as well as the whole. With the international competitive environment, this latter approach may be more appropriate and worth undertaking.

Performance Definition

Performance in this dissertation is concerned primarily with a relative efficiency or productivity ratio developed for each firm using a set of selected inputs and outputs critical to the operation and success of the firm. The ratio of the outputs to the inputs for a particular firm provides a measure of the efficiency of the organization. Comparisons of various firms' efficiency ratios during a single common time period provide a means of evaluating their relative efficiencies. Comparing such ratios in this single time period allows the researcher an opportunity to determine the most efficient frontier and to determine the best-performing organizations and the poorest ones. This type of analysis is commonly referred to as a static or cross-sectional analysis.

Such a study enabled the researcher to determine the relatively efficientfirms that lie on the efficient frontier. This result also identified the changes that inefficient firms need to consider in order to move into the efficient frontier. In this way, the management of the firm can develop added insights into these critical areas that warrant additional attention and make such improvements.

Enlarging the time horizon for the examination of the various firms' relative efficiencies over a longer time period can expand this study effort. Such an investigation provides the opportunity to compare relative efficiencies of a single firm over time. If there are events or market changes that occur at discrete points in time, then organizational response to these events or changes can be assessed. Analysis of the relatively efficient frontiers also can be examined over time. It is conceivable that the efficient frontier may be changing over time, and this type of analysis provides a way to examine such changes. This type of analysis is commonly referred to as a longitudinal analysis.

Norton (1994) proposed that the relative efficiency approach be undertaken to study the performance of individual functions within a single firm and/or individual subunit performance within a single firm. Troutt et al. (1996) suggested a similar approach for evaluating investment in information technology in firms in competition with one another cross-sectionally in a single time period and/or longitudinally. The specific interests in this dissertation are discussed more fully in Chapter 3, Methodology.

CHAPTER 3

METHODOLOGY

Industry Selection

The industry selected for this research effort is the electric utility industry. During the past several years, especially since the early 1970s, significant legislation and regulation have been enacted, affecting the firms within this industry. The enactment of environmental air and water quality legislation and passage of the Public Utility Regulatory Policies Act of 1978 (PURPA) have influenced greatly the way electric utilities operate and the nature of service they provide to their customers. In addition, the Clean Air Act Amendments of 1990 (CAAA), the National Energy policy Act of 1992 (NEPA), and the work of the Federal Energy Regulatory Commission (FERC) in opening up the electric transmission grid as a common carrier access for all wholesale power transactions also have resulted in major impacts on the industry. Electric utilities with fossil-fuel (coal) burning power plants are faced with reducing their sulfur dioxide air emissions dramatically in Phase I (1995-1999) and even further in Phase II (2000 and beyond).

How do these governmental policies and deregulation affect an individual electric utility? The firm is in a dilemma. It must balance the changing demands in its own customers' growth requirements and meet the changing demands of increased governmental attention to deregulate its business through open wholesale competition. At the same time, the firm also must take whatever action it can to position itself for the future competition of its operations and asset base. With the volatility and uncertainty of the environment and the demands and pressures from customers to reduce costs and provide more choice, utilities appear to be under increasing competition on every front and are under siege.

Study Horizon

This study was designed to examine electric utilities cross-sectionally for each year (1988, 1992, and 1997) and longitudinally using a three-year moving-average window for the 1988 through 1997 horizon. Firm performance was examined over the study horizon. Data for the input and output variables were collected from the respective RUS and FERC reports cited previously for each year of the study.

This study allowed the researcher to examine the firms in the sample before and after the regulatory actions of CAAA and EPACT. A review of the changes in the relative costs for the respective firms may provide additional insight into relative firm behavior and performance.

Unit of Analysis

The unit of analysis for this study was the individual electric utility company. The firm-level analysis considered the electric aspect of the company. For firms that limit business or products to electrical power and energy, the data collected were directly relevant to this analysis. For firms who are combination electricity and gas providers, the data required special attention to develop and separate the electric business from the combination.

Performance Definition

The research setting investigated the performance of a sample of U.S. midwestern electric utility companies during the 1988 to 1997 period. The performance definition utilized in this study was the relative efficiency measure reflecting the overall technical and scale efficiency of the CCR input-oriented DEA model. This relative efficiency measure reflected the average efficiency attainable at the most productive scale size of a reference firm or decision making unit (i.e., DMU) (Banker et al., 1984; Charnes et al., 1978, 1981). Banker (1984) defines most- productive scale size as follows:

> For a single-input single-output case, the most productive scale size is simply that scale for which the average productivity measured by the ratio of total output to total input is maximized. On the other hand, at the optimal scale size, the marginal productivity is equal to the ratio of the output price to the input price.
>
> The concept of average productivity is commonly extended to the case of multiple inputs by the use of input prices to aggregate the multiple inputs, and by the estimation of the correspondence between the total input cost and the output. But input prices are affected by many factors other than the pure technological correspondence between the inputs and outputs that characterize the production process. Prices are likely to be more volatile than the pure technological characteristics, and therefore, estimation of merely the cost function is likely to retain its relevance for managerial and policy decisions for a shorter period than the estimation of the purely technological relation between the physical quantities of inputs and outputs. It is useful, therefore, to distinguish between the problem of determining the minimum cost mix of inputs and outputs on the basis of their

relative prices, and the problem of determining the most productive scale size (= mpss) for particular input and output mixes. In other words, for each input and output mix there corresponds a mpss, while the overall optimal scale size depends on the prevailing prices. The former is related to the concept of returns to scale, while the latter is associated with economies of scale. (p. 35)

This study focused on the estimation of the most productive scale size for the various DMUs to be examined in the sample. "The CCR measure captures not only the productive inefficiency due to its actual scale size, but also any inefficiencies due to its actual scale size being different from the mpss" (Banker, 1984, p. 37).

Research Questions

The research questions contemplated in this research effort were:

Why do electric utilities in the sample of midwestern U.S. electric utilities differ?

Why are some electric utilities more successful than others even in the same industry?

What firms are the better performers and which are the poorer performing firms?

These research questions are more formally stated as follows:

Static or Cross-sectional Comparison and Analyses

Research Question 1: What firms are operating at the most efficient scale size and are situated on the most efficient frontier for the firms in the sample?

Research Question 2: What firms are not operating at the most productive scale size (i.e., inefficient firms) and are not operating on the most efficient frontier?

Research Question 3: What can the inefficient firms do to move to the efficient frontier or do to achieve most productive scale size?

Research Question 4: Since the sample contains two major types of firms, that is, investor-owned electric utilities and generation-and-transmission rural electric cooperative utilities, is there a difference in performance or relative efficiencies as measured by mpss between the two classes of firms?

Longitudinal Comparison and Analyses

Research Question 5: Using the relative efficiency measures for determining overall most productive scale size, are firms' relative efficiencies improving, remaining the same or declining over the full study horizon?

Research Question 6: What firms are the most relatively efficient over this horizon?

Research Question 7: What firms are relatively inefficient over this horizon?

Research Question 8: What can the relatively inefficient firms do to improve their performance over the horizon?

Research Question 9: Since the sample contains two major types of firms, that is, investor-owned electric utilities and generation-and-transmission rural electric cooperative utilities, is there a difference in performance or relative efficiencies between the two classes of firms over the horizon?

Sample Selection

Some researchers have studied the utility industry and selected comparative firms or organizational structures as all IOUs (Goto & Tsutsui, 1998; Haeri et al., 1997; Taylor & Thompson, 1995) for their investigations or all cooperatives (Charnes et al., 1989). The similar class organizations were undertaken to eliminate relative competitive advantages and disadvantages across the sample firms from influencing the analysis. While this may be valuable and useful from a research perspective, such imbalances and distortions exist in the industrial competitive environment. In spite of the unbalanced or unleveled playing fields, firms still must compete with one another.

This study is different in that all organizations considered to be in a particular firm's competitive group have been included in trying to define the relatively efficient frontier and the opportunities available for exploration by the various firms. A firm is somewhat limited by its past decisions with respect to its plant, facilities, service area, capacity mix, investment, and short- and long-term contract flexibility. However, in spite of these unique circumstances and situations, firms in a turbulent environment must compete with one another, declare bankruptcy, cease to exist, merge, or be acquired by a competitor in a competitive market.

This sample was selected for a specific purpose and cannot be considered a statistical random sample. Babbie (1994) refers to this type of nonprobability sampling as purposive or judgmental sampling. The implication in this study is that whatever findings result can only be attributed to those utilities in the study and are not able to be generalized across the industry as a whole. Even with this limitation, the study was deemed to be worthwhile. The sample could be considered a population in that it was selected to represent all companies that the specific utility deemed as its competitors. It is important to mention that the top management in the specific utility and its consultants were directly involved in the selection of these firms and this sample mix.

At the time that this sample was selected, a 200-mile radius from the specific utility headquarters was utilized to map the competitive marketplace. Utilities within this circle were identified and contacts were made with each utility to gain access to the specific information on a regular basis. Confidentiality agreements were executed between the parties to aid in the data gathering and collection process. The 200-mile radius was selected by evaluating neighboring utilities within two adjacent electric transmission systems from the specific utility. Practice within the electric industry has proven that transfers of power and energy more than two systems away result in uneconomic transmission delivery costs (i.e., production costs plus transportation costs).

Twenty-five electric utilities were selected for this sample. Twenty-one of the electric utilities were within two systems of the specific utility system. Management and the consultants selected four other utilities in addition to these for inclusion in the sample. These four other electric utilities were electric utilities similar in nature to the specific utility. They were generation-and-transmission rural electric cooperatives located in the northern U.S., the southern U.S., and in the southeastern U.S. Fourteen (56%) of the electric utilities were investor-owned electric utilities, and the other 11 (44%) were generation-and-transmission electric cooperative utilities.

Data Collection and Analysis

A database of comparative financial and operating statistics for 25 utilities had been compiled by a particular utility in the Midwest. The database includes public information available for utilities from Rural Utilities Services (formerly Rural Electrification Administration) in its REA Form 12 report and from FERC Form 1 reports. These reports are required by the respective agencies to be filed annually by each utility. Select performance measures for both financial and operating data were compiled from 1988 through 1997. This information was used in the strategic planning process as a means to provide trend and performance comparisons for the Midwest utility with the companies in the database. Nunamaker (1985) advises that the selection of variables to be included in the DEA analysis should be guided by the relevant literature and expert opinions. "The importance of a particular variable to the DEA results is established via a panel of experts, prior statistical work, the researcher's knowledge of the decision environment or a combination of the three" (p. 56). The selections of the variables in this study were developed as a result of the combination of these methods or approaches.

Troutt et al. (1996) cite a common deficiency in the data collection and performance measures process:

> This underscores a common deficiency in organization studies in both IT and POM areas. Often only one-respondent is used for each organization. For purposes of the present models, higher reliability of these measurements is very desirable. If multiple measures cannot be obtained, then the potential impact of standardization of variables across respondents should be investigated. Such an adjustment can mitigate the effects of individuals who tend to rate variables uniformly higher or lower than other respondents. (pp. 19-20)

Nunamaker (1985) also points out problems with variable selection and data collection and verification. He offers several ideas for improving reliability of DEA analyses:

> In any real-world application of DEA, these potential variable-selection and data variation problems must be recognized and, wherever possible, their impact upon the DEA efficiency scores reduced. For instance, DEA's reliability could be improved through implementation of standards of accounting and reporting requirements coupled with an extensive audit function. Such procedures should

help reduce the potential manipulative efforts of DMUs. In addition, standardization of data accumulation systems should aid in reducing variations across DMUs caused by different measurement methods. (p. 57)

The representative variables utilized in this study (i.e., inputs, outputs, and whereputs) were derived from each firm's operating and financial accounting information and data filed in accordance with government regulatory standard procedures, audit policies and practices. Each firm submitting its respective annual report understands the definitions and requirements. All of the firms follow the same guidelines and filing requirements. Utilizing these standardized variables and government reporting methods across all organizations helped to increase reliability of the information, data, and measures used for their interpretation as suggested by Troutt et al. (1998). In addition to this, the individual company's specific data were periodically cross checked and validated with other information and data tabulated for the respective firms when available.

As a validity check on G&T rural electric cooperatives that complete the RUS (REA) Form 12 Annual Reports, three other sources are available for cross-checking and verifying data and information for each DMU:

Annual Statistical Report Rural Electric Borrowers (U.S. Department of Agriculture)

Electrical World Directory of Electric Utilities (McGraw-Hill, Inc.)

Electrical World Directory of Electric Power Producers (McGraw-Hill, Inc.)

The first source contained a summary of descriptive information based on each G&T's REA (RUS) Form 12 annual reports for each year. The respective firms were compared to several operating and financial ratios along with a description of each firm.

The latter two sources referenced above contained specific information on operating and financial data and statistics for each firm. The information and data provided are for all utility type organizations including investor-owned and G&T's. This provided the researcher with an opportunity to check, verify, and validate the Form 12 reported data utilized as variables in this study.

Also, three sources are available for checking investor-owned FERC Form 1 operating and financial accounting data:

Moody's Public Utility Manual (Moody's Investors Services)

Electrical World Directory of Electric Utilities (McGraw-Hill, Inc.)

Electrical World Directory of Electric Power Producers (McGraw-Hill, Inc.)

The first source referenced above contained complete summary information and details on each investor-owned utility under FERC regulation. The operating and financial accounting data and information are provided along with a brief history of each firm and its respective bond and stock market ratings as of a specific time during the year. This information is available for each investor-owned firm annually from 1988 through 1997. The remaining two sources listed above provided the same information as discussed previously for both investor-owned and G&T organizations. Thus, the researcher was afforded similar opportunities for verification and validity checks for both firm types in this study. This capability and standardization improved the reliability of this study effort.

Study Approach

In studying this group or population of electric utilities using DEA, the cost minimization technique was considered as a part of this proposed approach to measure relative efficiency. The following inputs and outputs have been identified as representative for this approach:

1. Input Variables

   Fixed Expenses:

   - Taxes
   - Interest
   - Depreciation
   - Administrative and General

   Variable Expenses:

   - Fuel and Purchased Power
   - Non-Fuel Production and Transmission Operations and Maintenance
   - Full-Time Electric Employees
   - Net Installed Generation Capacity
   - Transmission Line Circuit Miles Installed

2. Output Variables

   - Total Kilowatt-hours Sold
   - Maximum Kilowatt Demand
   - Total Electric Revenue
   - Net Generation

Each of these variables is described more fully as follows.

Input Variable Identification

In using the cost minimization approach, it was necessary to determine the individual components of expenses that account for the total expenses of the firm. The total expenses for the firm can be expressed as the sum of its fixed costs and variable costs.

Fixed and Variable Expenses

Fixed expenses. Fixed costs are those costs or expenses that do not vary with changes in operations with respect to the short-term. Taxes, interest, depreciation, and administrative and general expenses represent the major fixed cost expenses for the firm. Fixed costs over a short term are considered to be sunk costs.

Variable expenses. Variable costs are those costs that vary with changes in the level of loads or sales and in the operation of the system on a short-term basis. In an electric utility, the variable costs considered are those out-of-pocket costs that will change with variations in load or sales (economic demand, weather, load shedding, and emergencies). In most instances, additional power and energy can be produced and sold to recover these variable costs. If power and energy are sold at the variable cost level, the firm is operating at break-even and maintaining operations, employment, and use of its production assets. However, it is not making a profit or contributing to the recovery of its fixed costs. In the event that the firm can produce additional power and energy in the short-term with existing infrastructure at prices above its variable costs, then it is earning a return on the transaction and recovering a portion of its fixed costs. Ideally, the firm should recover its total cost plus a profit, margin, or return for its investment and services.

Fuel and purchased power expenses and non-fuel production and transmission operation and maintenance expenses (Non-Fuel O & M) account for the variable costs for an electric utility. Management of the firm can determine these costs and profitability targets through an annual budget process and monitor conformance to the budgeted targets periodically. Corrections can be made if necessary during the monitoring or budget variance process. Changes in sales, weather, markets, and the economy also can be assessed as a part of this review process.

The marginal costs to produce the next kilowatt and/or kilowatt-hour can be approximated by a firm's variable cost divided by energy sales to determine its marginal unit cost. In a similar manner, the firm's total cost (i.e., fixed plus variable) can be divided by energy sales to determine a proxy for its average costs.

Manpower

Labor is considered also to be an input to the production process that is under the control of management. This study has been designed to evaluate the performance of electric utilities specifically. It is expected that some firms in the group will be combination gas and electric companies. In order to make representative comparisons across the group, it is necessary to employ a common definition for manpower or employees. In this study, manpower will be defined as full-time electric employees of the firm. The Rural Utilities Services and the Federal Energy Regulatory Commission financial accounting and operations reports provide this level of employment detail.

Net Installed Generating Capacity and Transmission Line Circuit Miles Installed

The net installed generating capacity in megawatts and the total transmission line circuit miles installed on the firm's system are included as proxy measures of capital investment. These two input variables provide a measure of the total capacity, size, and investment the firm has made in infrastructure to support the generation and transportation of its product to the marketplace and its customers. The Rural Utilities Services and the Federal Energy Regulatory Commission financial accounting and operations reports provide this level of detail.

Output Variable Identification

There are four outputs of significant importance to the electric utility: total kilowatt-hours sold, maximum kilowatt demand, total electric revenue, and net generation in megawatt-hours.

Total Kilowatt-hours Sold and Maximum Kilowatt Demand

The first output considered is the total volume of electric production sold in the market. When the electric utility produces electricity, it must deliver the capacity or power in kilowatts and the energy measured in kilowatt-hours to meet all of its customers' requirements. Electricity today is considered a commodity. The total electrical energy sold in the market measured in kilowatt-hours is the first key output. It is expected that changes in operations, weather, economy, market, and system conditions have an impact on sales volume. Sales volume among the firms in the group can be evaluated and compared. Maximum demand in kilowatts on the system is a measure of the impact of customer loads on the firm's system.

An annual system load factor can be calculated as a ratio and converted to a percentage. The numerator of this ratio is the total kilowatt-hours or megawatt-hours sold for the firm. The denominator of this ratio is found by multiplying the firm's maximum demand in kilowatts or megawatts by the number of hours in a year. The annual system load factor is equal to the ratio of the numerator divided by the denominator and expressed on a percentage base. The maximum annual load factor possible is 100%. In order for a firm to have a maximum load factor of 100%, the maximum demand in kilowatts would have to be placed on the system continuously for every hour of the year. The minimum annual system load factor is 0%. In order for this condition to prevail, the maximum system load in kilowatts connected to the system would never be energized or consumed in any hour of the year. Most typical utility electric systems have annual system load factors in the range of 45% to 55%. Firms with annual system load factors above this range have predominantly industrial electrical loads on their systems that operate continuously. Aluminum smelters and steel mills, for example, operate continuously near 80% to 100% of the time near full capacity. They usually operate fifty-two weeks of the year with a one or two week shutdown maintenance and vacation schedule. This load factor measure can be utilized to compare firms and the nature of their respective system loads.

Total Electric Revenue

The third output considered in this study is the total electric revenue for the firm. This revenue enables the researcher to examine the respective rates for the firms in the study and to develop an average rate for the group in various time periods. A firm's electric profits or margins also can be determined by subtracting total electric expenses from total electric revenues. The relative levels of profitability provide the researcher an opportunity to assess and rank the firms in the sample or group. This information also is available from the RUS and FERC sources.

Net Generation in Kilowatt-hours

Net generation is the total energy produced by the firm with its own installed generating capacity that is available for sale. Generation plant energy losses already have been accounted for in determining net plant energy output or net generation. Historically electric utilities planned their generation capacity additions so as to be able to provide for their full customer energy requirements plus an additional amount of reserves to be selfsufficient. Reserve levels were required to provide extra capacity to meet customer requirements in the event of maintenance and/or emergency outages caused by equipment failures or acts of nature. A comparison of the total kilowatt-hours sold with total net generation provides the researcher with a measure of how well installed generating capacity is being utilized to meet customer requirements. If total kilowatt-hours sold are greater than total net generation, it is an indication that the firm is seeking to supplement its sales by purchasing capacity and energy off-system from others in the marketplace.

Additional Firm System Characteristics

In order to provide measures of firm size and capital intensity, data regarding the total installed generating capacity in megawatts by type (i.e., steam by fuel type, hydro, combustion, nuclear, etc.) and total transmission circuit miles for each firm for each year of the study will be collected. In an effort to gain additional insight as to the overall size of each system, data on system net generation in kWh and the maximum summer and winter system peak kW load requirements for each firm will be available for this study. This information will allow one to determine how much total sales can be provided from a firm's own installed capacity and also to determine an empirical seasonal load factor for the load demanded by the respective system. Such measures in themselves are partial efficiency or productivity measures.

It also was desired to gather information on total customers for each firm as well as a detail comparison of customer types (i.e., residential, commercial, industrial, rural, and other). However, the firms included in the sample were representative of both investor-owned electric utilities and rural electric G&T cooperatives. The rural electric G&Ts officially do not serve these customer classes. They serve customers at wholesale, and their customers are considered customers of the individual retail rural electric distribution or municipal organizations for which they provide electric service. The G&T's sales are all sales for resale either to member and nonmember rural electric cooperatives.

The respective state public service commissions or energy regulatory commissions may regulate some of the utility firms in the sample. The status of each firm's state regulatory requirements were referenced and included in the study for consideration as a possible source of firm differences. In the event that all of the utilities in the sample are regulated by federal and/or state commissions, then this data would likely not be useful in explanation of firm differences and would not be utilized within this study.

Figure 4, entitled "Database Definition and Development," contains a detailed listing of the variables and firm characteristics gathered for this study. Definitions for each variable are shown, including detail source references and associated calculations. The cost information and system level details defined for each firm have been adjusted as noted to provide generation and transmission costs typical for the wholesale market side of the electric utility business. In other words, the electric distribution system costs and infrastructure were separated from the remaining costs for this study. This separation was essential to ensure a fair comparison among electric companies.

The variables and firms' characteristics included in the database were arranged into a data input file (Table 5). The database is expected to contain the 13 variables and firms' characteristics on an annual basis. With a sample of 25 electric utilities in a 10-year horizon, the total database size was expected to be approximately 4,500 data elements. The total size of the 25 DMUs with 13 input and output variables for the 10-

ID - Electric Utility / Firm Code Name
Two-digit number, 01 to 25, unique for each firm in the database.

Year - Electric Utility / Firm Database Information and Data
Database compiled for each year from 1988 through 1997.

Firm Type - Electric Utility / Firm Type
Code 1 = Electric cooperative utility
Code 2 = Investor-owned electric utility

State Commission Regulated Status
Yes Code = 1
No Code = 0

Taxes (other than income)
Electric cooperative utility
Source: REA Form 12
Taxes (page 12a, line 21)

Investor-owned electric utility
Source: FERC Form 1
taxes - other (page 115, line 13E)

Net Interest Expense
Electric cooperative utility
Source: REA Form 12
(+) Interest on long-term debt (page 12a, line 22)
(-) Interest charged to construction (page 12a, line 23)
(+) Other interest (page 12a, line 24)

Investor-owned electric utility
Source: FERC Form 1
(+) Net interest (page 117, line 64)
(-) Amortization of loss (page 117, line 58)

Depreciation Expense
Electric cooperative utility
Source: REA Form 12
(+) Total depreciation (page 12a, line 20)
(-) Distribution - line depreciation (page 121, line 24a)
(-) Distribution - substation depreciation (page 121, line 24b)

Investor-owned electric utility
Source: FERC Form 1
(+) Total depreciation (page 336, line 11e)
(-) Distribution depreciation (page 336, line 8e)

Fuel and Purchased Power Expense
Electric cooperative utility
Source: REA Form 12
(+) Operations expense - fuel (page 12a, line 6)
(+) Purchased Power (page 12c, line 21f)

Investor-owned electric utility
Source: FERC Form 1
(+) Fuel - Steam (page 320, line 5)
(+) Fuel - Nuclear (page 320, line 24).
(+) Fuel - Other (page 321, line 63)
(+) Purchased Power (page 321, line 76)

figure continues

Figure 3. Database definition and development.

Non-fuel Production & Transmission Expense
Electric cooperative utility
Source: REA Form 12
(+) Operations expense - Production less fuel (page 12a, line 5)
(+) Operations expense - Other power (page 12a, line 7)
(+) Operations expense - Transmission (page 12a, line 8)
(+) Maintenance expense - Production (page 12a, line 15)
(+) Maintenance expense - Transmission (page 12a, line 6)
(-) Purchased power (page 12c, line 21f)
(-) Transmission by others (page 121, line 8a)

Investor-owned utility
Source: FERC Form 1
(+) Total power production operations and maintenance (page 321, line 80)
(-) Fuel - steam (page 320, line 5)
(-) Fuel - nuclear (page 320, line 25)
(-) Fuel - other (page 321, line 63)
(-) Purchased power (page 321, line 76)
(+) Total transmission operations and maintenance (page 321, line 100)
(-) Transmission by others (page 321, line 88)

Administrative and General Expense
Electric cooperative utility
Source: REA Form 12
(+) Operations administrative and general expense (page 12a, line 13b)
(+) Maintenance administrative and general expense (page 12a, line 18b)

Investor-owned electric utility
Source: FERC Form 1
Total administrative and general expense (page 323, line 168)

Total Electric Revenue
Electric cooperative utility
Source: REA Form 12
Operating revenue (page 12a, line 4)

Investor-owned electric utility
Source: FERC Form 1
Operating revenue (page 300, line 27b)

Full-Time Electric Employees
Electric cooperative utility
Source: REA Form 12
Total employees (12h, p. 5, sec. j, 1.1)

Investor-owned electric utility
Source: FERC Form 1
Total employees (page 323)

Total KWh Sold
Electric cooperative utility
Source: REA Form 12
KWh sold (page 12b, line 77d)

Investor-owned electric utility
Source: FERC Form 1
KWh sold (page 320, line 12d)

figure continues

Figure 3. (continued)

Total Installed Generating Capacity in MW
Electric cooperative utility
Source: Electrical World Directory of Electric Utilities
(+) Steam - coal
(+) Steam - oil
(+) Combustion
(+) Hydro
(+) Nuclear
Total system

Investor-owned electric utility
Source: Electrical World Directory of Electric Utilities
(+) Steam - coal
(+) Steam - oil
(+) Combustion
(+) Hydro
(+) Nuclear
Total system

Transmission Circuit Miles
Electric cooperative utility
Source: Electrical World Directory of Electric Utilities

Investor-owned electric utility
Source: Electrical World Directory of Electric Utilities

Net Generation in KWh
Electric cooperative utility
Source: Electrical World Directory of Electric Utilities

Investor-owned electric utility
Source: Electrical World Directory of Electric Utilities

Maximum Summer Peak Demand in MW
Electric cooperative utility
Source: Electrical World Directory of Electric Utilities

Investor-owned electric utility
Source: Electrical World Directory of Electric Utilities

Maximum Winter Peak Demand in MW
Electric cooperative utility
Source: Electrical World Directory of Electric Utilities

Investor-owned electric utility
Source: Electrical World Directory of Electric Utilities

Figure 3. (continued)

Table 5

Input Database Matrix Format

ID	YEAR	FIRMTYPE	REGULATD	TAXES	INTEREST	DEPR	FUELPPWR

Where ID = Electric utility / firm code name
YEAR = Electric utility / firm database year
FIRMTYPE = Rural electric cooperative G&T (Type 1) or Investor-owned utility (Type 2)
REGULATD = State commission regulated status: Yes (1) or No (0)
TAXES = Taxes (other than income)
INTEREST = Net interest expense
DEPR = Depreciation expense
FUELPPWR = Fuel and purchased power expense

NOFUEL	A&G	REVENUE	EMPLOYEES	KWHSOLD	INSTGCAP

Where NOFUEL = Non-fuel production and transmission expense
A&G = Administrative and general expense
REVENUE = Total electric revenue
EMPLOYEES = Total electric employees
KWHSOLD = Total KWh sold
INSTGCAP = Total installed generating capacity

TRANMILE	NETGENRG	SUMMERPK	WINTERPK

Where TRANMILE = Transmission circuit miles
NETGENRG = Net generation in KWh
SUMMERPK = Maximum summer peak demand in MW
WINTERPK = Maximum winter peak demand in MW

year base was expected to be approximately 3,250 data elements. This does not include the three-year moving-average window increases in the degrees of freedom in the longitudinal analysis.

Study Methodology

The DEA mathematical programming method was selected to perform the relative efficiency measurements necessary to determine the answers posed in the research questions. The CCR input-oriented DEA model was utilized. This model enables the researcher to:

1. Develop relative measures of efficiency;
2. Know nothing about proposed relations;
3. Require identification of inputs;
4. Require identification of outputs;
5. Assist in developing empirically relatively efficient frontier;
6. Identify efficient firms and inefficient firms; and
7. Identify input changes and output changes for inefficient firms to move to efficient frontier.

The CCR ratio input-oriented form of the linear fractional model is shown as follows (Charnes, Cooper, Lewin, & Seiford, 1994, pp. 40-41). The ratio model provides a reduction of the multiple output multiple input situations for each DMU or firm included in the sample to that of a single virtual output and a single virtual input. The ratio of this virtual output to virtual input provides a single relative efficiency measure for each DMU or firm. The objective function is to maximize this relative efficiency measure for each firm subject to the technological constraints of each DMU.

CCR Ratio Model (Input-Oriented)

$$\max_{u,v} \frac{\sum_r u_r y_{ro}}{\sum_i v_i x_{io}}$$

$$\frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1 \quad \text{, for } j = 1, \ldots, n \text{ DMUs}$$

$$\frac{u_r}{\sum_i v_i x_{io}} \geq \varepsilon \quad \text{, for } r = 1, \ldots, s \text{ outputs}$$

$$\frac{v_i}{\sum_i v_i x_{io}} \geq \varepsilon \quad \text{, for } i = 1, \ldots, m \text{ inputs}$$

where y_{rj} = output variables for $r = 1, \ldots, s$ outputs for the j_{th} DMU

x_{ij} = input variables for $i = 1, \ldots, m$ inputs for the j_{th} DMU

u_r = output variable weights, such as dollar benefit per unit of output y_r

v_i = input variable weights, such as dollar cost per unit of input x_i

j = DMU reference for $j = 1, \ldots, n$ DMUs

ε = non-Archimedean infinitesimal usually equal to the value one millionth

Charnes and Cooper (1962) utilized linear programming techniques and developed a transformation for converting the linear fractional programming problem using the dual and primal linear programming (LP) models as equivalent solutions. The dual and primal LP CCR equivalent models are shown below (Charnes, Cooper, Lewin, & Seiford, 1994, pp. 40-41).

LP CCR Dual Model (Input-Oriented)

$$\max_{u,v} \; w_o = \sum_r u_r y_{ro}$$

subject to

$$\sum_i v_i x_{io} = 1$$

$$\sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 0$$

$$u_r \geq \varepsilon \quad and \quad v_i \geq \varepsilon$$

LP CCR Primal Model (Input-Oriented)

$$\min_{\theta,\lambda,s^+,s^-} \; z_0 = \theta - \varepsilon \sum_r s_r^+ - \varepsilon \sum_i s_i^-$$

subject to

$$\sum_j \lambda_j Y_j - s^+ = Y_o$$

$$\theta X_o - \sum_j \lambda_j X_j - s^- = 0$$

$$\lambda_j, \; s_r^+, \; s_i^- \geq 0$$

where y_{rj} = output variables for $r = 1, \ldots, s$ outputs for the j_{th} DMU

x_{ij} = input variables for $i = 1, \ldots, m$ inputs for the j_{th} DMU

u_r = output variable weights, such as dollar benefit per unit of output y_r

v_i = input variable weights, such as dollar cost per unit of input x_i

j = DMU reference for $j = 1, \ldots, n$ DMUs

ε = non-Archimedean infinitesimal, usually equal to the value one millionth which allows minimization over θ to preempt the optimization involving slack variable quantities

θ = scalar variable which is the proportional reduction applied to all inputs of the DMU being evaluated (DMU_0) to improve efficiency

s^+ and s^- = model slack and/or surplus variables

λ = the variable weights utilized to determine proportional reductions in respective inputs for each DMU under evaluation.

Charnes et al. (1981) state the following:

> We shall instead assume that the desired outputs and the designated inputs, as well as the way they are to be measured, have already been determined. This will allow us to focus on the issue of efficiency in the conduct of such programs which we may characterize by reference to the following output and input orientations:
>
> i. Output Orientation: A Decision Making Unit (= DMU) is not efficient if it is possible to augment any output without increasing any input and without decreasing any other output.
>
> ii. Input Orientation: A DMU is not efficient if it is possible to decrease any input without augmenting any other input and without decreasing any output.
>
> A DMU will be characterized as efficient if, and only if, neither (i) nor (ii) obtains. (p. 669)

The input-orientation for the dual and primal LP models was selected primarily because the managers or decision-makers of the respective DMUs have discretion and control over the quantity and quality of the input resources available to the respective firms or DMUs in their production processes. The capability to make changes and adjustments in input resource levels allows managers the option to make improvements leading to increasing overall relative efficiency of the respective DMU. Notice that the solution of the dual and primal LP CCR models involves solving two LP formulations. Charnes, Cooper, Lewin and Seiford (1994) point out the following:

> Thus, the optimization can be computed in a two-stage process with maximal

reduction of inputs being first achieved, via the optimal θ^*; then, in the second stage, movement onto the efficient frontier is achieved via the slack variables (s^+ and s^-). Evidently the following two statements are equivalent:

1. A DMU is efficient if and only if the following two conditions are satisfied:

   (a) $\theta^* = 1$;

   (b) all slacks are zero.

2. A DMU is efficient if and only if $w^*_0 = z^*_0 = 1$

The nonzero slacks and the value of $\theta^* \leq 1$ identify the sources and amount of any efficiencies that may be present. (p. 32)

The solution to the two-stage LP model results in the identification of the relatively efficient firms and the inefficient firms overall measure. The sources and amounts of changes in the resource input levels also are identified to enable the decision-makers or management of the inefficient DMUs to move to the efficient frontier and become efficient.

Figure 5, entitled "Methodology Overview Flowchart," provides a brief summary flowchart of the major steps involved in this research proposal methodology section. The first six elements considered in this figure have been discussed previously in this section. The study methodology selection elements to be pursued are discussed as follows.

Cross-sectional Analyses (1988, 1992, and 1997)

In performing the cross-sectional analysis of this study, it was proposed that three different annual periods be selected for analysis. The years 1988, 1992, and 1997 were proposed for this analysis. Figure 6 shows a flowchart of the first two phases for this cross-sectional analysis. Phase I examination of the DMUs in the year 1988 provided

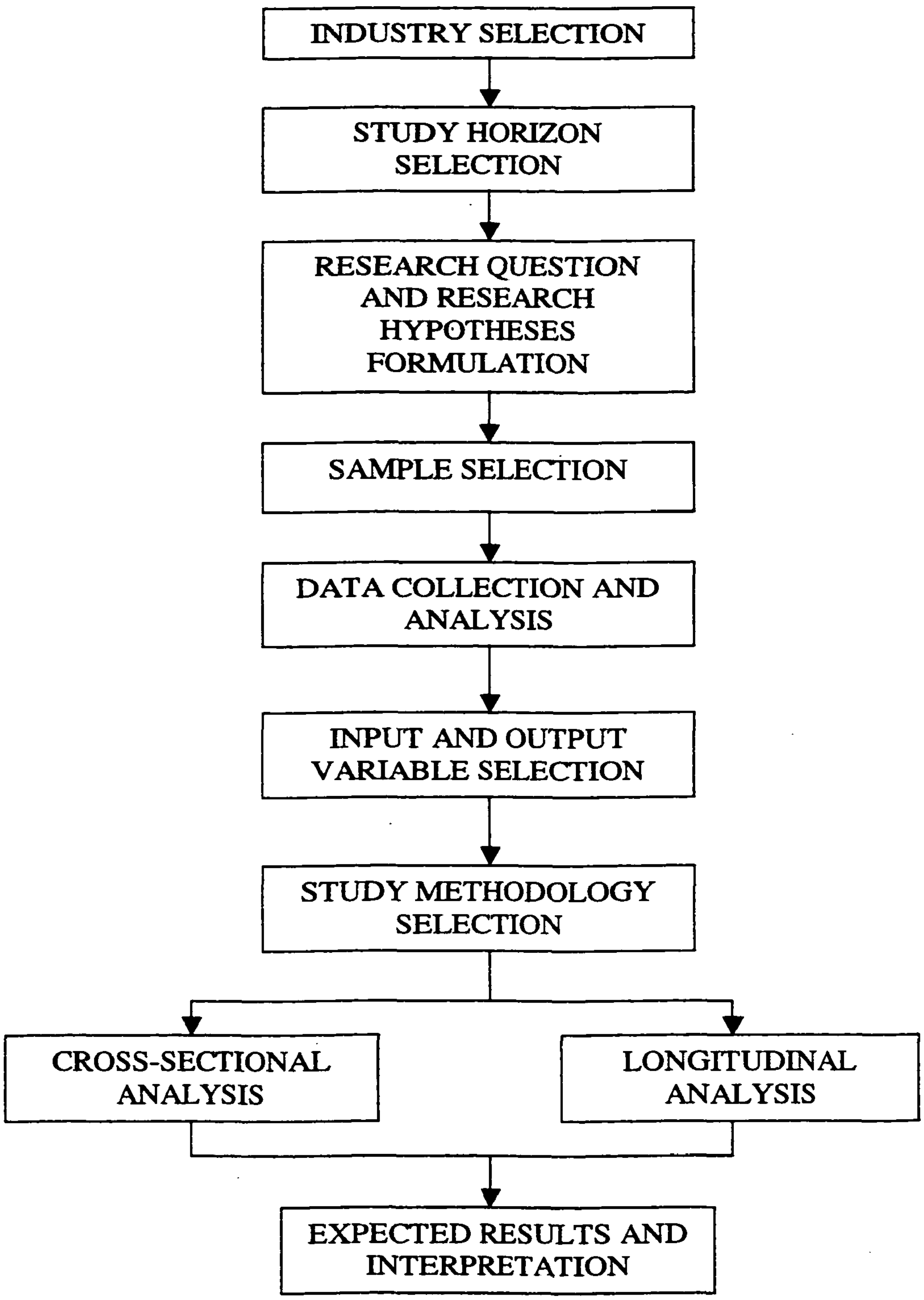


Figure 4. Methodology overview flowchart.

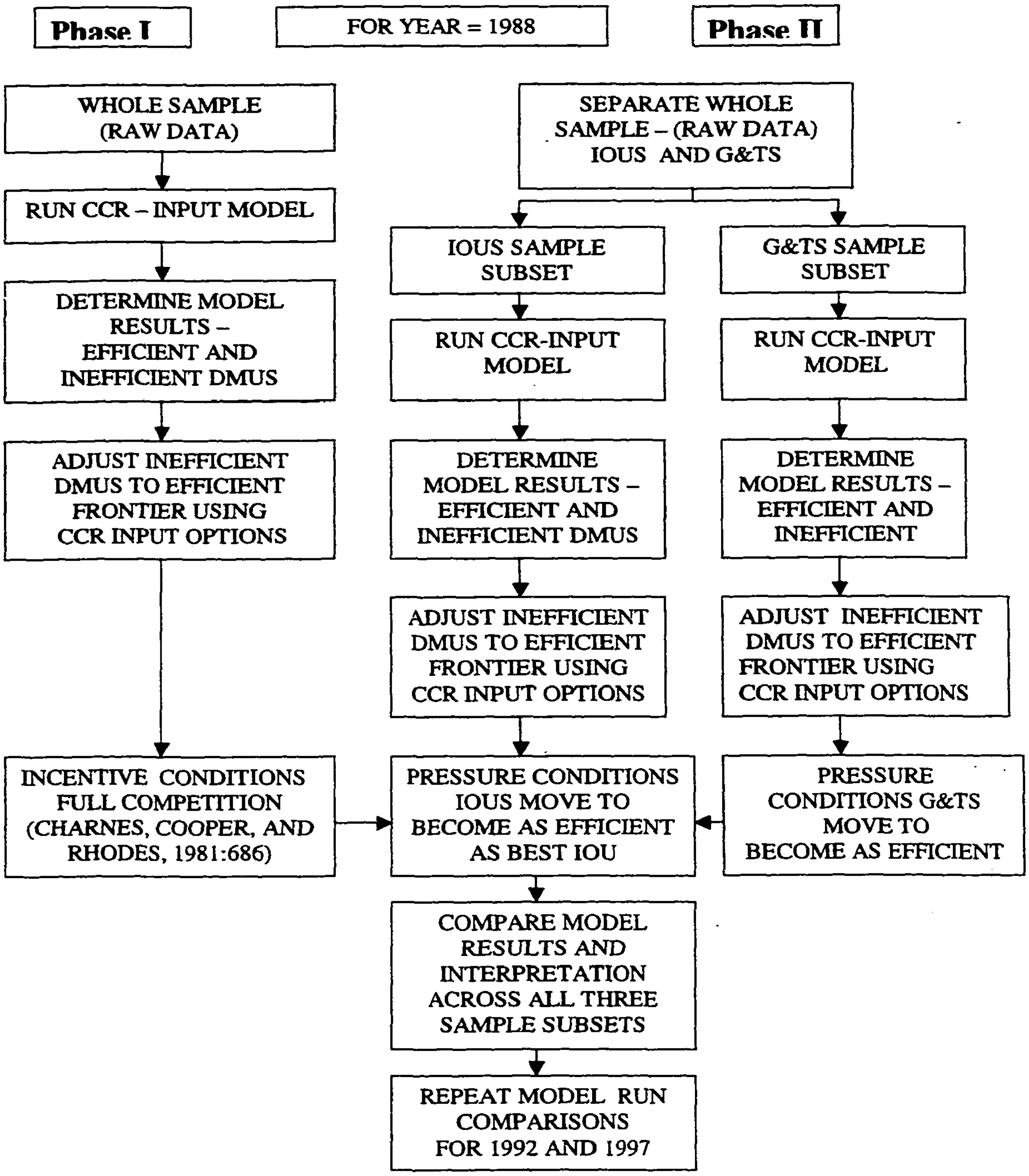


Figure 5. Cross-sectional analysis - Phase I and phase II.

the researcher an opportunity to determine relative efficiency measures for each DMU and to determine those DMUs which are efficient and those which are inefficient. It also was possible to determine what sources and quantities of input resources to change in order for each inefficient DMU to move to the efficient frontier or surface. These findings for the year 1988 established the base performance levels for each DMU at the beginning of the study. Charnes et al. (1981) suggested in their study that firms or DMUs have two primary influences to consider in assessing their individual performance. The performance levels and the most efficient frontier may shift depending upon which option the individual firm chooses to pursue. These two influences or options are treated as pressure conditions and incentive conditions. These two influences stem from the level of economic conditions prevalent for the firm or DMU.

> We can relate this situation to the one we are considering by regrouping the usual economic conditions for the existence of such possibilities into the following two types:
>
> Pressure conditions: All firms (DMU's) are forced to become as efficient as the most efficient members of the reference set.
>
> Incentive conditions: The most efficient firms (DMU's) will move to the frontiers that technology makes possible. (Charnes et al., 1981, p. 686)

These two influences or options were explored in the cross-sectional analysis as Phase I and Phase II, respectively.

In each year, it was possible to establish the overall efficiency of all firms in the sample as well as to establish the efficiencies of the investor-owned electric utilities and the generation-and-transmission rural electric cooperatives separately. A comparison of their respective relative efficiency levels of both groups can be compared using statistical t-tests.

In performing the cross-sectional analysis in each of the three individual years, the following procedure was proposed for this analysis. For the complete unadjusted sample of investor-owned electric utilities and G&T rural electric cooperative utilities combined, the researcher needs to apply CCR input-oriented DEA analysis to determine the relatively efficient electric utilities for the sample. However, for those DMUs that are found to be relatively inefficient, DEA modifications should be incorporated in the inputs to move these inefficient DMUs to the efficient frontier surface. For each of the two groups in the unadjusted sample, that is, the investor-owned electric utilities and the G&T rural electric cooperative utilities, the researcher performed separately the following procedures on each group.

1. Apply CCR input-oriented DEA analysis to determine the relatively efficient frontier separately for each of the two groups, that is, investor-owned and G&T utilities in the sample.
2. For those DMUs that are found to be relatively inefficient incorporate the DEA modifications in the inputs to move these inefficient DMUs to the efficient frontier surface.
3. Apply CCR input-oriented DEA analysis to the combined adjusted data pooled from both groups. Here adjusted refers to improving the inefficient DMUs to the efficient frontier by incorporating DEA suggested modifications to the variables. The number of efficient and inefficient DMUs in the investor-owned and G&T's performance can be compared with one another in the

three individual time periods (i.e., 1988, 1992, and 1997).

The analysis proposed in step 3 above is shown in Figure 7, Cross-sectional Analysis – Phase III.

In order to provide a comparison of the CCR input-oriented DEA methodoiogy, the maximin efficiency ratio model (MER) was performed. Troutt and Zhang (1993) proposed this model initially as an alternative to be applied on the efficient DMUs found in a DEA analysis in order to find the most efficient DMUs of the efficient set. This alternative enhances the DEA approach by providing information as to how efficient firms may overcome the "Miller's Time Curse" and find ways for continuous improvement. Later, Troutt and Zhang also realized that while the MER model is good at distinguishing the efficient set, it also provides a simple solution and check on the DEA results in a single run of the model. Using the Charnes and Cooper (1962) transformation, Troutt and Zhang developed the LP Model, FMER, as the formulation for performing this analysis. This model is shown below.

Maximin Efficiency Ratio Model

MODEL FMER:

Let

$$m = \left[\textit{minimum } (j) \frac{\sum_r u_r y_{rj}}{\sum_i w_i x_{ij}} \right]$$

Maximize m

Subject to

$$\sum_r u_r y_{rj} \geq m \quad \text{, for all j}$$

$$\sum_i w_i x_{ij} \leq 1 \quad \text{, for all j}$$

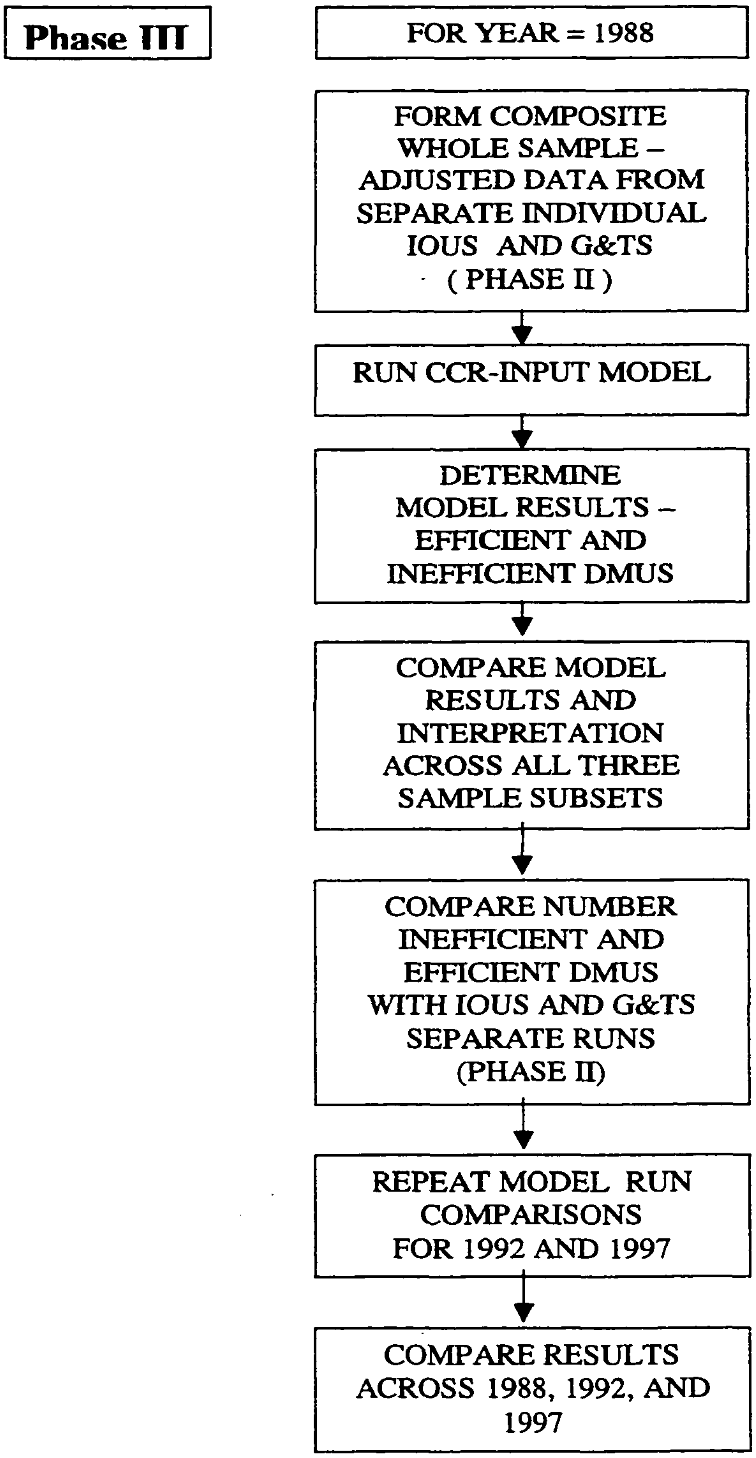


Figure 6. Cross-sectional analysis - Phase III.

$$\sum_r u_r y_{rj} \leq \sum_i w_i x_{ij}, \text{ for all j}$$

$$u_r, w_i \geq 0 \quad \text{, for all r and j}$$

Where

y_{rj} = output variables for $r = 1, \ldots, s$ outputs for the j_{th} DMU

x_{ij} = input variables for $i = 1, \ldots, m$ inputs for the j_{th} DMU

u_r = output variable weights, such as dollar benefit per unit of output y_r

w_i = input variable weights, such as dollar cost per unit of input x_i

j = DMU reference for $j = 1, \ldots, n$ DMUs. (Troutt & Zhang, 1993, p. 6)

Using this FMER Model, the following steps were performed in this cross-sectional analysis. A Cross-sectional Analysis – Phase IV flowchart for this process is shown in Figure 8.

1. Apply the FMER LP Model to the combined original unadjusted data for a particular year for all DMUs in the sample. Here unadjusted refers to use of the data as raw data without adjustments in any of the variables.
2. Calculate the means of the FMER LP Model scores for the two groups (i.e., investor-owned and G&T's) and perform a means t-test comparison to test for the Null Hypothesis of no difference between the respective two means. A variances t-test comparison also could be made to test for the Null Hypothesis of no difference between the respective two variances.

The results of the CCR input-oriented analysis and the FMER LP Model analysis can be compared to one another. Such a comparison provides a validity check on the DEA model choice. Troutt and Zhang (1993) utilized this idea of analyses in their test of

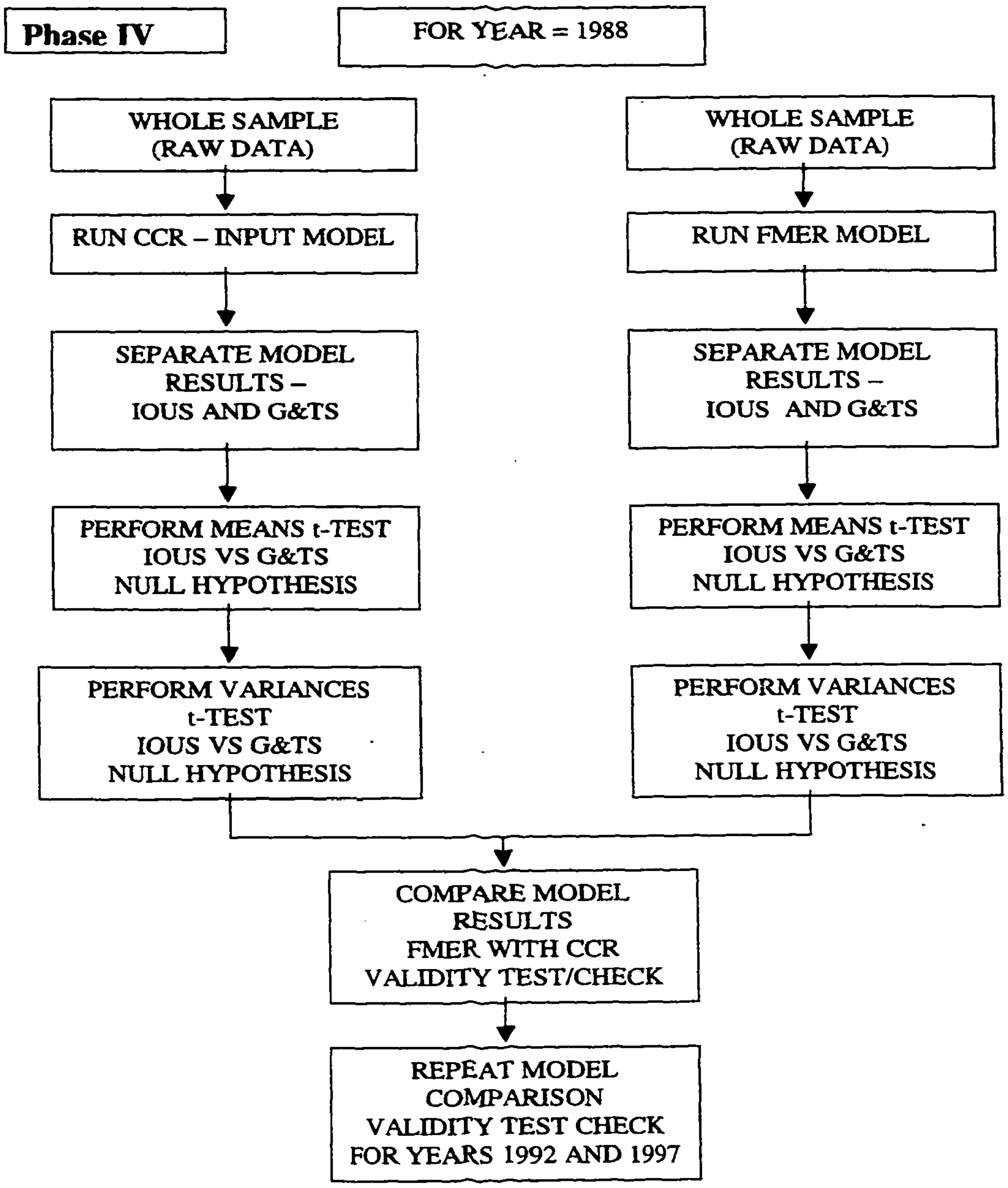


Figure 7. Cross-sectional analysis - Phase IV.

Charnes et al.'s (1981) Program Follow Through data comparison and evaluation using the FMER model.

Relative Efficiency Histograms and Cumulative Frequency Distribution Analysis

In order to provide further checks and analysis, a separate analysis of the frequency distributions for the whole-unadjusted sample and for the investor-owned and G&Ts should be performed. The histograms for each of these relative efficiency measures should be viewed and a comparison with standard distributions should be made (Troutt et al., 1998). Additionally, cumulative frequency distributions also should be made under each of the three groupings and a comparison with standard distributions made. It was expected that the cumulative frequency distributions of the relative efficiency measures should resemble a monotone increasing function. It was also expected that the measures would be shifted in order to have many firms at relative high efficiency measures with a few at relatively low efficiency measures. This pattern would fit the explanation and assumptions of Decisional Efficiency (DE) in that management, using purposeful decision-making, would act to maximize the efficiency and performance of the individual firms. All firms acting purposefully in a competitive environment would lead the sample to behave as assumed. This check would help verify such assumptions.

Relative Efficiency Measure Outlier Analyses

An analysis of the outliers was also undertaken (Epstein & Henderson, 1989). DMUs found to be efficient in the analysis may not necessarily be efficient. Data- coding errors, misreported data, or chance may account for this result. Troutt et al. (1996) pointed out the following with respect to outliers.

Possible highliers are of concern in all models. In fact, such possibilities may be regarded as among the most fundamental concerns in all efficiency modeling methods, and perhaps, may be a major motivation for considering stochastic frontier methods. Put briefly, when a unit is declared fully efficient there must always be a doubt whether this is due to excellent management or some chance event such as windfall outputs or measurement error. Highliers of the latter kind should be withheld from analysis since the constraints $v_t <= 1$ may then inappropriately limit one or more other v_t values. Thus selective deletion of one or more such highliers has the potential not only to improve conformance to distributional assumptions, but also to improve average scores of the remaining v_t values.

A further interesting aspect of some highliers is what may be called robustness to weight choices. For example in the extreme case, if an observation has outputs uniformly higher than other units, and inputs uniformly lower, then it will always be fully efficient no matter what admissible pi and eta values are selected. Clearly such units are not informative to the weight estimation problem and can clearly be excluded from the models proposed here. This argument also suggests the possibility that deletion of other similar, but less dramatic cases may not have much impact on the resulting parameter estimates. (pp. 15-16)

Efforts to evaluate possible lowliers also was considered. Possible lowliers may not have much impact on the usual DEA models, but Troutt et al. (1996) contend that possible lowliers should be carefully considered in all MER type models.

Lowliers appear to present little concern for models of the G+ and IA types. However, they may be critically important for the MER type models since the model criterion is the minimum value v_t, itself. A preliminary suggestion is to first select possible highliers using the G+ or IA models. After deletion of these, then trials on possible lowliers in the MER model might be performed seeking distribution fit, improved DE values, and stability of resulting estimates. Namely, if deletion of a suspected lowlier makes little change in the estimates, some evidence is gained that the unit was typical rather than lowlying in an inappropriately influential way (p. 16).

While possible highliers and lowliers should always be considered, a special case of zero weights for input and/or output variables should also be carefully evaluated. A final solution quality, or model adequacy is the face validity of the weight estimates with respect to positivity and its connection with variable correlations. Variables selected for analysis are generally believed by either analyst or client to be obviously important to the performance measurement task in question. If such a variable should receive an estimated weight of zero, reasonable doubt therefore exists about the quality of the model solution in general. One exception is known and is illustrated in Section 8. If, say, one or more output or input variables are highly correlated with another output or input, respectively, then weighted sums of these variables may be expressed in terms of fewer output or input variables. Hence we seek positive weight solutions except that zero weights may be considered valid when the associated variable is highly correlated with a more dominant variable of the same status (Troutt et al., 1996, pp. 16-17).

It is suggested that when all-zero output vectors are found in the model, an option is available. Troutt et al. (1998) propose that a dummy output variable y_0 be added so that all of their respective values would be equal to unity. Thus, the optimal multipliers assigned to the output variable would serve as a nonnegative intercept term for the efficiency numerators (pp. 214-215).

This type of analysis was performed for each year (i.e., 1988, 1992, and 1997) of the three periods and comparisons made for the various DMUs and the two electric utility classes. The number of efficient firms as well as inefficient firms was counted across periods and their respective average performance levels compared to see if electric utility performance is improving, remaining constant, or declining. The changes in regulations as noted elsewhere in this study occurred in 1990, 1992, and throughout Phase I 1995 through 1999. For DMUs to remain competitive, decision-makers or management should be making continuous improvements in the utilization of their respective resources over time, leading to enhanced efficiencies and performance.

Longitudinal Analysis (1988 through 1997)

In conducting the longitudinal analyses, it was proposed that the LP CCR input-oriented DEA model be incorporated into DEA window analysis (Charnes, Clark, et al., 1985) using a three-year window moving average over a 10-year horizon. Figure 9 shows a flowchart for the longitudinal analysis process. The variables involving dollar amounts or values were all expressed on a current-period basis using the producer price index (PPI). The index was needed to take into consideration relative changes from year to year due to inflation impacts. Using a three-year window moving average of the multiple-output multiple-input variables for all DMUs enabled the researcher to consider the same DMU as a separate DMU for each period in the window. This window technique increases the number of degrees of freedom from 25 DMUs to 75 DMUs included in the efficiency

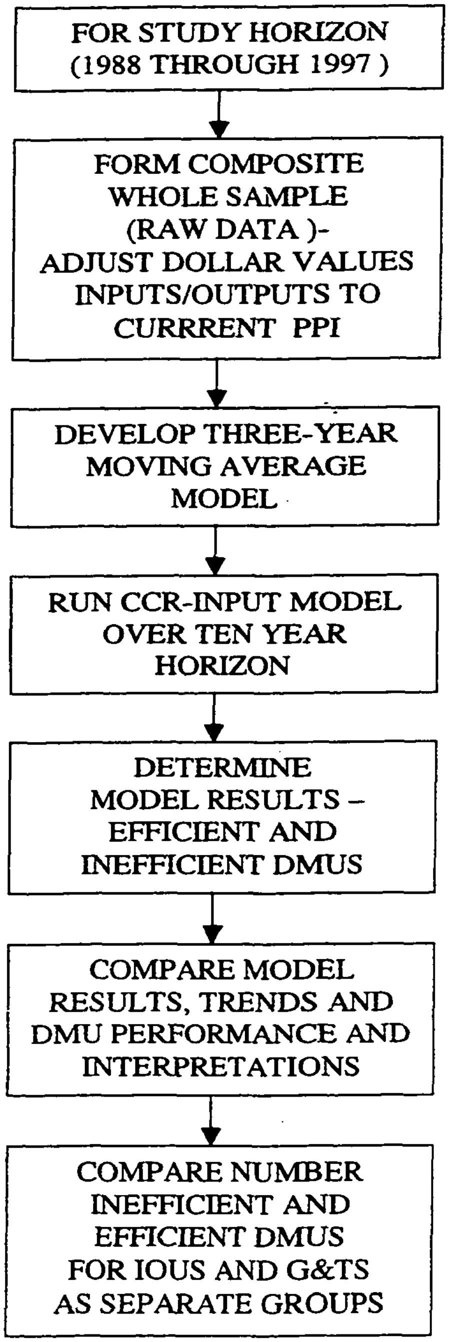


Figure 8. Longitudinal analysis.

ratings (Charnes, Clark, et al., 1985, p. 103). The efficiency measure results for each DMU can be averaged and tracked for each period throughout the horizon. Performance trends for each DMU can be analyzed and the DMU whose performance is improving, remaining the same, or declining can be identified.

> As noted by Sherman (1984), DEA is capable of detecting inefficiencies which go undetected by simple ratio analysis. The DEA metric may thus provide a very meaningful estimate of relative performance, and one that is appropriate for detecting trends. (Epstein & Henderson, 1989, p. 109)

Improvements in performance for inefficient firms could also be determined. The performance for each electric utility classification can be tracked over the horizon. Consideration and analysis of outliers (i.e., lowliers and highliers) can be examined and checks for possible misreported data or data errors can be observed and investigated.

Nunamaker (1985) advises that DEA's usefulness and value can be enhanced by its application across several DEA models and evaluation in differing variable set situations.

> Another possibility for improving DEA's usefulness would be to calculate efficiency scores under a variety of alternatives variable sets and specifications. This procedure might provide insight into the best dimensions of a DMU's operations and indicate on which dimensions management should strive to improve future performance. Certainly, future DEA research should explore additional methods for handling the variable selection and data variation problems reported herein, as well as empirically testing our conclusions in a variety of management control settings. (p. 57)

This study implemented Nunamaker's ideas through multiple cross-sectional DEA CCR input-oriented model, the FMER LP model, and the DEA CCR input-oriented windows model over a 10-year horizon. The additional outlier evaluations and attention to data collection and validation methods all served to increase the reliability and validity of the study and its findings and results.

CHAPTER 4

MODEL DEVELOPMENT

The model development process employed in this study follows the flowchart as shown in Figure 5, Methodology Overview Flowchart.

Industry Selection

The electric utility industry was selected as the industry focus for this study. This industry is in transition and is moving from a monopolistic to a competitive and deregulated environment.

Study Horizon

The horizon selected for this research effort was the period 1988 through 1997. This period was chosen primarily because of the changing nature of the competitive and regulatory environmental changes occurring throughout the United States. Enactment of the 1990 Clean Air Act Amendments, the 1992 Energy Policy Act, and the passage of Federal Energy Regulatory Commission Orders 888 and 889 provided stringent limitations and requirements on existing electric utilities throughout this period. These legislative and regulatory initiatives serve to require tighter emission limits and controls as well as to move the industry to a more-competitive environment. The competitive environment created as a result of these initiatives has led to the creation of a free market for the production and generation of electric demand and energy by non-utility entities. The free market sources for electric supply has made possible the creation of a free market for energy services for wholesale electric consumers throughout the United States. These legislative acts also created an opportunity for government to utilize the existing electric network as a common carrier for the transportation and delivery of energy services to the respective wholesale customers of the electric utility's existing electric customers. Such motivations can have adverse impacts on the traditional electric utility's business, market share, profitability, and customer base.

Sample Selection

Twenty-five electric utilities in the midwestern U.S. provided the sample for this study. These utilities were selected by consultants and top management of a midwestern electric G&T utility as its competitors in providing electric power, energy, and services to its customers and markets. These respective firms are among the lowest cost and lowest electric rate utilities in the United States. Their selection provided the researcher with a unique opportunity to study relatively low-cost electric utilities in a changing environment.

This sample was selected for a specific purpose and cannot be considered a random sample. Babbie (1994) refers to this type of nonprobability sampling as purposive or judgmental sampling. The implication in this result is that the findings of this study are not generalizable across the industry as a whole but are attributable only to those utilities within the sample. Even with this limitation, the study was deemed to be worthwhile.

Unit of Analysis

The unit of analysis was the individual electric utility company. The individual firm in this study was considered to be the electric utility company for those firms that were electric utility organizations. Some firms within the sample were combination gas- and-electric companies. For these companies, the operating and financial data and information selected for analysis were determined only for the electric business. For those organizations that represented fully vertically integrated electric utilities with generation, transmission, and distribution, the distribution aspect of the business was also separated from the operating and financial data and information. The primary data and variables utilized in this study were representative of electric utilities that are engaged in the generation and transmission of electric energy services. These adjustments were necessary in order to provide comparison between the rural electric G&T utility companies and the investor-owned electric utilities.

Data Collection and Analysis

A set of operating and financial data was collected for each of the 25 electric utilities in the sample for the study horizon. The data for 1988 through 1994 as originally aggregated were obtained directly from each utility in the sample. Confidentiality agreements were executed among the parties, stipulating that the original data would not be identified with the respective utility. The researcher continued the data collection effort by contacting each company and requesting the information for the years through 1997. Each company provided the annual operating and financial reports to the researcher for this study. Many of these organizations requested that the researcher provide a summary of the study findings for their information.

The data requested consisted of operating and financial data and information that each respective company files with Rural Utilities Services (formerly Rural Electrification Administration), that is, RUS FORM 12, and with the Federal Energy Regulatory Commission, that is, FERC FORM 1 annual reports. Utilizing these standardized data and government reporting methods across all organizations helped to increase reliability of the information, data, and measures used for their interpretations as suggested by Nunamaker (1985) and Troutt et al. (1996).

Input and Output Variable Selection

In studying this group or population of electric utilities using DEA, the cost minimization technique was considered to measure relative efficiency. The following inputs and outputs have been identified as representative for this study.

1. Input Variables

   Fixed Expenses:

   - Taxes
   - Interest
   - Depreciation
   - Administrative and General

   Variable Expenses:

   - Fuel and Purchased Power
   - Non-Fuel Production and Transmission Operations and Maintenance
   - Full-Time Electric Employees
   - Net Installed Generation Capacity
   - Transmission Line Circuit Miles Installed

2. Output Variables

   - Total Kilowatt-hours Sold
   - Maximum Kilowatt Demand
   - Total Electric Revenue

Net Generation

Each of these variables is described more fully in Chapter 3.

In order to make the companies within the sample equivalent to one another, the input and output variables were adjusted to express them on a comparable basis. Figure 4, Database Definition and Development, contains a listing and description for each of these variables and shows the derivation and sources of their respective development.

Upon collection and aggregation of these variables for the years 1988 through 1997, the data values and information periodically were cross-checked and validated with the multiple separate external sources for the respective rural electric G&Ts and IOUs companies. These sources, as utilized in this effort, are noted as follows:

Annual Statistical Report Rural Electric Borrowers (U.S. Department of Agriculture)

Electrical World Directory of Electric Utilities (McGraw-Hill, Inc.)

Electrical World Directory of Electric Power Producers (McGraw-Hill, Inc.)

The respective input and output variables are shown in Table 6 entitled "Sample Input and Output Data – 1988." The sample data as represented in this table contains the data in raw data form for all 25 electric utilities within the entire sample or population. The term raw data implies that no adjustments in the financial data have been made and the monetary values are in 1988 dollars. The data have been checked for accuracy and arranged in proper format.

Study Methodology Selection

The DEA mathematical programming method was selected to perform the relative efficiency measurements necessary to determine the answers posed in the research questions. The CCR (input-oriented) model was selected. The input-orientation for the dual and primal LP models was selected primarily due to the fact that managers or decision-makers have discretion and control over the quantity and quality of the input resources available to the respective firms or DMUs in their production processes. The capability to make changes and adjustments in input resource levels allows managers the option to make improvements which lead to an increase in overall relative efficiency of the respective DMU. Utilizing both the dual and primal LP model solutions also enabled the researcher and managers of the respective DMU to examine changes in its input resource levels. It allows them to determine what specific input resource level changes can be made to improve the relative efficiency of the DMU and to move the respective DMU to the most efficient frontier or to its most productive scale size (mpss). The CCR (input-oriented) model is more fully discussed in detail in Chapter 3.

Cross-sectional Analysis (1988, 1992, and 1997)

Phase I Cross-sectional Analysis

In performing the cross-sectional analysis in each of the three individual years, the following procedure as shown in Figure 6 flow chart for Phase I was performed. For the complete unadjusted sample of investor-owned electric utilities (IOUs) and G&T rural electric cooperatives (G&Ts) combined, the CCR-I (input-oriented) model was selected. This model was utilized in special WDEA software developed by the Warwick School of Business at the University of Warwick in the United Kingdom. The CCR-I (input-oriented) model, using constant returns-to-scale assumption, was prepared with the sample data for all 25 electric utilities for the year 1988, as shown in Table 6, in accordance with the guidelines offered by Thanassoulis and Emrouznejad (1996).

Table 6

Sample Input And Output Data - 1988

ID	YEAR	TAXES	INTEREST	DEPR	A&G	FUELPPWR	NOFUEL	EMPLOYEES	INSTGCAP	TRANMILE	MWHSOLD	MAXKWDMD	REVENUE	NETGENRG
DMU1	1988	2,739,091	30,219,935	12,416,046	6,568,335	78,128,525	13,015,049	435	600,250	1,729	3,599,636	789,200	150,458,410	3,738,182,390
DMU2	1988	7,390,821	69,334,901	29,005,083	11,798,992	222,848,967	53,738,386	1005	2,313,000	546	12,700,552	1,879,000	397,060,618	10,722,179,000
DMU3	1988	10,509,260	150,716,320	52,878,994	15,234,320	112,114,975	80,481,568	1093	2,313,000	2,068	13,116,099	904,000	430,525,554	13,575,465,000
DMU4	1988	3,906,621	103,607,079	49,310,860	13,052,545	162,294,863	51,155,494	855	1,774,000	1,159	11,003,122	990,000	399,277,507	9,270,206,000
DMU5	1988	2,353,048	242,867,117	78,057,284	14,477,320	153,044,291	67,000,551	602	1,884,000	57	9,869,725	1,235,573	448,164,614	9,932,041,000
DMU6	1988	42,895,113	40,416,961	44,845,638	28,589,418	112,185,746	68,935,671	2322	3,148,956	4,563	7,444,399	1,724,000	499,485,201	8,042,690,998
DMU7	1988	97,444,177	87,490,290	56,452,603	50,354,065	301,278,798	84,798,828	3450	4,205,200	1,571	18,426,405	3,996,000	981,941,599	19,491,325,000
DMU8	1988	72,460,247	72,893,636	30,591,211	32,308,489	304,914,190	63,108,080	2388	2,863,962	2,208	14,031,663	3,507,000	778,119,273	14,924,000,000
DMU9	1988	6,408,405	24,829,074	17,190,391	13,388,364	72,097,026	21,373,538	671	976,310	3,278	4,430,994	606,000	156,502,180	3,962,329,000
DMU10	1988	80,833,059	157,146,439	70,300,007	86,832,248	226,136,055	176,800,955	4181	2,769,000	697	14,401,242	2,372,000	1,063,258,563	12,436,238,354
DMU11	1988	3,711,479	69,619,631	21,882,436	12,867,241	99,790,803	33,555,517	583	1,308,000	2,348	7,970,712	1,104,000	254,630,300	7,179,938,000
DMU12	1988	4,308,898	68,625,800	13,115,151	7,644,700	92,861,279	30,777,419	466	1,213,200	1,319	5,342,532	594,000	237,527,504	5,183,955,300
DMU13	1988	51,357,177	106,240,604	105,853,273	52,582,031	280,448,885	147,802,363	3361	4,552,987	5,163	19,375,031	4,571,000	983,065,564	21,005,000,000
DMU14	1988	25,207,730	51,308,567	41,630,550	30,698,504	149,820,260	58,971,795	2107	2,899,776	1,074	11,941,121	2,475,000	586,087,461	11,886,395,600
DMU15	1988	5,306,649	20,892,898	11,725,368	11,822,729	129,043,099	22,527,476	856	1,096,800	1,172	6,182,828	1,336,000	257,576,014	6,599,000,000
DMU16	1988	10,487,547	36,448,330	35,847,580	36,011,837	216,333,751	48,752,127	1985	3,496,627	4,409	14,061,450	2,767,000	547,778,548	14,291,507,000
DMU17	1988	10,324,132	45,088,728	34,530,101	28,558,480	130,464,542	64,794,435	3413	2,717,170	791	9,067,038	2,141,000	483,726,761	9,534,449,000
DMU18	1988	32,182,878	31,585,448	30,953,297	23,464,763	276,058,237	65,429,116	1515	2,348,465	2,004	14,626,429	1,542,000	582,022,019	15,325,082,200
DMU19	1988	28,500,449	329,290,996	105,771,879	18,542,055	369,657,480	106,081,388	512	2,684,700	1,919	15,212,112	3,194,000	936,802,064	9,625,696,000
DMU20	1988	17,594,207	29,701,013	21,211,757	18,101,294	88,447,459	24,345,621	1697	949,112	657	5,021,676	666,000	278,163,842	5,225,858,451
DMU21	1988	39,202,650	89,853,978	66,073,737	128,499,756	357,211,012	93,546,841	4040	5,692,000	5,390	19,972,202	4,401,000	1,043,316,813	21,481,000,000
DMU22	1988	9,410,593	55,468,745	20,431,263	13,218,661	211,941,493	56,665,055	514	1,295,125	259	7,368,816	1,560,274	388,625,367	7,549,335,000
DMU23	1988	1,225,065	8,759,202	4,497,138	1,554,005	13,899,182	3,703,043	100	272,000	811	892,171	188,119	35,495,299	1,144,153,000
DMU24	1988	9,332,810	18,482,518	25,439,399	10,572,379	89,950,016	29,102,255	793	1,271,090	860	5,463,459	665,800	250,585,606	4,411,784,260
DMU25	1988	188,466,900	182,767,572	132,207,658	105,896,408	435,969,946	189,886,356	6795	8,061,759	3,190	30,022,877	6,978,100	1,938,295,732	32,405,938,400

This model, using the nine input variables and the four output variables for each electric utility or Decision-Making Unit (DMU) for the full 25-firm sample, determined the relative efficiencies for each DMU in the full sample or population. The relative efficiencies so determined revealed the firm or firms which are most relatively efficient and those which are relatively inefficient. This model maintains the same output variable levels for each respective firm and provides suggested target or changes in the input variable levels for each relatively inefficient DMU or firm to become relatively efficient. The target adjustments in the respective input variables were reductions in the respective input variable levels that the firm or its management may choose to alter in order to improve its relative performance.

The results for the years 1988, 1992, and 1997 are shown in Table 7. In 1988, 24 of the 25 firms were found to be relatively efficient at 100%. Only one firm or DMU9 was found to be relatively inefficient at 89.5%. This procedure was performed for the 25-firm sample for each year 1992 and 1997.

In 1992, 24 of the 25 firms were found to be relatively efficient at 100%. Only one firm or DMU9 was found to be relatively inefficient at 78.0%.

Twenty-two firms were found to be relatively efficient at 100% for 1997. Three firms (DMU6, DMU9, and DMU24) were found to be relatively inefficient at 96.2%, 92.2%, and 96.8%, respectively.

Phase II Cross-sectional Analysis

The procedure for Phase II as shown in Figure 6 flow chart was performed. The complete unadjusted sample of the 25 electric utility firms was divided into two separate subgroups, that is, investor-owned electric utilities (IOUs) and G&T rural electric

Table 7

Cross-Sectional Analysis Results

CCR-I (INPUT-ORIENTED) MODEL
RELATIVE EFFICIENCIES (PERCENT)

	1988			1992			1997		
	Phase I	Phase II	Phase II	Phase I	Phase II	Phase II	Phase I	Phase II	Phase II
FIRM TYPE	ALL	G&Ts	IOUs	ALL	G&Ts	IOUs	ALL	G&Ts	IOUs
NUMBER OF FIRMS	25	11	14	25	11	14	25	11	14
ID									
DMU1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU6	100.0	100.0	100.0	100.0	100.0	100.0	96.2	100.0	96.7
DMU7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU9	89.5	100.0	100.0	78.0	100.0	100.0	92.2	100.0	100.0
DMU10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU11	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU12	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU13	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU14	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU15	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU16	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU17	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU18	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU19	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU20	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU21	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU22	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU23	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMU24	100.0	100.0	100.0	100.0	100.0	100.0	96.8	100.0	98.3
DMU25	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

cooperatives (G&Ts). The CCR-I (input-oriented) model was utilized in special WDEA software similar to that undertaken in Phase I analysis. The CCR-I (input-oriented) model, using constant returns-to-scale assumption, was prepared individually for each subgroup for the year 1988.

This CCR-I input-oriented model using the nine input variables and the four output variables for each electric utility or Decision-Making Unit (DMU) for each subgroup determined the relative efficiencies for each DMU in each respective subgroup. The relative efficiencies so determined revealed the firm or firms that are most relatively efficient and those that are relatively inefficient in each subgroup. This model maintained the same output variable levels for each respective firm and provided suggested target or changes in the input variable levels for each relatively inefficient DMU or firm to become relatively most efficient. The target adjustments in the respective input variables were reductions in the respective input variable levels that the firm or its management may choose to alter in order to improve its relative performance.

The results for Phase II for each subgroup for the years 1988, 1992, and 1997 are shown in Tables 7 and 8. For the year 1988, all 11 DMUs in the G&T subgroup and all 14 DMUs in the IOU subgroup were found to be relatively efficient at 100%. No DMU or firm was found to be relatively inefficient when the WDEA model was applied to each subgroup separately for the year 1988. This analysis was performed for each subgroup separately for 1992 and 1997.

All 11 DMUs in the G&T subgroup and all 14 DMUs in the IOU subgroup were found to be relatively efficient at 100% for 1992. No DMU or firm was found to be relatively inefficient when the WDEA model was applied to each subgroup separately for

Table 8

Cross-Sectional Analysis Results

CCR-1 (INPUT-ORIENTED) MODEL
RELATIVE EFFICIENCIES (PERCENT)

COMPARISON BY FIRM TYPE		1988 Phase I	1988 Phase II	1992 Phase I	1992 Phase II	1997 Phase I	1997 Phase II
RURAL ELECTRIC G&T COOPERATIVES							
NUMBER OF FIRMS		11	11	11	11	11	11
	DMU1	100.0	100.0	100.0	100.0	100.0	100.0
	DMU2	100.0	100.0	100.0	100.0	100.0	100.0
	DMU3	100.0	100.0	100.0	100.0	100.0	100.0
	DMU4	100.0	100.0	100.0	100.0	100.0	100.0
	DMU5	100.0	100.0	100.0	100.0	100.0	100.0
	DMU9	89.5	100.0	78.0	100.0	92.2	100.0
	DMU11	100.0	100.0	100.0	100.0	100.0	100.0
	DMU12	100.0	100.0	100.0	100.0	100.0	100.0
	DMU19	100.0	100.0	100.0	100.0	100.0	100.0
	DMU22	100.0	100.0	100.0	100.0	100.0	100.0
	DMU23	100.0	100.0	100.0	100.0	100.0	100.0
INVESTOR OWNED ELECTRIC UTILITIES							
NUMBER OF FIRMS		14	14	14	14	14	14
	DMU6	100.0	100.0	100.0	100.0	96.2	96.7
	DMU7	100.0	100.0	100.0	100.0	100.0	100.0
	DMU8	100.0	100.0	100.0	100.0	100.0	100.0
	DMU10	100.0	100.0	100.0	100.0	100.0	100.0
	DMU13	100.0	100.0	100.0	100.0	100.0	100.0
	DMU14	100.0	100.0	100.0	100.0	100.0	100.0
	DMU15	100.0	100.0	100.0	100.0	100.0	100.0
	DMU16	100.0	100.0	100.0	100.0	100.0	100.0
	DMU17	100.0	100.0	100.0	100.0	100.0	100.0
	DMU18	100.0	100.0	100.0	100.0	100.0	100.0
	DMU20	100.0	100.0	100.0	100.0	100.0	100.0
	DMU21	100.0	100.0	100.0	100.0	100.0	100.0
	DMU24	100.0	100.0	100.0	100.0	96.8	98.3
	DMU25	100.0	100.0	100.0	100.0	100.0	100.0

the year 1992.

Furthermore, all 11 DMUs in the G&T subgroup were found to be relatively efficient at 100% for 1997. Twelve of the 14 DMUs in the IOU subgroup were found to be relatively efficient. Two firms (DMU6 and DMU24) were found to be relatively inefficient at 96.7% and 98.3%, respectively, for the year 1997.

The CCR-I model input variable target reductions suggested by the WDEA software are shown in Table 9 for each DMU found to be relatively inefficient in Phase I and Phase II. A summary of the relatively inefficient electric utility firms or DMUs determined by the WDEA software is as follows:

Phase I: Full Sample		Phase II: G&T Subgroup	Phase III: IOU Subgroup
1988	DMU9	None	None
1992	DMU9	None	None
1997	DMU6, DMU9, DMU24	None	DMU6, DMU24

The CCR-I model input variable target reductions suggested by the WDEA software are shown in Table 9 for each DMU found to be relatively inefficient in Phase I and Phase II.

The relatively inefficient firms or DMUs found in either Phase I or Phase II were adjusted to conform to the CCR-I WDEA software target recommendations within the respective sample groups and subgroups with which they were associated.

Phase III Cross-sectional Analysis

For those DMUs that were found to be relatively inefficient in Phase II, DEA modifications were made in the input variables in order to move these inefficient DMUs to

Table 9

Phase I And II CCR-I Input Reductions
Cross-Sectional Analysis Results

CCR-I (INPUT-ORIENTED) MODEL
RELATIVE EFFICIENCIES (PERCENT)

	1988			1992			1997					
	Phase I ALL 25	Phase II G&Ts 11	Phase II IOUs 14	Phase I ALL 25	Phase II G&Ts 11	Phase II IOUs 14	Phase I ALL 25			Phase II G&Ts 11	Phase II IOUs 14	
RELATIVELY INEFFICIENT FIRM OR DMU	DMU 9 89.52% (G&T)			DMU 9 77.97% (G&T)			DMU 9 (G&T) 92.16%	DMU 6 (IOU) 96.22%	DMU 24 (IOU) 96.82%		DMU 6 (IOU) 96.70%	DMU 24 (IOU) 98.29%
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)												
1 TAX EXPENSE	10.5			28.9			38.4	41.5	17.9		44.3	13.1
2 INTEREST EXPENSE	10.5			22.0			25.8	3.8	3.2		3.3	8.7
3 DEPRECIATION EXPENSE	29.7			35.7			37.9	3.8	13.0		5.1	12.5
4 ADMIN & GENERAL EXPENSE	33.5			32.1			41.2	3.8	3.2		3.4	7.3
5 FUEL & PURCH POWER EXPENSE	10.5			22.0			7.8	3.8	3.2		3.3	1.7
6 NON FUEL EXPENSE	11.0			22.0			7.8	3.8	3.2		3.3	3.6
7 EMPLOYEES	23.0			22.0			17.7	26.6	3.2		26.6	1.7
8 INSTALLED GENERATION CAPACITY	10.5			22.4			7.8	52.2	24.6		52.1	31.9
9 TRANSMISSION LINE MILEAGE	70.9			67.6			82.8	75.4	55.9		73.6	61.1

the efficient frontier surface. The CCR input-oriented WDEA analysis with a constant returns-to-scale assumption was applied to the combined adjusted data pooled from both groups. In this analysis, adjusted refers to improving the inefficient DMUs to the efficient frontier by incorporating DEA suggested modifications to the input variables. Nine input variables and four output variables were maintained in this analysis consistent with the previous Phase I and Phase II cross-sectional analyses. The procedure for Phase III was performed as shown in the Figure 7 flow chart.

The Phase II findings for the year 1988 utilizing the CCR-I WDEA analysis revealed that no DMU was found to be inefficient in the G&T subgroup DEA analysis. Furthermore, no DMU was found to be inefficient in the IOU subgroup DEA analysis. As a result, the G&T and IOU subgroups with all relatively efficient firms were combined into a single sample of 25 electric utilities. The CCR-I WDEA model was performed on this sample in accordance with the Phase III flow chart shown in Figure 7 for the year 1988. The results of this analysis are displayed in Table 10. One notices that DMU9 was found to be relatively inefficient at 89.5%. This procedure was performed for each subgroup separately for each year 1992 and 1997.

The Phase II findings for the year 1992 utilizing the CCR-I WDEA analysis revealed that no DMU was found to be inefficient in the G&T subgroup DEA analysis, and no DMU was found to be inefficient in the IOU subgroup DEA analysis. Therefore, the G&T and IOU subgroups with all relatively efficient firms were combined into a single sample of 25 electric utilities. The CCR-I WDEA model was performed on this sample in accordance with the Phase III flow chart (Figure 7) for the year 1992, and the results of this analysis are shown in Table 11. DMU9 was found to be relatively inefficient at 78%.

Table 10

Phase I, Phase II, and Phase III Cross-Sectional Analysis Results

CCR-I (INPUT-ORIENTED) MODEL
RELATIVE EFFICIENCIES (PERCENT)

COMPARISON BY FIRM TYPE		1988				1992				1997			
		Phase I	Phase II	Phase II	Phase III Combined Sample	Phase I	Phase II	Phase II	Phase III Combined Sample	Phase I	Phase II	Phase II	Phase III Combined Sample
RURAL ELECTRIC G&T COOPERATIVES													
NUMBER OF FIRMS		11	11	11	11	11	11	11	11	11	11	11	11
	DMU1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU9	89.5	100.0	100.0	89.5	78.0	100.0	100.0	78.0	92.2	100.0	100.0	92.2
	DMU11	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU12	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU19	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU22	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU23	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
INVESTOR OWNED ELECTRIC UTILITIES													
NUMBER OF FIRMS		14	14	14	14	14	14	14	14	14	14	14	14
	DMU6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.2	100.0	96.7	100.0
	DMU7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU13	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU14	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU15	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU16	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU17	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU18	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU20	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU21	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	DMU24	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.8	100.0	98.3	99.8
	DMU25	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The Phase II findings for the year 1997 utilizing the CCR-I WDEA analysis revealed that no DMU was found to be inefficient in the G&T subgroup DEA analysis. Two firms (DMU6 at 96.7% and DMU24 at 98.3%) were found to be inefficient in the IOU subgroup DEA analysis. The DMU6 and DMU24 input variables were adjusted to reflect the WDEA suggested improvements to move these DMUs to the most efficient frontier surface. The G&T and IOU subgroups with all relatively efficient firms were combined into a single sample of 25 electric utilities. The CCR-I WDEA model was performed on this sample in accordance with the Phase III flow chart (Figure 7) for the year 1997. The results of this analysis are shown in Table 10. Notice that DMU9 and DMU24 were found to be relatively inefficient at 92.2% and 99.8%, respectively. The CCR-I model input variable target reductions suggested by the WDEA software are shown in Table 11 for each DMU found to be relatively inefficient in Phase III.

A summary of the relatively inefficient electric utility firms or DMUs determined by the WDEA software are listed for Phase III as follows:

Phase III: Combined Adjusted Pooled Sample

1988 DMU9

1992 DMU9

1997 DMU9, DMU24

The CCR-I model input variable target reductions suggested by the WDEA software for each DMU found to be relatively inefficient in Phase III are shown in Table 11.

Phase IV Cross-sectional Analysis

In order to provide a comparison of the CCR-I input-oriented WDEA

TABLE 11

Phase I, Phase II, and Phase III CCR-I Input Reductions
Cross-Sectional Analysis Results

CCR-I (INPUT-ORIENTED) MODEL
RELATIVE EFFICIENCIES (PERCENT)

	1988				1992				1997					1997	
	Phase I ALL 25	Phase II G&Ts 11	Phase II IOUs 14	Phase III Combined Sample	Phase I ALL 25	Phase II G&Ts 11	Phase II IOUs 14	Phase III Combined Sample	Phase I ALL 25		Phase II G&Ts 11	Phase II IOUs 14		Phase III Combined Sample	
RELATIVELY INEFFICIENT FIRM OR DMU	DMU 9 89.52% (G&T)			DMU 9 89.52% (G&T)	DMU 9 77.97% (G&T)			DMU 9 77.97% (G&T)	DMU 6 (IOU) 96.22%	DMU 24 (IOU) 96.82%		DMU 6 (IOU) 96.70%	DMU 24 (IOU) 98.29%	DMU 9 (G&T) 92.16%	DMU 24 (IOU) 99.61%
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)															
1 TAX EXPENSE	10.5			10.5	28.9			28.9	41.5	17.9		44.3	13.1	38.4	9.7
2 INTEREST EXPENSE	10.5			10.5	22.0			22.0	3.8	3.2		3.3	8.7	25.6	0.2
3 DEPRECIATION EXPENSE	29.7			29.7	35.7			35.7	3.8	13.0		5.1	12.5	37.9	0.2
4 ADMIN & GENERAL EXPENSE	33.5			33.5	32.1			32.1	3.8	3.2		3.4	7.3	41.2	2.4
5 FUEL & PURCH POWER EXPENSE	10.5			10.5	22.0			22.0	3.8	3.2		3.3	1.7	7.8	0.2
6 NON FUEL EXPENSE	11.0			11.0	22.0			22.0	3.8	3.2		3.3	3.6	7.8	0.2
7 EMPLOYEES	23.0			23.0	22.0			22.0	26.6	3.2		26.6	1.7	17.7	0.2
8 INSTALLED GENERATION CAPACITY	10.5			10.5	22.4			22.4	52.2	24.6		52.1	31.9	7.8	0.3
9 TRANSMISSION LINE MILEAGE	70.9			29.1	67.6			67.6	75.4	55.9		73.6	61.1	82.8	1.1

methodology, the maximin efficiency ratio model (MER) was performed. Troutt and Zhang (1993) proposed this model initially as an alternative to be applied on efficient DMUs found in a DEA analysis in order to find the most efficient DMUs of the efficient set. This alternative enhances the DEA approach by providing information that efficient firms may utilize to overcome the "Miller's Time Curse" and find ways for continuous improvement. Later, Troutt and Zhang also realized that while the MER model was good at distinguishing the efficient set, it also provided a simple solution and check on the DEA results in a single run of the model. The maximin efficiency ratio model is discussed more fully in Chapter 3. The researcher in this study contacted and worked with Troutt and Zhang in obtaining the MER model. The MER model as developed by these original authors utilizes the SAS/IML software offered by SAS Institute, Inc. to perform its basic functions and solutions.

It was the researcher's intent to utilize the MER model as a check of the WDEA model validity. A comparison of the MER and WDEA model results provided one with the opportunity to assess the accuracy, validity, and respective results of both independent model performance measures.

In performing the cross-sectional analysis in each of the three individual years, the procedure shown in Figure 8 flow chart for Phase IV was followed. For the complete unadjusted sample of investor-owned electric utilities (IOUs) and G&T rural electric cooperatives (G&Ts) combined, the FMER model was selected. This model, developed by Troutt and Zhang (1993), operates within SAS/IML software offered by the SAS Institute, Inc.

It is important to note that this model utilized nine input variables and four output variables for all 25 electric utility companies for this part of the cross-sectional analyses. The only adjustments made to this data were that the researcher scaled each input and output variable by dividing every data value by multiples of 10 to produce a data set with data values less than one hundred. A primary advantage of using DEA methodologies is that scaling of the data is permissible and does not alter the corresponding performance results.

The results for the FMER maximin efficiency ratio model for all 25 firms for Phase IV for the year 1988 are shown in Table 12. The relative efficiencies ranged from a low value of 78.5% to a high value of 100.0%. Only three of the 25 firms were relatively efficient with the remaining 22 firms being relatively inefficient. When Phase IV results were compared with Phase I, it was interesting to observe that the single relatively inefficient firm (DMU9)in Phase I was the lowest relative inefficient firm in the Phase IV model results.

The results for the FMER maximin efficiency ratio model for all 25 firms for Phase IV for the year 1992 are also shown in Table 12. The relative efficiencies ranged from a low value of 72.6% to a high value of 100.0%. Only four firms were relatively efficient, and the remaining 21 firms were relatively inefficient. Comparing Phase IV results with Phase I showed that the Phase I single relatively inefficient firm (DMU9) was also the lowest relatively efficient firm in the Phase IV FMER model results.

The results for the FMER maximin efficiency ratio model for all 25 firms for the year 1997 are shown in Table 12. The relative efficiency values ranged from 78.4% to 100.0%. The Phase I results showed three firms as being relatively inefficient. When the most inefficient firm (DMU9) in Phase I was compared with Phase IV, it was observed

Table 12

Cross-Sectional Analysis Results

COMPARISON CCR-I (INPUT-ORIENTED) MODEL AND FMER MODEL RESULTS
RELATIVE EFFICIENCIES (PERCENT)

	1988 CCR-I MODEL Phase I	1988 FMER MODEL Phase IV	1992 CCR-I MODEL Phase I	1992 FMER MODEL Phase IV	1997 CCR-I MODEL Phase I	1997 FMER MODEL Phase IV
FIRM TYPE	ALL	ALL	ALL	ALL	ALL	ALL
NUMBER OF FIRMS	25	25	25	25	25	25
ID						
DMU1	100.0	84.5	100.0	95.3	100.0	83.0
DMU2	100.0	84.4	100.0	85.1	100.0	96.3
DMU3	100.0	100.0	100.0	100.0	100.0	90.7
DMU4	100.0	93.3	100.0	86.5	100.0	86.4
DMU5	100.0	78.5	100.0	72.6	100.0	99.9
DMU6	100.0	78.5	100.0	72.6	96.2	78.4
DMU7	100.0	97.3	100.0	99.6	100.0	100.0
DMU8	100.0	93.1	100.0	89.4	100.0	93.5
DMU9	89.5	78.5	78.0	72.6	92.2	78.4
DMU10	100.0	95.2	100.0	81.4	100.0	82.9
DMU11	100.0	95.2	100.0	91.5	100.0	86.5
DMU12	100.0	82.5	100.0	90.2	100.0	100.0
DMU13	100.0	95.6	100.0	72.6	100.0	89.6
DMU14	100.0	100.0	100.0	100.0	100.0	100.0
DMU15	100.0	90.3	100.0	100.0	100.0	97.6
DMU16	100.0	88.4	100.0	94.7	100.0	98.2
DMU17	100.0	78.5	100.0	96.4	100.0	100.0
DMU18	100.0	100.0	100.0	85.6	100.0	100.0
DMU19	100.0	81.6	100.0	100.0	100.0	96.6
DMU20	100.0	88.7	100.0	92.9	100.0	78.4
DMU21	100.0	81.4	100.0	86.5	100.0	100.0
DMU22	100.0	83.0	100.0	78.1	100.0	91.0
DMU23	100.0	78.5	100.0	72.6	100.0	78.4
DMU24	100.0	91.2	100.0	89.3	96.8	92.7
DMU25	100.0	99.6	100.0	96.3	100.0	91.7

that it was ranked the lowest value in the FMER model results as well as the second lowest relative inefficient firm (DMU6) in Phase I in the FMER model results.

Comparison of the FMER model with the CCR-I WDEA model showed that the CCR-I model within the DEA modeling approach was validated with respect to the replication of firm results across both models. It was evident that the DEA models, as Troutt et al. (1996) recognize, expressed each firm in its best light. The FMER model was more discriminating and robust in its accuracy and measurement assessments. The same performance results are shown in both Table 12 and Table 13. They are arranged by individual subgroups for the G&Ts and IOUs in Table 13.

Relative Efficiency Histograms and Cumulative Frequency Distribution Analysis

For the CCR-I input-oriented WDEA cross-sectional analyses performed, four frequency distribution type tables were prepared. These four tables were the frequency distribution, cumulative frequency distribution, relative frequency distribution, and the cumulative relative frequency distribution. These tables show the distribution of the relative efficiencies observed in each of the previous cross-sectional analyses. Relative efficiency histograms also were prepared for each of the previous cross-sectional analyses. Figure 10 shows these four frequency type distributions and histograms for the full 25-DMU sample for Phase I of the cross-sectional analyses for each year 1988, 1992, and 1997. These data analyses showed that the relative inefficient firms for each of these three years were one DMU, one DMU, and three DMUs. When these relatively inefficient firms or DMUs were plotted as shown, the resulting data distributions were skewed to the upper end of the relative efficiency level. The skewness toward the upper relative

Table 13

Cross-Sectional Analysis Results

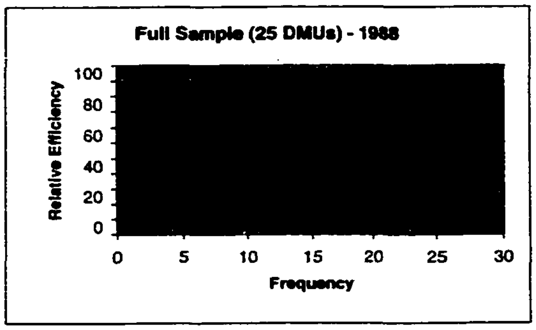
COMPARISON CCR-I (INPUT-ORIENTED) MODEL AND FMER MODEL RESULTS
RELATIVE EFFICIENCIES (PERCENT)

COMPARISON BY FIRM TYPE		1988 CCR-I MODEL Phase I	1988 FMER MODEL Phase IV	1992 CCR-I MODEL Phase I	1992 FMER MODEL Phase IV	1997 CCR-I MODEL Phase I	1997 FMER MODEL Phase IV
RURAL ELECTRIC G&T COOPERATIVES							
NUMBER OF FIRMS		11	11	11	11	11	11
	DMU1	100.0	84.5	100.0	95.3	100.0	83.0
	DMU2	100.0	84.4	100.0	85.1	100.0	96.3
	DMU3	100.0	100.0	100.0	100.0	100.0	90.7
	DMU4	100.0	93.3	100.0	86.5	100.0	86.4
	DMU5	100.0	78.5	100.0	72.6	100.0	99.9
	DMU9	89.5	78.5	78.0	72.6	92.2	78.4
	DMU11	100.0	95.2	100.0	91.5	100.0	86.5
	DMU12	100.0	82.5	100.0	90.2	100.0	100.0
	DMU19	100.0	81.8	100.0	100.0	100.0	96.6
	DMU22	100.0	83.0	100.0	78.1	100.0	91.0
	DMU23	100.0	78.5	100.0	72.6	100.0	78.4
INVESTOR OWNED ELECTRIC UTILITIES							
NUMBER OF FIRMS		14	14	14	14	14	14
	DMU6	100.0	78.5	100.0	72.6	96.2	78.4
	DMU7	100.0	97.3	100.0	99.6	100.0	100.0
	DMU8	100.0	93.1	100.0	89.4	100.0	93.5
	DMU10	100.0	95.2	100.0	81.4	100.0	82.9
	DMU13	100.0	95.6	100.0	72.6	100.0	89.8
	DMU14	100.0	100.0	100.0	100.0	100.0	100.0
	DMU15	100.0	90.3	100.0	100.0	100.0	97.8
	DMU16	100.0	88.4	100.0	94.7	100.0	98.2
	DMU17	100.0	78.5	100.0	96.4	100.0	100.0
	DMU18	100.0	100.0	100.0	85.6	100.0	100.0
	DMU20	100.0	88.7	100.0	92.9	100.0	78.4
	DMU21	100.0	81.4	100.0	86.5	100.0	100.0
	DMU24	100.0	91.2	100.0	89.3	96.8	92.7
	DMU25	100.0	99.6	100.0	96.3	100.0	91.7

Relative Efficiency Distributions
Phase I Cross-Sectional Analyses - Full Sample

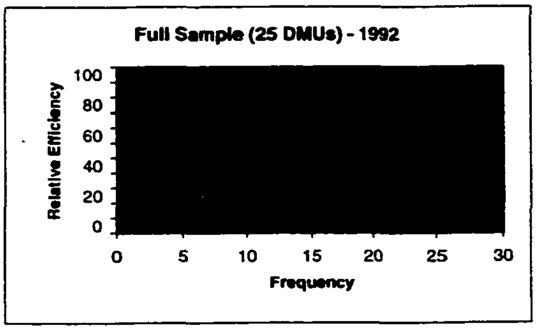
1988 Phase I - Full Sample (25 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	1	1	4	4
100	24	25	96	100



1992 Phase I - Full Sample (25 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	1	1	4	4
80	0	0	0	4
90	0	0	0	4
100	24	25	96	100



1997 Phase I - Full Sample (25 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	3	3	12	12
100	22	25	88	100

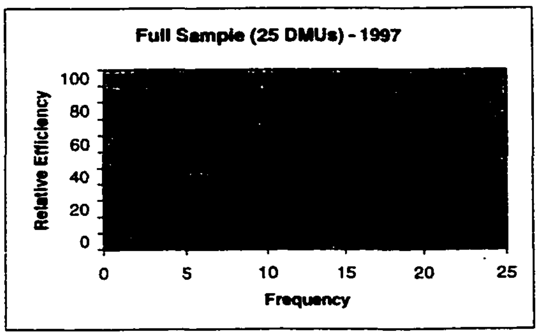


Figure 9. Relative efficiency distributions - Phase I cross-sectional analyses (full sample)

efficiency level and the lack of inefficient units below the 60% efficiency level support Troutt et al.'s assertions that management is actively making changes and managing the respective firms to achieve their strategies, goals, and objectives. These distributions as observed were not normal distributions.

Figure 11 and Figure 12 show the respective G&T Subsets and the IOU Subsets for Phase II of the cross-sectional analyses for 1988, 1992, and 1997. No relatively inefficient firm or DMU in either subset was observed except for the IOU Subset for the year 1997. In this year two DMUs were found to be relatively inefficient. These data distributions were also found to be skewed toward the upper or maximum relative efficiency level.

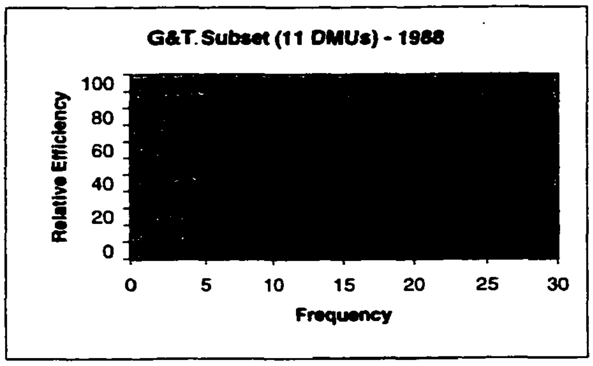
The combined sample with adjustments made to move relatively inefficient firms found in separate G&T and IOU Subset runs to full efficiency was also analyzed in Phase III of the cross-sectional analyses. The results are shown in Figure 13. One relatively inefficient DMU was found in this Phase III for 1988 and 1992. Two relatively inefficient DMUs were observed in this same phase for 1997. Results similar to that observed in the other analyses resulted. Few relatively inefficient firms were observed, and the magnitudes of the relative efficiencies were high, resulting in skewing the distributions toward the upper maximum efficiency level.

Similar investigations were conducted on the relative efficiencies observed in the Phase IV validation portion of the cross-sectional analyses. The FMER Model results for the full 25-DMU sample are shown in Figure 14. The FMER Model was more discriminating in its treatment of relative efficiency analysis as noted earlier by Troutt and Zhang (1996). Notice that the number of relatively inefficient firms as well as their

Relative Efficiency Distributions
Phase II Cross-Sectional Analyses - G&T Subset

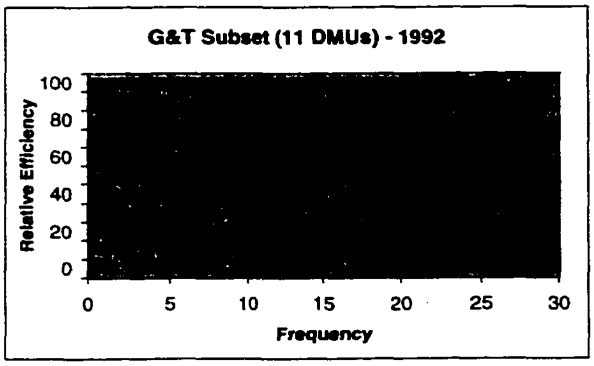
1988 Phase II - G&T Subset (11 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	0	0	0	0
100	25	25	100	100



1992 Phase II - G&T Subset (11 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	0	0	0	0
100	25	25	100	100



1997 Phase II - G&T Subset (11 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	0	0	0	0
100	25	25	100	100

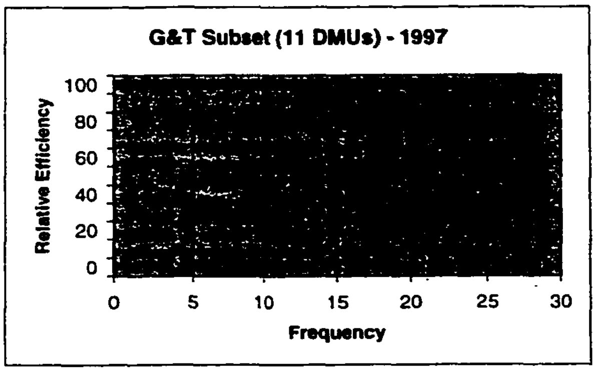
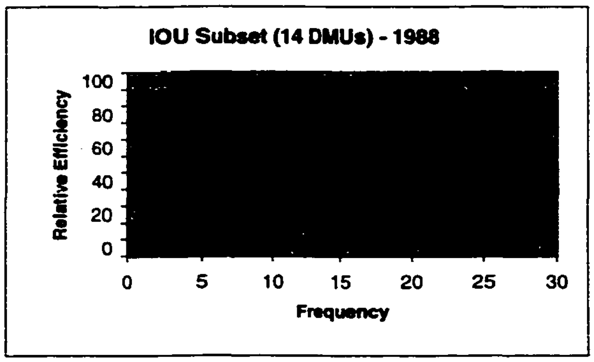


Figure 10. Relative efficiency distributions - Phase II cross-sectional analyses (G&Ts)

Relative Efficiency Distributions
Phase II Cross-Sectional Analyses - IOU Subset

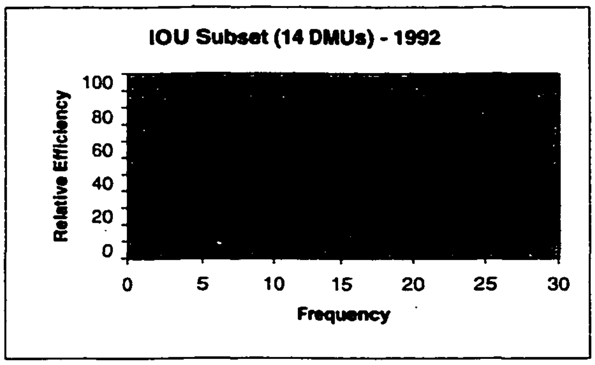
1988 Phase II - IOU Subset (14 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	0	0	0	0
100	25	25	100	100



1992 Phase II - IOU Subset (14 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	0	0	0	0
100	25	25	100	100



1997 Phase II - IOU Subset (14 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	2	2	8	8
100	23	25	92	100

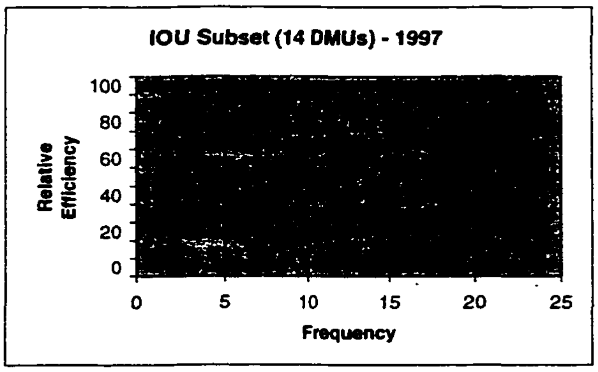
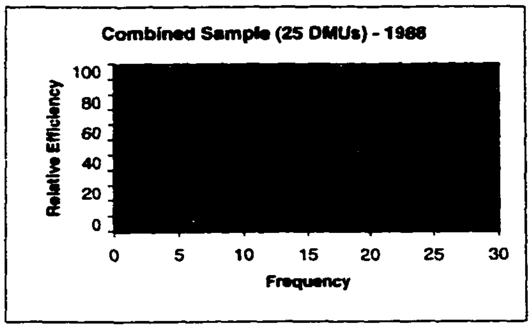


Figure 11. Relative efficiency distributions - Phase III cross-sectional analyses (IOUs).

Relative Efficiency Distributions
Phase III Cross-Sectional Analyses - Combined Sample

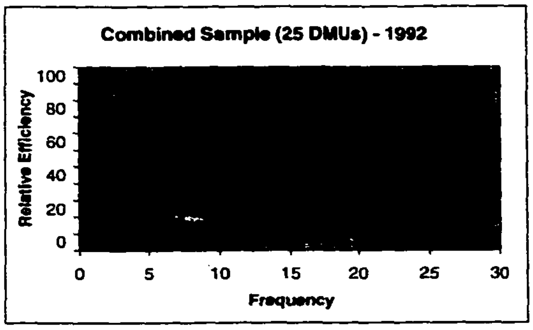
1988 Phase III - Combined Sample (25 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	1	1	4	4
90	0	0	0	4
100	24	25	96	100



1992 Phase III - Combined Sample (25 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	1	1	4	4
80	0	1	0	4
90	0	1	0	4
100	24	25	96	100



1997 Phase III - Combined Sample (25 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0.	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	2	2	8	8
100	23	25	92	100

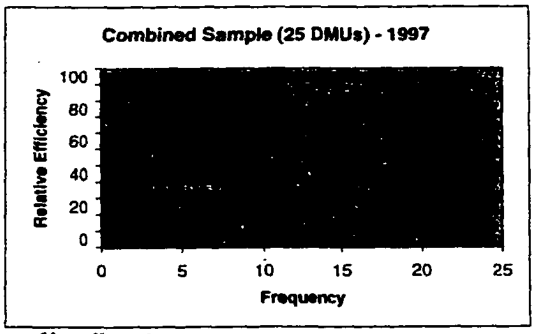


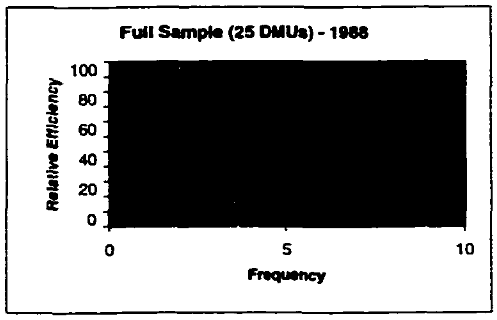
Figure 12. Relative efficiency distributions - Phase III cross-sectional analyses (combined sample).

Relative Efficiency Distributions
Phase IV Cross-Sectional Analyses - Full Sample

FMER Model Results

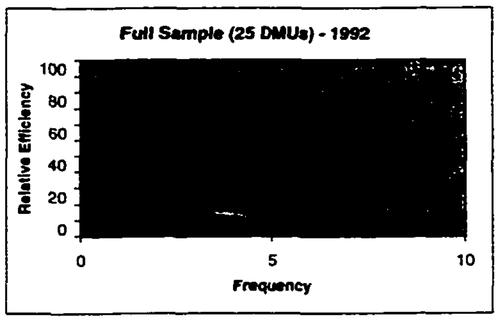
1988 Phase IV - Full Sample (25 DMUs)
FMER Model:

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	5	5	20	20
80	8	13	32	52
90	9	22	36	88
100	3	25	12	100



1992 Phase IV - Full Sample (25 DMUs)
FMER Model:

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	6	6	24	24
80	7	13	28	52
90	8	21	32	84
100	4	25	16	100



1997 Phase IV - Full Sample (25 DMUs)
FMER Model:

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	4	4	16	16
80	5	9	20	36
90	10	19	40	76
100	6	25	24	100

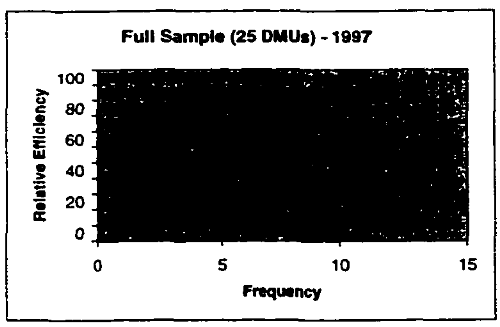


Figure 13. Relative efficiency distributions - Phase IV cross-sectional analyses (full sample)

magnitudes has increased with the application of this model. Twenty-two DMUs, 21 DMUS, and 19 DMUs were observed to be relatively inefficient for the years 1988, 1992, and 1997, respectively. The range of the magnitudes of relative inefficient DMUs was lower and wider than those observed with the CCR-I Model. However, even though the magnitudes were lower and wider, the relative inefficiencies remained skewed to the upper maximum efficiency level as observed earlier.

Relative Efficiency Measure Outlier Analysis

In order to consider outliers within the CCR-I input-oriented model, a comparison of each input variable with respect to its highlier value was performed. The highlier was defined as a variable whose particular value for a DMU exceeded its mean plus a three-standard-deviation limit as determined for that variable from all the DMUs included in the representative sample or subset, respectively. This comparison was performed for the full 25-DMU sample for 1988, 1992, and 1997 in the cross-sectional analyses. Separate comparisons also were performed individually for the G&Ts subset (11 DMUs) and for the IOUs subset (14 DMUs) for each year 1988, 1992, and 1997, respectively. If one or more input variables were observed to have a value greater than this upper outlier limit, then that particular DMU was defined as a highlier. The results of highliers observed in each of these comparisons are summarized in Table 14.

CCR-I input-oriented WDEA model analysis was performed for each respective representative sample or subset for 1988, 1992, and 1997. The WDEA analysis was performed using nine input variables and four output variables under the assumption of constant returns to scale. This is the same set of assumptions and modeling as performed in the earlier cross-sectional analyses. The primary difference in this outlier analysis is that

Table 14

Highliers in the CCR-I Input-oriented Model

Year	Full Sample	G&T Sample	IOU Sample
1988	DMU19 DMU21 DMU25	None	None
1992	DMU13 DMU21 DMU25	None	None
1997	DMU19 DMU21 DMU25	None	None

the highlier DMUs were excluded from the respective sample or subset CCR-I WDEA model runs. The results of the CCR-I input-oriented WDEA deleted highlier model runs are summarized in Table 15. All of the other DMUs in the samples or subsets not listed in Table 15 were found to be 100% relative efficient.

If one compares the results for both previous CCR-I WDEA model runs with the highliers intact and with the highliers deleted, then results are as shown in Table 16:

The results with and without highliers for the year 1988 are the same. However, the results for the year 1992 are slightly different with the relative efficiency of DMU9 slightly higher with deletion of highliers. The 1997 results show the most significant differences for all three years. With deletion of highliers, DMU6 was found to become relatively efficient at 100% while DMU9 and DMU24 remained the same.

Table 15

Results of the CCR-I Input-oriented WDEA Deleted Highlier Model

Year	Full Sample	G&T Sample	IOU Sample
1988 (22 DMUs)	DMU9 (89.52%)	None	None
1992 (22 DMUs)	DMU9 (78.06%)	None	None
1997 (22 DMUs)	DMU9 (92.16%) DMU24 (96.82%)	None	None

Table 16

Comparison of Results With and Without Highliers

Year	Full Sample with No Highlier Deletions	Full Sample with Highlier Deletions
1988	DMU9 (89.52%)	DMU9 (89.52%)
1992	DMU9 (77.97%)	DMU9 (78.06%)
1997	DMU9 (92.16%) DMU24 (96.82%) DMU6 (96.22%)	DMU9 (92.16%) DMU24 (96.82%) --

All of the variables were greater than zero; none was equal to zero or negative. Lowlier analysis was performed for 1988, 1992, and 1997. Analyses of the full 25-DMU samples, the 11-DMU G&T subsets, and the 14-DMU IOU subsets revealed that none of the variables for these years were below the lowlier value limit. The definition utilized to determine the lowlier value limit was the respective mean less three standard deviations for each variable. Therefore, there are no lowliers in the variable sets based on this definition.

Thus, no additional CCR-I input-oriented WDEA analyses were undertaken.

Data distribution analyses were undertaken for the full samples for the years 1988, 1992, and 1997 with the highliers removed from the respective samples. Figure 15 shows the four frequency distribution types and the histogram as discussed earlier in this study. Results similar to those reported earlier for Phases I, II, III, and IV also were observed. One relatively inefficient DMU was found in this sample in 1988 and 1992. Two relatively inefficient DMUs were observed in 1997. As reported previously, the relative efficiencies were also observed to be skewed toward the maximum efficiency level.

Longitudinal Analysis (1988 through 1997)

The longitudinal analysis was performed in accordance with the process shown in the flow chart of Figure 9. The CCR-I (input-oriented) WDEA model was utilized in performing a three-year moving-window analysis of the 25 electric utility companies over the 10-year horizon. Use of the three-year moving-window CCR-I model enabled the researcher to increase the degrees of freedom of the analysis from 25 firms to 75 firms in a single composite sample frame. While the respective firm or DMU is represented in the sample for three separate time periods, each firm representation is treated as a separate independent DMU. By observing the movement of the relative performance of the firm over time, a researcher can measure and assess not only individual firm performance but also trends in firm performance over time.

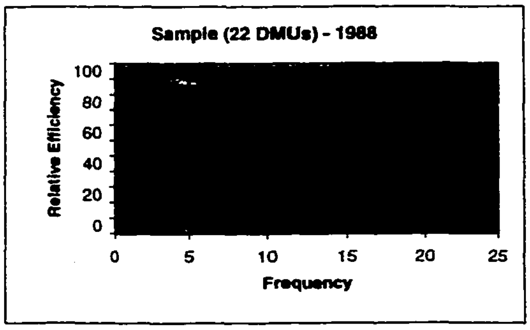
Several of the input and output variables were expressed in dollar values. The fixed expenses (taxes, interest, depreciation, and administrative and general expenses) and the variable expenses (fuel and purchased power, non-fuel production and transmission operations, and maintenance expenses) as well as total electric revenue were adjusted to

Relative Efficiency Distributions
Highlier Analysis Cross-Sectional Analyses

CCR-I WDEA Model Results Excluding Highliers

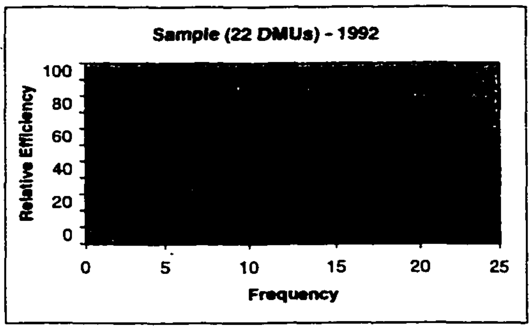
1988 Excluding Highliers - Sample (22 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	1	1	4.6	4.6
90	0	1	0	4.6
100	21	22	95.5	100.0



1992 Excluding Highliers - Sample (22 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	1	1	4.6	4.6
80	0	1	4.6	4.6
90	0	1	4.6	4.6
100	21	22	95.5	100.0



1997 Excluding Highliers - Sample (22 DMUs)

Class	Freq	Cum Freq	Percent	Cum Percent
0	0	0	0	0
10	0	0	0	0
20	0	0	0	0
30	0	0	0	0
40	0	0	0	0
50	0	0	0	0
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0
90	2	2	9.1	9.1
100	20	22	90.9	100.0

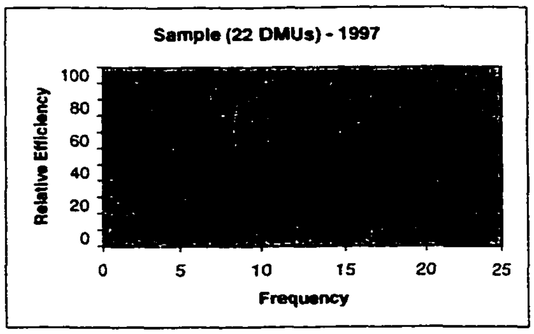


Figure 14. Relative efficiency distributions Highlier cross-sectional analyses.

the 1997 PPI to offset the effects of inflation over the study horizon. In order to provide for this adjustment, all of the study variable dollar values for each year were adjusted using the producer price index (PPI) for all commodities based on the Bureau of Labor Statistics Data source to reflect the 1997 PPI level. The all- commodities PPI index was selected for this adjustment. The Bureau of Labor Statistics Data for the all-commodities index utilized in this study is listed below. The base year for this index was 1982 (PPI = 100.0).

Year	Index
1982	100.0
1988	106.9
1989	112.2
1990	116.3
1991	116.5
1992	117.2
1993	118.9
1994	120.4
1995	124.7
1996	127.7
1997	127.6

Eight three-year moving windows were required to perform this analysis. The eight moving windows are identified below:

Window	Time Period
1	1988-1989-1990
2	1989-1990-1991

3	1990-1991-1992
4	1991-1992-1993
5	1992-1993-1994
6	1993-1994-1995
7	1994-1995-1996
8	1995-1996-1997

The data set for the first three-year window was constructed by placing the nine input variables and four output variables for each of the 25 firms for 1988, 1989, and 1990 into a single composite sample. The only adjustments made to this data were those involved in changing the respective variable dollar values to the 1997 PPI base. The CCR-I input-oriented WDEA model using the constant returns-to-scale assumption was applied to this 75-DMU data set. Once the first window was performed, the first year 1988 data set was deleted and the next 1991 data set was added to form the second window 75-DMU composite set. The CCR-I WDEA analysis was performed and the process was repeated until all eight windows were evaluated.

The results for the CCR-I three-year window WDEA analysis are presented in Table 17. The table is arranged in the numerical order of each of the 25 DMUs in the sample. The relative efficiency values are shown for each period of each of the eight windows beginning in 1988 through 1997. There are 24 relative efficiency values for each of the respective 25 DMUs.

The CCR-I input-oriented WDEA model also recommended improvements or adjustments for the relatively inefficient DMUs observed in each three-year window. The recommended detail changes or reductions in each of the nine input variables are

Table 15

Longitudinal Analysis Results

CCR-I (INPUT-ORIENTED) MODEL
RELATIVE EFFICIENCIES (PERCENT)

WINDOW		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
I	DMU1	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	98.39	100.00					
IV					97.82	100.00	100.00				
V						100.00	100.00	100.00			
VI							99.77	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	99.69
I	DMU2	100.00	100.00	100.00							
II			100.00	100.00	98.75						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								96.99	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU3	100.00	98.78	100.00							
II			99.80	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU4	100.00	100.00	100.00							
II			100.00	100.00	97.60						
III				100.00	99.11	99.39					
IV					100.00	100.00	100.00				
V						100.00	100.00	96.63			
VI							100.00	93.05	100.00		
VII								89.72	100.00	99.63	
VIII									89.68	97.28	100.00
I	DMU5	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	99.34	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU6	99.85	95.56	98.71							
II			95.12	98.69	97.37						
III				98.92	96.68	98.79					
IV					94.81	95.58	100.00				
V						94.53	100.00	100.00			
VI							100.00	100.00	99.72		
VII								100.00	99.71	97.99	
VIII									97.84	95.81	95.65

WINDOW		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
I	DMU7	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU8	100.00	100.00	100.00							
II			100.00	100.00	95.93						
III				100.00	96.83	100.00					
IV					97.92	98.40	100.00				
V						95.45	98.47	100.00			
VI							95.75	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU9	82.64	85.69	85.16							
II			79.93	80.19	79.96						
III				77.26	77.50	74.29					
IV					78.80	74.88	80.00				
V						73.93	78.58	80.84			
VI							76.83	79.58	85.74		
VII								77.30	84.69	93.05	
VIII									83.57	89.35	90.85
I	DMU10	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU11	100.00	100.00	99.26							
II			100.00	99.32	98.35						
III				100.00	100.00	99.85					
IV					100.00	98.39	100.00				
V						98.60	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU12	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	98.91	100.00					
IV					98.80	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00

WINDOW		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
I	DMU13	100.00	94.75	100.00							
II			94.20	100.00	100.00						
III				100.00	100.00	97.47					
IV					100.00	96.66	100.00				
V						97.50	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU14	100.00	99.54	100.00							
II			98.27	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU15	99.09	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	97.39	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU16	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	99.04	100.00	
VIII									99.61	100.00	100.00
I	DMU17	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU18	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	98.66	100.00

WINDOW		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU20	100.00	100.00	100.00							
II			98.47	96.99	100.00						
III				94.64	100.00	100.00					
IV					100.00	100.00	94.02				
V						100.00	92.74	98.70			
VI							94.91	98.61	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU21	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	98.93	100.00				
V						99.18	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00
I	DMU22	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	99.46	100.00	
VIII									99.23	100.00	100.00
I	DMU23	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	87.63		
VII								100.00	82.71	100.00	
VIII									81.48	100.00	100.00
I	DMU24	100.00	98.78	100.00							
II			98.87	100.00	100.00						
III				100.00	100.00	97.07					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	98.77	95.15		
VII								95.50	94.23	93.89	
VIII									92.02	92.45	96.25
I	DMU25	100.00	100.00	100.00							
II			100.00	100.00	100.00						
III				100.00	100.00	100.00					
IV					100.00	100.00	100.00				
V						100.00	100.00	100.00			
VI							100.00	100.00	100.00		
VII								100.00	100.00	100.00	
VIII									100.00	100.00	100.00

summarized in Table 18 through Table 25. The input reductions are listed for each relatively inefficient DMU in each respective window beginning with the most- inefficient DMU observed in the particular window.

A statistical summary of the relative efficiency scores for each firm was performed for the 1988 through 1997 longitudinal analysis. The summary was made considering each observation for each firm in each window over the study horizon. Table 26 contains a listing of the respective means, standard deviation, variance, maximum, and minimum efficiency performance scores over the 10-year horizon. Each representative efficiency value was given equal weight and consideration in these summary measures. Only five firms or DMUs had mean relative efficiency scores of 100% over the 10 years: DMU7, DMU10, DMU17, DMU19, and DMU25. Fourteen firms had mean relative inefficiency scores ranging from 99.11% through 99.97%: DMU8, DMU13, DMU11, DMU1, DMU2, DMU15, DMU12, DMU14, DMU21, DMU3, DMU16, DMU18, DMU22, and DMU5, respectively. DMU24, DMU4, and DMU20 had mean relative inefficiency scores ranging from 98.04% through 98.71%. Two firms had relative inefficiency values of 97.97% (DMU6) and 97.99% (DMU23). DMU9 had the lowest relative inefficiency score of 81.28%.

Table 18

Longitudinal Analysis CCR-I Input Reductions

CCR-I (INPUT-ORIENTED) MODEL
WINDOW "1" RESULTS
RELATIVE EFFICIENCIES (PERCENT)

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 988 82.64% (G&T)	DMU 990 85.16% (G&T)	DMU 989 85.69% (G&T)	DMU 1389 94.75% (IOU)	DMU 689 95.56% (IOU)	DMU 690 98.71% (IOU)	DMU 389 98.78% (G&T)	DMU 2489 98.78% (IOU)	DMU 1588 99.09% (IOU)	DMU 1190 99.26% (G&T)	DMU 1489 99.54% (IOU)	DMU 688 99.85% (IOU)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)												
1 TAX EXPENSE	48.7	48.9	45.7	23.3	4.4	1.3	11.0	1.2	0.9	0.7	1.9	0.2
2 INTEREST EXPENSE	17.4	14.8	14.8	5.2	4.4	1.3	1.2	1.2	0.9	2.0	0.5	0.2
3 DEPRECIATION EXPENSE	48.1	45.8	36.2	23.3	23.9	21.8	10.5	22.5	0.9	11.3	2.4	21.5
4 ADMIN & GENERAL EXPENSE	37.2	39.2	28.8	5.2	7.6	14.0	1.2	1.2	0.9	12.9	60.4	0.2
5 FUEL & PURCH POWER EXPENSE	17.4	14.8	14.3	5.2	4.4	1.3	1.2	1.2	2.5	0.7	0.5	0.2
6 NON FUEL EXPENSE	17.4	14.8	14.3	5.2	4.4	19.2	30.8	1.2	0.9	0.7	0.5	20.3
7 EMPLOYEES	22.7	26.1	22.0	5.2	4.4	29.1	16.0	1.2	9.4	0.7	0.5	19.7
8 INSTALLED GENERATION CAPACITY	17.4	14.8	14.3	5.9	34.7	32.9	1.2	10.1	5.5	6.7	1.5	26.8
9 TRANSMISSION LINE MILEAGE	73.7	71.7	71.6	29.0	76.0	69.5	4.2	7.4	15.1	12.7	12.4	76.9

Table 19

Longitudinal Analysis CCR-I Input Reductions

CCR-I (INPUT-ORIENTED) MODEL
WINDOWS "2" RESULTS
RELATIVE EFFICIENCIES (PERCENT)

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 989 79.93% (G&T)	DMU 991 79.96% (G&T)	DMU 990 80.19% (G&T)	DMU 1389 94.20% (IOU)	DMU 689 95.12% (IOU)	DMU 891 95.93% (IOU)	DMU 2090 96.99% (IOU)	DMU 691 97.37% (IOU)	DMU 491 97.60% (G&T)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)									
1 TAX EXPENSE	45.4	45.9	39.4	17.8	4.9	40.7	16.7	2.6	2.4
2 INTEREST EXPENSE	20.1	20.0	19.8	5.8	4.9	4.1	3.0	2.6	2.4
3 DEPRECIATION EXPENSE	39.7	42.4	46.7	21.9	24.1	14.9	9.4	19.8	10.1
4 ADMIN & GENERAL EXPENSE	31.6	35.8	37.7	5.8	5.6	10.2	3.0	11.8	6.4
5 FUEL & PURCH POWER EXPENSE	20.1	20.0	19.8	5.8	4.9	4.1	3.0	2.6	2.4
6 NON FUEL EXPENSE	20.1	20.0	19.8	5.8	4.9	4.1	25.2	12.1	12.2
7 EMPLOYEES	29.5	23.7	29.4	5.8	4.9	4.1	36.4	2.6	4.8
8 INSTALLED GENERATION CAPACITY	20.1	20.0	19.8	6.3	34.9	4.1	3.0	27.0	2.4
9 TRANSMISSION LINE MILEAGE	72.6	67.0	75.5	37.4	75.9	4.1	9.9	58.3	3.4

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 1489 98.27% (IOU)	DMU 1191 98.35% (G&T)	DMU 2089 98.47% (IOU)	DMU 690 98.69% (IOU)	DMU 291 98.75% (G&T)	DMU 2489 98.87% (IOU)	DMU 1190 99.32% (G&T)	DMU 389 99.80% (G&T)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)								
1 TAX EXPENSE	1.7	1.7	1.5	1.3	1.3	1.1	0.7	0.2
2 INTEREST EXPENSE	1.7	1.7	6.9	1.3	15.2	1.1	3.0	12.4
3 DEPRECIATION EXPENSE	1.7	16.0	17.9	21.9	1.3	13.3	13.1	17.6
4 ADMIN & GENERAL EXPENSE	30.4	57.7	17.4	15.4	14.5	1.1	16.7	0.2
5 FUEL & PURCH POWER EXPENSE	1.7	1.7	1.5	1.3	1.3	1.1	0.7	0.2
6 NON FUEL EXPENSE	1.7	12.0	8.5	16.0	1.3	1.1	0.7	26.8
7 EMPLOYEES	1.7	1.7	36.5	31.1	1.3	1.1	0.7	11.6
8 INSTALLED GENERATION CAPACITY	2.1	1.7	1.5	34.5	4.6	2.8	5.3	0.2
9 TRANSMISSION LINE MILEAGE	14.7	16.0	15.9	69.6	1.3	7.1	25.3	0.2

Table 20

Longitudinal Analysis CCR-I Input Reductions

CCR-I (INPUT-ORIENTED) MODEL
WINDOW "3" RESULTS
RELATIVE EFFICIENCIES (PERCENT)

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 992 74.29% (G&T)	DMU 990 77.26% (G&T)	DMU 991 77.50% (G&T)	DMU 2090 94.64% (IOU)	DMU 691 96.68% (IOU)	DMU 891 96.83% (IOU)	DMU 2492 97.07% (IOU)	DMU1392 97.47% (IOU)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)								
1 TAX EXPENSE	44.7	22.7	46.5	20.1	3.3	53.8	2.9	2.5
2 INTEREST EXPENSE	25.7	22.7	22.5	5.4	3.3	3.2	2.9	2.5
3 DEPRECIATION EXPENSE	41.5	40.2	40.9	9.6	10.0	6.1	36.6	5.0
4 ADMIN & GENERAL EXPENSE	33.1	29.2	33.6	5.4	12.4	3.5	2.9	4.9
5 FUEL & PURCH POWER EXPENSE	25.7	22.7	22.5	5.4	3.3	3.2	2.9	2.5
6 NON FUEL EXPENSE	25.7	22.7	22.5	26.0	3.3	3.2	2.9	26.8
7 EMPLOYEES	25.7	22.7	22.5	34.7	3.3	3.2	2.9	2.5
8 INSTALLED GENERATION CAPACITY	25.7	22.7	22.5	5.4	23.7	3.2	22.1	2.5
9 TRANSMISSION LINE MILEAGE	71.2	83.2	69.9	30.7	64.8	3.2	32.8	13.0

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 191 98.39% (G&T)	DMU 692 98.79% (IOU)	DMU 1291 98.91% (G&T)	DMU 690 98.92% (IOU)	DMU 491 99.11% (G&T)	DMU 492 99.39% (G&T)	DMU 1192 99.85% (G&T)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)							
1 TAX EXPENSE	1.6	26.0	1.1	5.1	0.9	0.6	0.2
2 INTEREST EXPENSE	1.6	1.2	18.1	1.1	0.9	0.6	0.2
3 DEPRECIATION EXPENSE	1.6	15.5	1.1	17.4	8.3	14.7	12.3
4 ADMIN & GENERAL EXPENSE	3.5	2.3	5.0	10.2	2.3	10.3	28.8
5 FUEL & PURCH POWER EXPENSE	1.6	1.2	1.1	1.1	0.9	0.6	0.2
6 NON FUEL EXPENSE	12.4	28.4	1.1	1.1	10.9	9.4	22.4
7 EMPLOYEES	1.6	18.0	1.1	30.8	1.4	2.9	0.2
8 INSTALLED GENERATION CAPACITY	4.7	2.5	9.7	32.4	0.9	2.9	0.2
9 TRANSMISSION LINE MILEAGE	9.3	34.9	23.2	66.7	0.9	0.6	14.5

Table 21

Longitudinal Analysis CCR-I Input Reductions

CCR-I (INPUT-ORIENTED) MODEL
WINDOW "4" RESULTS
RELATIVE EFFICIENCIES (PERCENT)

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 992 74.86% (G&T)	DMU 991 76.60% (G&T)	DMU 993 80.00% (G&T)	DMU 2093 94.02% (IOU)	DMU 691 94.61% (IOU)	DMU 692 95.58% (IOU)	DMU 1392 96.66% (IOU)	DMU191 97.82% (G&T)	DMU 891 97.92% (IOU)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)									
1 TAX EXPENSE	37.9	45.9	20.0	21.7	6.2	4.4	3.3	2.2	33.9
2 INTEREST EXPENSE	26.7	40.7	20.0	11.3	5.2	4.4	3.3	5.9	11.2
3 DEPRECIATION EXPENSE	34.0	34.3	40.2	6.0	13.2	22.4	4.0	2.2	2.1
4 ADMIN & GENERAL EXPENSE	26.8	22.5	51.4	11.2	5.2	4.7	3.3	2.2	2.1
5 FUEL & PURCH POWER EXPENSE	25.1	21.2	20.0	6.0	5.2	4.4	3.3	2.2	2.1
6 NON FUEL EXPENSE	25.1	21.2	20.0	6.0	5.2	28.1	21.7	2.2	2.1
7 EMPLOYEES	25.1	21.2	20.0	26.0	6.2	29.1	3.3	13.9	10.5
6 INSTALLED GENERATION CAPACITY	31.7	24.5	28.9	16.5	22.6	14.2	3.3	5.3	2.1
9 TRANSMISSION LINE MILEAGE	75.1	67.3	73.1	58.8	40.9	43.8	8.6	19.2	2.1

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 1192 98.39% (G&T)	DMU 692 98.40% (IOU)	DMU 1291 98.60% (G&T)	DMU 2192 98.93% (IOU)	DMU 592 99.34% (G&T)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)					
1 TAX EXPENSE	1.6	31.3	1.2	1.1	24.7
2 INTEREST EXPENSE	15.9	23.6	27.2	1.1	0.7
3 DEPRECIATION EXPENSE	3.6	10.8	1.2	2.0	4.4
4 ADMIN & GENERAL EXPENSE	1.6	3.0	1.2	6.6	10.9
5 FUEL & PURCH POWER EXPENSE	1.6	1.6	6.2	1.1	1.3
6 NON FUEL EXPENSE	1.6	1.6	1.2	1.1	15.9
7 EMPLOYEES	1.6	1.6	1.2	3.8	13.1
8 INSTALLED GENERATION CAPACITY	11.8	1.6	16.6	1.1	1.1
9 TRANSMISSION LINE MILEAGE	21.6	9.2	12.5	3.3	0.7

Table 22

Longitudinal Analysis CCR-I Input Reductions

CCR-I (INPUT-ORIENTED) MODEL
WINDOW "5" RESULTS
RELATIVE EFFICIENCIES (PERCENT)

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 992 73.93% (G&T)	DMU 993 78.58% (G&T)	DMU 994 80.84% (G&T)	DMU 2093 92.74% (IOU)	DMU 692 94.53% (IOU)	DMU 892 95.45% (IOU)	DMU 494 96.63% (G&T)	DMU 1593 97.39% (IOU)	DMU 1392 97.50% (IOU)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)									
1 TAX EXPENSE	26.1	21.4	19.2	7.3	5.5	26.3	3.4	2.6	2.5
2 INTEREST EXPENSE	29.5	21.4	19.2	16.9	5.5	22.5	8.3	2.6	2.5
3 DEPRECIATION EXPENSE	33.3	40.6	30.9	9.2	17.4	7.2	7.1	2.6	4.9
4 ADMIN & GENERAL EXPENSE	26.1	47.8	32.0	7.3	5.5	4.6	15.9	2.6	2.5
5 FUEL & PURCH POWER EXPENSE	26.1	21.4	19.2	7.3	5.5	4.8	3.4	2.6	2.5
6 NON FUEL EXPENSE	26.1	21.4	19.2	7.3	5.5	4.6	7.9	11.4	20.7
7 EMPLOYEES	26.1	21.4	19.2	28.6	29.1	4.8	4.6	5.4	3.9
8 INSTALLED GENERATION CAPACITY	34.0	26.9	21.9	16.7	14.8	4.6	8.5	3.7	2.5
9 TRANSMISSION LINE MILEAGE	77.9	72.4	70.8	55.6	34.9	16.0	3.4	3.2	2.5

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 893 98.47% (IOU)	DMU 1192 98.60% (G&T)	DMU 2094 98.70% (IOU)	DMU 2192 99.18% (IOU)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)				
1 TAX EXPENSE	14.9	1.4	4.5	3.3
2 INTEREST EXPENSE	1.5	33.4	19.3	2.2
3 DEPRECIATION EXPENSE	7.3	6.4	4.5	0.8
4 ADMIN & GENERAL EXPENSE	19.4	25.6	17.1	4.3
5 FUEL & PURCH POWER EXPENSE	1.5	1.4	1.3	0.8
6 NON FUEL EXPENSE	1.5	1.4	1.3	0.8
7 EMPLOYEES	1.5	1.4	21.4	2.8
8 INSTALLED GENERATION CAPACITY	6.0	16.3	1.3	0.8
9 TRANSMISSION LINE MILEAGE	9.4	40.1	52.9	0.8

Table 23

Longitudinal Analysis CCR-I Input Reductions

CCR-I (INPUT-ORIENTED) MODEL
WINDOW "6" RESULTS
RELATIVE EFFICIENCIES (PERCENT)

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 993 76.83% (G&T)	DMU 994 79.58% (G&T)	DMU 995 85.74% (G&T)	DMU 2395 87.63% (G&T)	DMU 494 93.05% (G&T)	DMU 2093 94.91% (IOU)	DMU 2495 95.15% (IOU)	DMU 893 95.75% (IOU)	DMU 2094 98.61% (IOU)	DMU 2494 98.77% (IOU)	DMU 695 99.72% (IOU)	DMU 193 99.77% (G&T)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)												
1 TAX EXPENSE	23.2	20.4	32.9	38.2	6.9	5.1	4.8	12.9	2.5	1.2	5.2	0.2
2 INTEREST EXPENSE	23.2	20.4	25.6	12.4	21.7	27.3	4.8	4.2	24.7	1.2	0.3	23.9
3 DEPRECIATION EXPENSE	36.0	21.4	36.9	12.4	20.7	5.1	6.4	7.6	1.4	6.6	0.3	28.6
4 ADMIN & GENERAL EXPENSE	43.4	29.4	48.3	12.4	22.3	5.1	4.8	15.5	15.7	1.2	17.8	12.3
5 FUEL & PURCH POWER EXPENSE	23.2	20.4	14.3	12.4	6.9	5.1	4.8	4.2	1.4	1.2	0.3	0.2
6 NON FUEL EXPENSE	23.2	20.4	14.3	46.4	17.0	18.1	4.8	4.2	5.6	1.2	5.3	0.2
7 EMPLOYEES	23.2	20.4	14.3	12.4	19.5	24.4	4.8	4.2	22.7	1.2	0.3	0.2
8 INSTALLED GENERATION CAPACITY	23.2	20.4	14.3	25.8	8.2	22.9	18.7	22.9	1.8	5.4	2.7	9.5
9 TRANSMISSION LINE MILEAGE	79.5	85.5	74.3	68.9	6.9	46.7	36.0	14.9	53.1	1.2	30.2	38.9

Table 24

Longitudinal Analysis CCR-I Input Reductions

CCR-I (INPUT-ORIENTED) MODEL
WINDOW "7" RESULTS
RELATIVE EFFICIENCIES (PERCENT)

RELATIVELY INEFFICIENT FIRM OR DMU INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS *(IN PERCENT)*	DMU 994 77.30% (G&T)	DMU 2395 82.71% (G&T)	DMU 995 84.69% (G&T)	DMU 494 89.72% (G&T)	DMU 996 93.05% (G&T)	DMU 2496 93.89% (IOU)	DMU 2495 94.23% (IOU)	DMU 2494 95.50% (IOU)	DMU 294 96.99% (G&T)
1 TAX EXPENSE	22.7	17.3	26.2	10.3	49.6	6.1	5.8	4.5	3.0
2 INTEREST EXPENSE	26.5	17.3	34.3	57.7	7.0	6.1	5.8	4.5	29.4
3 DEPRECIATION EXPENSE	24.1	17.3	38.1	33.9	27.9	6.1	13.9	16.5	3.0
4 ADMIN & GENERAL EXPENSE	25.2	17.3	44.1	32.7	44.4	6.1	5.8	4.5	27.5
5 FUEL & PURCH POWER EXPENSE	22.7	17.3	15.3	10.3	7.0	6.1	5.8	4.5	3.8
6 NON FUEL EXPENSE	22.7	26.8	15.3	20.6	7.0	6.1	5.8	4.5	13.2
7 EMPLOYEES	22.7	18.4	17.1	31.1	26.6	6.1	5.8	4.5	15.0
8 INSTALLED GENERATION CAPACITY	22.7	22.3	15.3	10.3	7.0	18.1	18.9	8.3	5.2
9 TRANSMISSION LINE MILEAGE	86.3	45.5	73.8	10.3	80.3	51.1	41.6	47.1	3.0

RELATIVELY INEFFICIENT FIRM OR DMU INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)	DMU 696 97.99% (IOU)	DMU 1695 99.04% (IOU)	DMU 2295 99.46% (G&T)	DMU 496 99.63% (G&T)	DMU 695 99.71% (IOU)
1 TAX EXPENSE	14.4	1.7	0.5	0.4	1.3
2 INTEREST EXPENSE	2.0	3.8	0.5	30.7	0.3
3 DEPRECIATION EXPENSE	2.0	1.0	0.5	16.3	0.3
4 ADMIN & GENERAL EXPENSE	5.7	3.6	8.5	56.3	19.3
5 FUEL & PURCH POWER EXPENSE	2.0	1.0	0.5	0.4	0.3
6 NON FUEL EXPENSE	2.0	1.0	0.6	5.4	2.9
7 EMPLOYEES	2.0	4.0	0.5	30.7	0.3
8 INSTALLED GENERATION CAPACITY	8.4	3.2	0.5	14.6	5.5
9 TRANSMISSION LINE MILEAGE	35.2	1.5	3.5	0.4	36.8

Table 25

Longitudinal Analysis CCR-I Input Reductions

CCR-I (INPUT-ORIENTED) MODEL
WINDOW "8" RESULTS
RELATIVE EFFICIENCIES (PERCENT)

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 2395 81.48% (G&T)	DMU 995 83.57% (G&T)	DMU 996 89.35% (G&T)	DMU 495 89.68% (G&T)	DMU 997 90.85% (G&T)	DMU 2495 92.02% (IOU)	DMU 2496 92.45% (IOU)	DMU 697 95.65% (IOU)	DMU 696 95.81% (IOU)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)									
1 TAX EXPENSE	18.5	43.4	45.6	10.3	42.8	8.0	7.5	12.1	12.1
2 INTEREST EXPENSE	18.5	36.3	11.3	56.4	23.1	8.0	7.5	4.4	4.2
3 DEPRECIATION EXPENSE	18.5	39.1	41.2	32.3	38.1	13.6	11.8	4.4	4.2
4 ADMIN & GENERAL EXPENSE	18.5	44.3	42.0	24.9	44.3	8.0	7.5	11.6	11.2
5 FUEL & PURCH POWER EXPENSE	18.5	16.4	10.6	10.3	9.2	8.0	7.5	4.4	4.2
6 NON FUEL EXPENSE	22.8	16.4	10.6	10.7	9.2	8.0	7.5	4.4	4.2
7 EMPLOYEES	18.5	16.4	22.7	16.0	19.6	8.0	7.5	25.8	29.1
8 INSTALLED GENERATION CAPACITY	18.5	16.4	26.8	18.2	15.7	16.9	7.5	61.1	4.2
9 TRANSMISSION LINE MILEAGE	42.5	78.0	79.1	10.3	79.2	58.4	57.8	81.0	76.1

RELATIVELY INEFFICIENT FIRM OR DMU	DMU 2497 96.25% (IOU)	DMU 496 97.28% (G&T)	DMU 695 97.84% (IOU)	DMU 1896 98.66% (IOU)	DMU 2295 99.23% (G&T)	DMU 1695 99.61% (IOU)	DMU 197 99.69% (G&T)
INPUT VARIABLE REDUCTIONS PER MODEL SUGGESTIONS (IN PERCENT)							
1 TAX EXPENSE	12.9	2.7	10.3	1.3	0.8	0.4	0.3
2 INTEREST EXPENSE	3.7	33.0	2.2	1.3	0.8	1.8	0.3
3 DEPRECIATION EXPENSE	13.5	20.2	2.2	1.3	0.8	0.4	1.3
4 ADMIN & GENERAL EXPENSE	3.7	54.0	18.8	32.1	7.4	4.8	0.3
5 FUEL & PURCH POWER EXPENSE	3.7	2.7	2.2	1.3	0.8	0.4	0.3
6 NON FUEL EXPENSE	3.7	2.7	2.2	1.3	0.8	0.4	0.3
7 EMPLOYEES	3.7	26.8	32.1	1.3	0.8	7.7	12.3
8 INSTALLED GENERATION CAPACITY	28.1	23.8	2.2	1.3	0.8	2.2	7.1
9 TRANSMISSION LINE MILEAGE	56.1	2.7	79.4	22.2	0.8	6.1	23.5

Table 26

Longitudinal Analysis Results

CCR-I (INPUT-ORIENTED) MODEL
RELATIVE EFFICIENCIES (PERCENT)

	TOTAL	MEAN	VARIANCE	STANDARD DEVIATION	MAX	MIN
DMU1	2395.67	99.82	0.29	0.54	100.00	97.82
DMU2	2395.74	99.82	0.43	0.65	100.00	96.99
DMU3	2398.58	99.94	0.06	0.25	100.00	98.78
DMU4	2362.09	98.42	9.84	3.14	100.00	89.68
DMU5	2399.34	99.97	0.02	0.13	100.00	99.34
DMU6	2351.33	97.97	3.94	1.98	100.00	94.53
DMU7	2400.00	100.00	0.00	0.00	100.00	100.00
DMU8	2378.75	99.11	2.43	1.56	100.00	95.45
DMU9	1950.61	81.28	26.14	5.11	93.05	73.93
DMU10	2400.00	100.00	0.00	0.00	100.00	100.00
DMU11	2393.77	99.74	0.29	0.54	100.00	98.35
DMU12	2397.71	99.90	0.10	0.32	100.00	98.80
DMU13	2380.58	99.19	3.01	1.74	100.00	94.20
DMU14	2397.81	99.91	0.13	0.36	100.00	98.27
DMU15	2396.48	99.85	0.31	0.56	100.00	97.39
DMU16	2398.65	99.94	0.04	0.21	100.00	99.04
DMU17	2400.00	100.00	0.00	0.00	100.00	100.00
DMU18	2398.66	99.94	0.07	0.27	100.00	98.66
DMU19	2400.00	100.00	0.00	0.00	100.00	100.00
DMU20	2369.08	98.71	5.14	2.27	100.00	92.74
DMU21	2398.11	99.92	0.07	0.27	100.00	98.93
DMU22	2398.69	99.95	0.04	0.19	100.00	99.23
DMU23	2351.82	97.99	30.36	5.51	100.00	81.48
DMU24	2352.98	98.04	7.39	2.72	100.00	92.02
DMU25	2400.00	100.00	0.00	0.00	100.00	100.00

The data in Table 27 were sorted in order of ascending minimum relative inefficiency values. The minimum inefficiency values listed below are those values that range from 73.93% to 95.00%.

Table 27

Minimum Relative Inefficiency Values Less Than 95%

Firm	Mean	Variance	Minimum	Maximum
DMU9	81.28	26.14	73.93	93.05
DMU23	97.99	30.36	81.48	100.00
DMU4	98.42	9.84	89.68	100.00
DMU24	98.04	7.39	92.02	100.00
DMU20	98.71	5.14	92.74	100.00
DMU13	99.19	3.01	94.20	100.00
DMU6	97.97	3.94	94.53	100.00

It is interesting to observe that the variances of this data set ranged from 26.14 to 3.94. These seven DMUs accounted for the largest variances in relative inefficiency found in this 10-year longitudinal analysis. It was further noted that the relative inefficient firms found in the cross-sectional analyses for each phase were as shown in Table 16:

It is interesting to observe that the same three firms (DMU6, DMU9, and DMU24) were also found to be relatively inefficient in the longitudinal analysis. DMU9 was found to be the most relatively inefficient firm in both the cross-sectional and longitudinal analyses. Several other firms were found to be relatively inefficient in the longitudinal analysis. These are shown in Table 28. However, four additional firms (DMU 23, DMU4, DMU20, and DMU13) were found to exhibit larger variances and ranges in their relative inefficiency values as noted earlier in the data sort listing.

Table 28

Firms' Relative Inefficiency Values, Longitudinal Analysis

Phase/Firm	1988	1992	1997
Phase I			
DMU9	89.5	78.0	92.2
DMU6			96.2
DMU24			96.8
Phase II			
DMU6			96.7 (IOU)
DMU24			98.3 (IOU)
Phase III			
DMU9	89.5	78.0	92.2
DMU24			99.8
Phase IV (Full Sample)			
DMU9	89.5	78.1	92.2
DMU24			96.9

CHAPTER 5

RESULTS

The results of the CCR-I input-oriented Data Envelopment Analysis (DEA) are summarized in this section of the study. The DEA analyses enabled the researcher to study the 25 firms or DMUs in the sample and to study the firms divided into their respective Investor-Owned Utilities (IOUs) and Generation & Transmission (G&Ts) subsets separately.

Use of the DEA model enabled the researcher to identify each of the firms as relatively efficient or inefficient with respect to one another. The model suggests improvement in each of the respective input variables to enable the relatively inefficient firm to become relatively efficient and to move to the most efficient frontier. While the model may suggest target improvements for relatively inefficient firms, it is the management of these respective firms that have the opportunity and discretion to reposition the firm. The value in this approach is that the model provides management with the capability to measure firm performance with this single measure and to provide a process for continuous improvement.

Research Questions

The research questions contemplated in this research effort are:

Why do electric utilities in the sample of midwestern U.S. electric utilities differ?

Why are some electric utilities more successful than others even in the same industry?

What firms are the best performers and which are the poorest performing firms?

These research questions are more formally stated as follows. (The static or cross-sectional analyses in this study looked specifically at the years 1988, 1992, and 1997.)

Static or Cross-sectional Comparison and Analyses

Research Question 1: What firms are operating at the most efficient scale size and are situated on the most efficient frontier for the firms in the sample?

Twenty-four of the 25 firms were found to be relatively efficient at 100% in the years 1988 and 1992. The only firm found to be relatively inefficient in these years was DMU9. Twenty-two of the 25 firms were found to be relatively efficient at 100% in the year 1997. DMU6, DMU9, and DMU24 were found to be relatively inefficient. These results for Phase I were shown previously in Table 7.

Research Question 2: What firms are not operating at the most productive scale size (i.e., inefficient firms) and are not operating on the most efficient frontier?

DMU9 was found to be relatively inefficient at 89.5%, 78.0%, and 92.2% in 1988, 1992, and 1997, respectively. In 1997, DMU6 and DMU24 were found to be relatively inefficient at 96.2% and 96.8%, respectively.

Research Question 3: What can the inefficient firms do to move to the efficient frontier or to achieve the most productive scale size?

The CCR-I input-oriented model-suggested reductions for the relatively inefficient DMUs are summarized in Table 29:

Table 29

CCR-I Model Input Reduction Suggestions, in Percentage

Expense Type	DMU9 1988	DMU9 1992	DMU9 1997	DMU6 1997	DMU24 1997
Tax	10.5	28.9	38.4	41.5	17.9
Interest	10.5	22.0	25.8	3.8	3.2
Depreciation	29.7	35.7	37.9	3.8	13.0
Admin. & General	33.5	32.1	41.2	3.8	3.2
Fuel & Purchased Power	10.5	22.0	7.8	3.8	3.2
Non-Fuel	11.0	22.0	7.8	3.8	3.2
Employees	23.0	22.0	17.7	26.6	3.2
Installed Generation Capacity	10.5	22.4	7.8	52.2	24.6
Transmission Line Miles	70.9	67.6	82.8	75.4	55.9

Table 29 indicates that for the firm DMU9, reductions recommended for taxes and interest expenses of 10.5% in 1988 grow to reductions of 38.4% and 25.8% in 1997. In 1988, reductions for this same DMU9 were targeted at 29.7% for depreciation and at 33.5% for administrative and general expenses. However, depreciation and administrative and general expenses increase to 37.9% and 41.2%, respectively, in 1997. The fuel and purchased power expenses vary from suggested targets of 10.5%, 22.0%, and 7.8% in 1988, 1992, and 1997. In a similar manner, the non-fuel expenses vary from target reductions of 11.0%, 22.0%, and 7.8% in these same years. The number of full-time electric employees target reductions is 23.0%, 22.0%, and 17.7%. It appears from the model suggestions that management of the firm had made adjustments in fuel and purchased power and non-fuel expenses. In addition, they had made some adjustments in the number of full-time electric employees. However, they had not been successful in the other expense categories or as aggressive as the model suggested in improving the relative efficiency of the firm. This particular firm is a G&T rural electric cooperative. The model suggested extensive reductions in the installed transmission system circuit miles and generating capacity of this same firm. Reductions in generating capacity were fluctuating with system demand and energy requirements. The transmission investment reductions are significant. In most electric utility situations, the regulatory requirements of the electric service franchise territory carry an obligation to serve all present and future electric customers within the service area in accordance with existing approved tariffs. The firm must have adequate electric facilities, including transmission capacity, in place in order to provide this service. Once the investments are made in the transmission system, all customers and the electric interconnected network utilize them. It would be difficult for firm management to alter these service arrangements without extensive regulatory hearings and approvals. However, other firms specializing in this type of service may offer other alternatives for consideration by firm management, resulting in its ability to lower its costs and enhance its service.

Two other firms that were relatively efficient in 1988 and 1992 were found to become relatively inefficient in 1997. Both of these organizations are IOU electric utilities. The model suggested that DMU6 required significant reductions in tax expenses (41.5%), full-time electric employees (26.6%), installed generating capacity (52.2%), and transmission line circuit miles (75.4%). Reductions in the remaining input variables of 3.8% also were suggested. Management of this firm appeared to be able to consider reducing the input variables as suggested with the possible exception of the transmission and generation facilities, as noted earlier.

The model suggested reductions for DMU24 for taxes (17.9%), depreciation (13.0%), installed generation capacity (24.6%), and transmission line circuit miles (55.9%). Reductions of 3.2% were targeted for the remaining input variables for this firm. It appears that management of this firm also had the opportunity to make these similar adjustments as those of DMU6.

Research Question 4: Since the sample contains two major types of firms, that is, investor-owned electric utilities and generation-and-transmission rural electric cooperative utilities, is there a difference in performance or relative efficiencies as measured by mpss between the two classes of firms?

The full sample of 25 DMUs or firms was divided into the respective IOU and G&T subsets. There are 11 firms in the G&Ts subset and 14 firms in the IOUs subset. The CCR-I input-oriented WDEA model was applied to each of the subsets separately for the years 1988, 1992, and 1997. The results for each subset of the three years are shown in Table 7 for all 25 firms collectively and in Table 8 for each of the respective subsets individually. All 11 DMUs in the G&Ts subset and all 14 DMUs in the IOUs subset are relatively efficient at 100.0% for 1988 and 1992. However, for 1997 all 11 DMUs in the G&Ts subset were relatively efficient at 100.0% while 12 of the 14 DMUs in the IOUs subset were relatively efficient at 100.0%. Two of the 14 DMUs in the IOUs subset for

1997 were found to be relatively inefficient, DMU6 (96.7%) and DMU24 (98.3%).

When compared to its own firm type, it appears that the G&T subset is operating at relatively efficient levels. It also appears that the IOUs subset, when compared with its own firm type, is operating at relatively efficient levels with the exception of 1997. This finding would cause the researcher to contend that the management of the firms in assessing firm performance pay more attention to members of their own organization type rather than considering the other competitors. The only differences found when assessing each firm type separately were those previously mentioned. Apparently there is no discernible cross-sectional difference between the subsets. One cannot help but notice that when all of the 25 firms are aggregated into a total single sample there is a difference in the number and type of firms found to be both relatively efficient and inefficient with respect to both subset type organizations.

The targeted input-level reductions suggested by the model for management of the respective relatively inefficient firms to consider were shown in Table 8. They are summarized in Table 30. The largest target reductions suggested by the model were for taxes (44.3%), full-time electric employees (26.6%), installed generating capacity (52.1%), and installed transmission line circuit miles (73.6%). The reductions in the remaining input variable for this firm range from 3.3% to 5.1%. The largest target reductions suggested by the model for DMU24 are for taxes (13.1%), depreciation (12.5%), installed generating capacity (31.9%), and installed transmission line circuit miles (61.1%). The reductions in the remaining input variables for this DMU24 range from 1.7% to 8.7%.

Table 30

CCR-I Model Input Reduction Suggestions, in Percentage

Expense Type	DMU6 (1997)	DMU24 (1997)
Tax	44.3	13.1
Interest	3.3	8.7
Depreciation	5.1	12.5
Administrative & General	3.4	7.3
Fuel & Purchased Power	3.3	1.7
Non-Fuel	3.3	3.6
Employees (Full- Time Electric)	26.6	1.7
Installed Generation Capacity	52.1	31.9
Transmission Line Miles	73.6	61.1

Longitudinal Comparison and Analyses

Research Question 5: Using the relative efficiency measures for determining overall most productive scale size, are firms' relative efficiencies improving, remaining the same, or declining over the full study horizon?

In order to determine trends in firm performance over time, the researcher developed a process of assessing firm performance over the study horizon. The 24 relative efficiency values for each firm over the 10-year period as shown in Table 19 were averaged for each year for each firm. Constructing this average resulted in development of a single relative-efficiency measure for each firm for each year. By considering the relative-efficiency values for a firm, the researcher could determine which firms were relatively efficient and inefficient. Firms that were relatively efficient at 100% over the full horizon were judged to be the most relatively efficient in the sample. However, the performance trend for these firms was constant or flat and unchanging over the horizon. Even though the firm and its management probably were working diligently to maintain this level, for purposes of this study such firms were judged to be remaining the same over the horizon. The five firms remaining the same over the 1988 through 1997 period are shown in the Table 31.

Table 31

Firms Considered To Be Remaining The Same Over Time

Year	DMU7	DMU10	DMU17	DMU19	DMU25
1988	100.	100.	100.	100.	100.
1989	100.	100.	100.	100.	100.
1990	100.	100.	100.	100.	100.
1991	100.	100.	100.	100.	100.
1992	100.	100.	100.	100.	100.
1993	100.	100.	100.	100.	100.
1994	100.	100.	100.	100.	100.
1995	100.	100.	100.	100.	100.
1996	100.	100.	100.	100.	100.
1997	100.	100.	100.	100.	100.

It also was possible to observe firms with relative inefficient values for one, two, and three years of the horizon. A firm was considered to be improving over time if its relative inefficient values occurred during the first five years of the study, that is, 1988 though 1992. The nine firms considered to be improving over the full horizon are shown in

Table 32.

Table 32

Firms Considered to Be Improving Over Time

Firm	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
					One Period Inefficient					
DMU15	99.1	100.	100.	100.	100.	100.	100.	100.	100.	100.
DMU3	100.	99.3	100.	100.	100.	100.	100.	100.	100.	100.
DMU14	100.	98.9	100.	100.	100.	100.	100.	100.	100.	100.
DMU12	100.	100.	100.	99.2	100.	100.	100.	100.	100.	100.
DMU21	100.	100.	100.	100.	99.8	100.	100.	100.	100.	100.
DMU5	100.	100.	100.	100.	99.8	100.	100.	100.	100.	100.
					Two Periods Inefficient					
DMU13	100.	94.5	100.	97.2	100.	100.	100.	100.	100.	100.
					Three Periods Inefficient					
DMU11	100.	100.	99.5	99.5	98.9	100.	100.	100.	100.	100.
DMU8	100.	100.	100.	96.9	98.0	98.1	100.	100.	100.	100.

The only exception included in this case is DMU8 (see Table 32). DMU8 was considered as improving over time even though its most recent inefficient value occurred in 1993. From 1994 through 1997 this firm was able to operate at its maximum relative efficiency.

Firms considered to be declining in performance over time are those with lower relative efficiency values in the last five years of the horizon as compared to the first five years. There are 11 firms considered to be declining in relative efficiency over the 1988 through 1997 horizon. They are shown in Table 33, listed in the order of increasing number of periods of inefficiency. Note that firms (DMU6, DMU9, and DMU24) found to be relatively inefficient in the cross-sectional analyses were also found to be significantly declining in performance over the horizon. These are listed at the end of the table.

Research Question 6: What firms are the most relatively efficient over this horizon?

The firms found to be the most relatively efficient over the 1988 through 1997 horizon are DMU7, DMU10, DMU17, DMU19, and DMU25. These firms were found to have relative efficiency performance values of 100% for each year of the study. They were classified previously as those firms that remained the same during the longitudinal study period.

Research Question 7: What firms are relatively inefficient over this horizon?

The firms found to be relatively inefficient over this horizon were those firms previously regarded as declining in performance: DMU16, DMU22, DMU23, DMU18, DMU2, DMU1, DMU20, DMU4, DMU24, DMU6, and DMU9.

Research Question 8: What can the relatively inefficient firms do to improve their performance over the horizon?

The CCR-I input-oriented suggested target input variable reductions for each relatively inefficient firm were shown in Tables 18 through 26. The target input reductions are stated for each inefficient firm for each year included in all eight windows. The CCR-I

Table 33

Firms Considered to Be Declining Over Time

Firm	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
					One Period Inefficient					
DMU16	100.	100.	100.	100.	100.	100.	100.	99.6	100.	100.
DMU22	100.	100.	100.	100.	100.	100.	100.	99.6	100.	100.
DMU23	100.	100.	100.	100.	100.	100.	100.	83.9	100.	100.
DMU18	100.	100.	100.	100.	100.	100.	100.	100.	99.3	100.
					Two Periods Inefficient					
DMU2	100.	100.	100.	99.6	100.	100.	99.0	100.	100.	100.
					Three Periods Inefficient					
DMU1	100.	100.	100.	98.7	100.	99.9	100.	100.	100.	99.7
					Four Periods Inefficient					
DMU20	100.	99.2	97.2	100.	100.	93.9	99.1	100.	100.	100.
					Five Periods Inefficient					
DMU4	100.	100.	100.	98.9	99.8	100.	93.1	96.6	98.5	100.
					Six Periods Inefficient					
DMU24	100.	98.8	100.	100.	99.0	100.	98.1	93.8	93.2	96.3
					Eight Periods Inefficient					
DMU6	99.9	95.3	98.8	96.3	96.3	100.	100.	99.1	96.9	95.7
					Ten Periods Inefficient					
DMU9	82.6	82.8	80.9	78.8	74.4	78.5	79.2	84.7	91.2	90.9

model suggests target improvements for a firm or DMU found to be inefficient in any year of the 10-year horizon. The longitudinal analysis was made using the three-year moving-window CCR-I procedure. Each firm was represented for each year in the three-year window; thus, a firm was included as three individual entities in each window. A summary table was prepared for each relatively inefficient firm for the 10-year period Table34 through 41). The suggested target reductions for each input variable for each window are shown in the respective tables for DMU16, DMU22, DMU23, DMU18, DMU2, DMU1, DMU20, DMU4, DMU24, DMU6, and DMU9. The windows shown for each firm are those windows in which the particular firm was observed to be inefficient. Also note that a firm was observed to be inefficient as many times as the firm was included in a respective window. When a particular firm was observed to be inefficient more than once in a particular window, the range of target improvements suggested by the model for that firm was listed in that window.

Table 34

CCR-I Model Suggested Target Reductions for DMU16, in Percentage

	Window 7 1994-1996	Window 8 1995–1997
Taxes	1.7	0.4
Interest	3.8	1.8
Depreciation	1.0	0.4
Admin & General	3.6	4.8
Fuel & Purchased Power	1.0	0.4
Non-Fuel	1.0	0.4
Employees	4.0	7.7
Installed Generating Capacity	3.2	2.2
Installed Transmission Miles	1.5	6.1

The model suggests that the firm and its management reduce its key input variables by the percentage values shown. The largest percentage reductions are in the areas of interest expense, administrative and general expense, number of full-time electric employees, installed generating capacity, and installed transmission circuit miles.

Table 35

CCR-I Model Suggested Target Reductions for DMU22, in Percentage

	Window 7 1994-1996	Window 8 1995–1997
Taxes	0.5	0.8
Interest	0.5	0.8
Depreciation	0.5	0.8
Admin & General	8.5	7.4
Fuel & Purchased Power	0.5	0.8
Non-Fuel	0.6	0.8
Employees	0.5	0.8
Installed Generating Capacity	0.5	0.8
Installed Transmission Miles	3.5	0.8

The model (Table 35) suggests that the firm and its management reduce its key input variables by the percentage values shown. The largest percentage reduction is in the administrative and general expense.

Table 36

CCR-I Model Suggested Target Reductions for DMU23, in Percentage

	Window 6 1993-1995	Window 7 1994-1996	Window 8 1995–1997
Taxes	38.2	17.3	18.5
Interest	12.4	17.3	18.5
Depreciation	12.4	17.3	18.5
Admin & General	12.4	17.3	18.5
Fuel & Purchased Power	12.4	17.3	18.5
Non-Fuel	46.4	26.8	22.8
Employees	12.4	18.4	18.5
Installed Generating Capacity	25.8	22.3	18.5
Installed Transmission Miles	68.9	45.5	42.5

The model (Table 36) suggests that the firm and its management reduce its key input variables significantly in each input variable category by the percentage values shown.

Table 37

CCR-I Model Suggested Target Reductions for DMU18, in Percentage

	Window 8 1995–1997
Taxes	1.3
Interest	1.3
Depreciation	1.3
Admin & General	32.1
Fuel & Purchased Power	1.3
Non-Fuel	1.3
Employees	1.3
Installed Generating Capacity	1.3
Installed Transmission Miles	22.2

The model (Table 37) suggests that the firm and its management reduce its key input variables in each input variable by the percentage values shown. The largest percentage reductions are shown for administrative and general expense and installed transmission circuit miles.

Table 38

CCR-I Model Suggested Target Reductions for DMU2, in Percentage

	Window 2 1989-1991	Window 7 1994–1996
Taxes	1.3	3.0
Interest	15.2	29.4
Depreciation	1.3	3.0
Admin & General	14.5	27.5
Fuel & Purchased Power	1.3	3.8
Non-Fuel	1.3	13.2
Employees	1.3	15.0
Installed Generating Capacity	4.6	5.2
Installed Transmission Miles	1.3	3.0

The model (Table 38) suggests that DMU2 and its management reduce its key input variables in each input variable by the percentage values shown above. The largest percentage reductions are shown in the areas of interest expense, administrative and general expense, non-fuel expense, and number of full-time electric employees.

Table 39

CCR-I Model Suggested Target Reductions for DMU1, in Percentage

	Window 3 1990-1992	Window 4 1991–1993	Window 6 1993-1995	Window 8 1995-1997
Taxes	1.6	2.2	0.2	0.3
Interest	1.6	5.9	23.9	0.3
Depreciation	1.6	2.2	28.6	1.3
Admin & General	3.5	2.2	12.3	0.3
Fuel & Purchased Power	1.6	2.2	0.2	0.3
Non-Fuel	12.4	2.2	0.2	0.3
Employees	1.6	13.9	0.2	12.3
Installed Generating Capacity	4.7	5.3	9.5	7.1
Installed Transmission Miles	9.3	19.2	38.9	23.5

The model (Table 39) suggests that DMU1 and its management reduce its key input variables in each input variable by the percentage values shown above. It appears that over time management has made adjustments in the input variables and made some improvement. However, in the eighth window the largest input reduction percentage values are suggested in the number of full-time electric employees, installed generating capacity, and installed transmission circuit miles.

Table 40

CCR-I Model Suggested Target Reductions for DMU20, in Percentage

	Window 2 1989-1991	Window 3 1990-1992	Window 4 1991–1993	Window 5 1992-1994	Window 6 1993-1995
Taxes	1.5-16.7	20.1	21.7	4.5-7.3	2.5-5.1
Interest	3.0-6.9	5.4	11.3	16.9-19.3	24.7-27.3
Depreciation	9.4-17.9	9.6	6.0	4.5-9.2	1.4-5.1
Admin & General	3.0-17.4	5.4	11.2	7.3-17.1	5.1-15.7
Fuel & Purchased Power	1.5-3.0	5.4	6.0	1.3-7.3	1.4-5.1
Non-Fuel	8.5-25.2	26.0	6.0	1.3-7.3	5.6-18.1
Employees	36.4-36.5	34.7	25.0	21.4-28.6	22.7-24.4
Installed Generating Capacity	1.5-3.0	5.4	16.5	1.3-16.7	1.8-53.1
Installed Transmission Miles	9.9-15.9	30.7	58.8	52.9-55.6	46.7-53.1

The model (Table 40) suggests that the DMU20 and its management reduce its key input variables by the percentage values shown above.

Table 41

CCR-I Model Suggested Target Reductions for DMU4, in Percentage

	Window 2 1989-1991	Window 3 1990-1992	Window 5 1992–1994
Taxes	2.4	0.6-0.9	3.4
Interest	2.4	0.6-0.9	8.3
Depreciation	10.1	8.3-14.7	7.1
Admin & General	6.4	2.3-10.3	15.9
Fuel & Purchased Power	2.4	0.6-0.9	3.4
Non-Fuel	12.2	9.4-10.9	7.9
Employees	4.8	1.4-2.9	4.6
Installed Generating Capacity	2.4	0.9-2.9	8.5
Installed Transmission Miles	3.4	0.6-0.9	3.4
	Window 6 1993-1995	**Window 7 1994-1996**	**Window 8 1995–1997**
Taxes	6.9	0.4-10.3	2.7-10.3
Interest	21.7	30.7-57.7	33.0-56.4
Depreciation	20.7	16.3-33.9	20.2-32.3
Admin & General	22.3	32.7-56.3	24.9-54.0
Fuel & Purchased Power	6.9	0.4-10.3	2.7-10.3
Non-Fuel	17.0	5.4-20.6	2.7-10.3
Employees	19.5	30.7-31.1	16.0-26.8
Installed Generating Capacity	8.2	10.3-14.6	18.2-23.8
Installed Transmission Miles	6.9	0.4-10.3	2.7-10.3

The model (Table 41) suggests that the firm and its management reduce its key input variables in each input variable by the percentage values shown above. The largest target reductions suggested by the model are in the area of fixed expenses (i.e., interest expense, administrative and general expense, and depreciation expense) and the number of full-time electric employees.

It is interesting to note that the next three firms or DMUs are those firms that were found to be relatively inefficient in the cross-sectional analyses discussed previously. Each of these three firms (DMU24, DMU6, and DMU9) also exhibits significantly more periods of inefficiency than the other DMUs in the longitudinal analyses. The results of the longitudinal analyses with respect to determining the relatively inefficient firms in the sample determines the identity of those firms and shows them to be the poorest performers within the sample.

The model (Table 42) suggests that DMU24 and its management reduce its key input variables by the percentage values as shown. The largest target reductions suggested by the model are in the areas of depreciation expense, installed generation capacity, and installed transmission capacity.

The model (Table 43) suggests that DMU6 and its management reduce its key input variables by the percentage values shown above. The largest target reductions suggested by the model over the horizon are in the areas of depreciation expense, installed generation capacity, and installed transmission capacity.

The target reductions (Table 44) suggested by the model for DMU9 were significant for most of the key input variables as compared to the other firms in the

Table 42

CCR-I Model Suggested Target Reductions for DMU24, in Percentage

	Window 1 1988-1990	Window 2 1989-1991	Window 3 1990–1992
Taxes	1.2	1.1	2.9
Interest	1.2	1.1	2.9
Depreciation	22.5	13.3	36.6
Admin & General	1.2	1.1	2.9
Fuel & Purchased Power	1.2	1.1	2.9
Non-Fuel	1.2	1.1	2.9
Employees	1.2	1.1	2.9
Installed Generating Capacity	10.1	2.8	22.1
Installed Transmission Miles	7.4	7.1	32.8

	Window 6 1993-1995	Window 7 1994-1996	Window 8 1995–1997
Taxes	1.2-4.8	4.5-6.1	7.5-12.9
Interest	1.2-4.8	4.5-6.1	3.7-8.0
Depreciation	6.4-6.6	6.1-16.5	11.8-20.2
Admin & General	1.2-4.8	4.5-6.1	3.7-8.0
Fuel & Purchased Power	1.2-4.8	4.5-6.1	3.7-8.0
Non-Fuel	1.2-4.8	4.5-6.1	3.7-8.0
Employees	1.2-4.8	4.5-6.1	3.7-8.0
Installed Generating Capacity	5.4-18.7	8.3-18.9	7.5-28.1
Installed Transmission Miles	1.2-36.0	41.6-51.1	56.1-58.4

Table 43

CCR-I Model Suggested Target Reductions for DMU6, in Percentage

	Window 1 1988-1990	Window 2 1989–1991	Window 3 1990-1992	Window 4 1991-1993
Taxes	0.2-4.4	1.3-4.9	3.3-26.0	4.4-5.2
Interest	0.2-4.4	1.3-4.9	1.1-3.3	4.4-5.2
Depreciation	21.5-23.9	19.8-24.1	10.0-17.4	13.2-22.4
Admin & General	0.2-14.0	5.6-15.4	2.3-12.4	4.7-5.2
Fuel & Purchased Power	0.2-4.4	4.9-21.3	1.1-3.3	4.4-5.2
Non-Fuel	4.4-20.3	4.9-16.0	1.1-3.3	5.2-28.1
Employees	4.4-29.1	2.6-31.1	3.3-30.8	5.2-29.1
Installed Generating Capacity	26.8-34.7	27.0-34.9	2.5-32.4	14.2-22.6
Installed Transmission Miles	69.5-76.9	58.3-75.9	34.9-66.7	40.9-43.8
	Window 5 1992-1994	**Window 6 1993–1995**	**Window 7 1994-1996**	**Window 8 1995-1997**
Taxes	5.5	5.2	1.3-14.4	10.3-12.1
Interest	5.5	0.3	0.3-2.0	2.2-4.4
Depreciation	17.4	0.3	0.3-2.0	2.2-4.4
Admin & General	5.5	17.8	5.7-19.3	11.2-18.8
Fuel & Purchased Power	5.5	0.3	0.3-2.0	1.3-4.2
Non-Fuel	5.5	5.3	2.0-2.9	1.3-4.4
Employees	29.1	0.3	0.3-2.0	25.8-32.1
Installed Generating Capacity	14.8	2.7	5.5-8.4	2.2-61.1
Installed Transmission Miles	34.9	30.2	35.2-36.8	76.1-81.0

Table 44

CCR-I Model Suggested Target Reductions for DMU9, in Percentage

	Window 1 1988-1990	Window 2 1989–1991	Window 3 1990-1992	Window 4 1991-1993
Taxes	45.7-48.9	39.4-45.9	22.7-46.5	20.0-45.9
Interest	14.8-17.4	19.8-20.1	22.5-25.7	20.0-40.7
Depreciation	36.2-45.8	39.7-46.7	40.2-41.5	34.0-40.2
Admin & General	28.8-37.2	31.6-37.7	29.2-33.6	22.5-51.4
Fuel & Purchased Power	14.3-17.4	19.8-20.1	22.5-25.7	20.0-25.1
Non-Fuel	14.3-17.4	19.8-20.1	22.5-25.7	20.0-25.1
Employees	22.0-26.1	23.7-29.5	22.5-25.7	20.0-25.1
Installed Generating Capacity	14.3-17.4	19.8-20.1	22.5-25.7	24.5-31.7
Installed Transmission Miles	71.6-73.7	67.0-75.5	69.9-83.2	67.8-75.1

	Window 5 1992-1994	Window 6 1993–1995	Window 7 1994-1996	Window 8 1995-1997
Taxes	19.2-26.1	20.4-32.9	22.7-49.6	42.8-45.6
Interest	19.2-29.5	20.4-25.6	7.0-34.3	11.3-36.3
Depreciation	30.9-40.6	21.4-36.9	24.1-38.1	38.1-41.2
Admin & General	26.1-47.8	29.4-48.3	25.2-44.4	42.0-44.3
Fuel & Purchased Power	19.2-26.1	14.3-23.2	7.0-22.7	9.2-16.4
Non-Fuel	19.2-26.1	14.3-23.2	7.0-22.7	9.2-16.4
Employees	19.2-26.1	14.3-23.2	17.1-26.6	16.4-22.7
Installed Generating Capacity	21.9-34.0	14.3-23.2	7.0-22.7	15.7-26.8
Installed Transmission Miles	70.8-77.9	74.3-85.5	73.8-86.3	78.0-79.2

sample. Double- digit reductions were suggested within the range of each input. The last firm or DMU9 appears to be the most relatively inefficient firm in the full 25-firm sample. A significant task faces the management of this firm. While there has been some improvement in various inputs over time, the firm still is assessed the most relative inefficient firm. However, diligent management attention into the areas highlighted by the model can make it possible for this firm to dramatically improve its position and overall efficiency performance level.

Research Question 9: Since the sample contains two major types of firms, that is, investor-owned electric utilities and generation and transmission rural electric cooperative utilities, is there a difference in performance or relative efficiencies between the two classes of firms over the horizon?

Table 45 shows each firm and its classification. The data contained in Table 45 can be summarized into a contingency table (Table 46). The contingency table enables one to compare the entire sample of firms with the IOUs and G&Ts individual subsets by classification.

Twenty percent of the 25 firms have performances of 100% relative efficiency and remained the same at that level throughout the 10-year horizon. Of these most efficient firms 16% of the sample were IOUs and four percent were G&Ts. In considering those firms classed as "improving over time," 36% of the full sample were in this class, with IOUs and G&Ts representing 20% and 16%, respectively. Forty-four percent of the full sample of firms was classified as being in decline over time. Twenty percent of the firms were IOUs, and 24% were G&Ts.

Table 45

Summary of Firms by Performance Class

Firm	IOU	G&T
Firms remaining same over horizon		
DMU7	1	
DMU10	1	
DMU17	1	
DMU19		1
DMU25	1	
Subtotal	4	1
Firms improving over horizon		
DMU15	1	
DMU3		1
DMU14	1	
DMU12		1
DMU21	1	
DMU5		1
DMU13	1	
DMU11		1
DMU8	1	
Subtotal	5	4
Firms declining over horizon		
DMU16	1	
DMU22		1
DMU23		1
DMU18	1	
DMU2		1
DMU1		1
DMU20	1	
DMU4		1
DMU24	1	
DMU6	1	
DMU9		1
Subtotal	5	6
Total for Sample	14	11

Table 46

Firm Performance Classification, in Percentage

Firm Type	Remaining the Same	Improving	Declining	Total
IOU	16.0	20.0	20.0	56.0
G&T	4.0	16.0	24.0	44.0
Total	20.0	36.0	44.0	100.0

If one considers the IOUs as a separate group and compares the number of firms in each class in accordance with its own group, then the percentages are 28.6, 35.7, and 35.7 respectively for each performance classification. If the same assumption is made for the G&Ts group, then the percentages are 9.1, 36.4, and 54.5 respectively for each performance classification. Making the comparisons on each group's own base shows that the IOUs have significantly more of the firms in their subset at maximum efficiency as compared to the G&T group on its own base. Each subgroup appears to have approximately the same number of firms improving over time. However, there is a large difference in the number or percentage of firms in decline expressed on their own respective bases. More of the G&T group (54.5%) is in a period of declining performance between 1988 through 1997 than the IOU group (35.7%). Based on these comparisons, it appears that the IOUs are outperforming the G&Ts over this horizon.

Other Comparisons

Each of the 25 DMU values for each of the variables utilized in this study was arranged in numerical order, ranging from low to high. The ranking of this array was assigned a numerical value from 1 to 25 with the lowest value equal to 1 and the highest value equal to 25. Each firm was assigned a rank according to this analysis. The median value for a particular variable was the DMU or firm with the rank of 13. This data sorting and ranking was completed for each firm for each variable for the years 1988 through 1997. Key select variables were selected for comparison purposes for 1988, 1992, and 1997 from the longitudinal data set. The variables selected for consideration were those associated with firm size (full-time electric employees, installed generating capacity, installed transmission circuit miles, energy sold in megawatt-hours, maximum kilowatt system demand, net system generation, total electric revenue and total electric cost). The total electric cost per megawatt-hour and total electric revenue per megawatt-hour also were included in this ranking. It was expected that those firms that were the most efficient over the 10-year horizon would likely be those firms that were the largest in size. Five firms or DMUs were observed to be the most efficient over the horizon in this longitudinal analysis. These firms were classified as those firms that remained the same at 100% from 1988 through 1997. All five DMUs in this most efficient firm set or group had rankings greater than or equal to the median for maximum kilowatt system demand, net system generation, and total electric revenue. Four of the five firms in this class had rankings greater than or equal to the median in full-time electric employees, total electric cost, and total electric cost per megawatt-hour. Four to five of these same firms had rankings greater than or equal to the median in 1988, 1992, and 1997 in installed generating capacity, energy sold in megawatt-hours, and electric revenue per megawatt-hour. Size and economies of scale appeared to be important in the most efficient performance for these five firms.

The same comparison was made for those firms that were classified as declining in performance over the horizon. Seven to eight of these 11 firms had rankings less than median for the years 1988, 1992, and 1997 in net system generation, installed generating capacity, energy sold in megawatt-hours, maximum system demand in kilowatts, full-time electric employees, and total electric revenue. Five to six of these 11 firms had rankings less than the median in total electric cost, installed transmission circuit miles, total electric cost per megawatt-hour, and total electric revenue per megawatt-hour over the same period. The majority of the firms observed to be in decline were in the small firm size classification.

The utilities included in the sample contained various types of plant generating capacity. Major differences in the overall utility systems were observed with respect to the size, age, and fuel choice for the respective generating units. The size and age of individual units were not collected or included in this study. However, the total system installed net generating capacity utilized in this study was developed from summarizing the individual generating type classes for each system and/or DMU. For the firms that remained the same over the horizon, it was observed that three (DMU10, DMU19, and DMU25) of the five DMUs supplemented their coal and gas and/or oil-fired generation with nuclear generation capacity. In addition, three (DMU17, DMU19, and DMU25) of the five firms utilized some hydro generating capacity in their mix. DMU25 also has included pumped-storage generating capacity as a part of its available installed generation.

The firms declining in performance over the horizon were primarily coal-fired generation. In addition to their coal-fired generation, some firms were gas and/or oil-fired generation systems. Two (DMU20 and DMU22) of the 11 firms had nuclear capacity;

three firms had some hydro capacity; and one firm (DMU18) had pumped storage generation. The most efficient firms appeared to have a more diverse set of generation types for operating and serving their load requirements.

An electric utility in serving its system load requirements typically utilizes its own system-installed generation capacity to meet its own load requirements. From time to time, it may choose to supplement its own generation resources by purchasing energy from others, either to meet its own needs or to reduce its costs if it is economical to do so. In other situations, it may choose to sell its own generation capacity and energy to others if it has surplus capacity and energy. In looking at the firms that remained efficient over the horizon for 1988, three of the five DMUs were able to meet their own energy sales requirements from their own installed net generation. Two (DMU19 and DMU25) of these five firms were meeting their load requirements with their own capacity and also buying and selling energy in the market. By 1997, it was observed that all five firms were utilizing their own capacity to meet their load requirements and also buying and selling in the market. The overall level of the buying and selling transactions was higher in 1997 than in 1988. In making a similar comparison with the firms declining in performance over the horizon, it was observed that seven of the 11 firms were able to meet their total electric energy sales with their own installed generation. Four firms (DMU4, DMU9, DMU12, and DMU24) were meeting their load requirements with their own capacity and also buying and selling energy in the market. However, in 1997 all 11 firms were utilizing their own capacity to meet their load requirements and also buying and selling in the market. The overall level of the buying and selling transactions was higher in 1997 than in 1988.

The relative cost positions of these two classes of firms were considered for the beginning (1988), middle (1992), and end (1997) of the study horizon. The researcher expected that the firms that remained the same, i.e., the most relatively efficient firms, would be low cost and fall in the range from the lowest cost (rank 1) up to and below the median (rank 13) for all costs ranked from low to high value. It was observed that for these three periods, one to two of the five DMUs fell within this range for total cost per megawatt-hour. However, three of the five firms were ranked above the median. Similar findings were observed for fixed costs per megawatt-hour in this class. The fixed costs included in this category were taxes, interest, A & G expenses, and depreciation. The variable costs per megawatt-hour also were determined for these firms as the sum of the non-fuel operating and maintenance expenses and fuel and purchased power expenses divided by the energy sold in megawatt-hours. Three of the five firms were found to fall in the lower range. The electric revenues per megawatt-hour and electric profits per megawatt-hour also were determined and ranked. The researcher expected that the most relatively efficient firms also would be the firms that would be in the upper range from the median (rank 13) to the highest values (rank 25) for both electric revenue per megawatt-hour and electric profit per megawatt-hour. For the three periods, four to five of the five firms were observed to fall in this class, as expected.

The researcher also expected firms found to be declining over the horizon to be in the high cost, low revenue, and low profit ranges. Six to seven of the 11 firms (depending on the year) in the declining-over-the-horizon class were observed to be in low cost positions for total cost per megawatt-hour, fixed costs per megawatt-hour, and variable costs per megawatt-hour. However, six to seven of the 11 firms were observed to fall in the low range of electric revenue per megawatt-hour and electric profit per megawatt-hour. This observation conformed with the expectation. It appears that the rate structures of the respective firms for both classes have a major influence on the profitability of the DMUs within this study. The management of the most efficient firms appears to be able to support, justify, and maintain their profitability and efficiencies.

External Market Analysis and Validation

Stock Prices

Fourteen of the DMUs represented in the sample of 25 electric utilities were IOUs. Investors usually have an opportunity to invest in these companies by buying shares of their respective common stock through the stock market. The common stock prices for these firms were gathered for the years 1988 through 1997. The data were provided through the efforts of Mr. Rick Crabtree and the researchers at A. G. Edwards and Sons, Inc. The high and low stock price values for each of the IOUs were collected for each year. An average stock price was calculated for each firm utilizing these data. The 14 IOUs in the sample are listed as follows: DMU6, DMU7, DMU8, DMU10, DMU13, DMU14, DMU15, DMU16, DMU17, DMU18, DMU20, DMU21, DMU24, and DMU25. It was observed that DMU8, DMU13, and DMU15 were not traded directly in the stock market; they are subsidiaries of American Electric Power (AEP) Company, Inc. The parent company, however, is traded in the stock market. DMU18 also was found to be not traded directly in the stock market; however, it is a subsidiary of Allegheny Power Systems, Inc., which is traded in the stock market. It was decided to utilize the parents of these respective firms as proxies for this analysis. Allegheny and AEP were treated as DMU30 and DMU 31 respectively along with the other firms for this analysis.

The overall performance of the IOUs was made by calculating a mean for the group for each year from 1988 through 1997. A.G. Edwards also provided the annual high and low values for the Dow Jones and Utility indices for the same period. Arithmetic mean values were calculated for each index. The groups' mean performance was compared with the Dow Jones mean index and the Utility mean index for the same horizon. The value for each of these data series is shown in Table 47. In order to provide a more meaningful comparison of these series, each of these data series was normalized by calculating each series on a 1988 base or per unit basis. The result of this analysis is shown in Table 48.

Analysis of the data series in the 1988 base tabulation shows clearly that the Dow Jones Mean Index was more robust than the other series. The Dow Jones Mean Index grew to more than 3.6 times its 1988 value from 1988 through 1997. On the other hand, the Utility Mean Index increased more than 1.35 times its 1988 value in the same horizon. The IOU Group Mean, however, increased more than 1.38 times its 1988 value in the same period. It is observed in this analysis that the IOU group and Utility mean performances tracked closely and in the same general trend throughout the horizon.

An analysis was performed comparing the average stock price for each firm with the IOU group mean from 1988 through 1997. The results of this analysis are shown in Table 49.

Each firm's average stock price for each year was compared with the IOU group average stock price. A firm's performance was considered to be above average when its average stock price was greater than the IOUs group average performance. Firms considered to be the best performers were those with average stock prices greater than the IOU group average over the 1988 through 1997 period. DMU31 and DMU25 were the

Table 47

Comparison of IOU Group Mean with Dow-Jones and Utility Mean Indices Over Time

Year	Dow-Jones Mean Index	Utility Mean Index	IOU Group Mean
1988	2020.53	178.23	23.42
1989	2468.11	208.75	25.38
1990	2684.29	212.46	26.24
1991	2825.82	210.54	29.85
1992	3261.33	213.07	28.42
1993	3519.09	236.70	29.67
1994	3761.82	200.90	26.57
1995	4530.55	203.73	28.64
1996	5812.02	221.36	29.13
1997	7327.99	241.01	30.41

Table 48

Comparison of IOU Group Mean with Dow-Jones and Utility Adjusted Mean Indices Over Time

Year	Dow-Jones Mean Index	Utility Mean Index	IOU Group Mean
1988	1.000	1.000	1.000
1989	1.222	1.171	1.086
1990	1.329	1.192	1.140
1991	1.399	1.181	1.283
1992	1.614	1.195	1.241
1993	1.742	1.328	1.307
1994	1.862	1.127	1.128
1995	2.242	1.143	1.197
1996	2.876	1.242	1.233
1997	3.627	1.352	1.385

Table 49

Best In Performance Over Time

Year	DMU31	DMU8*	DMU13*	DMU15*	DMU25	IOU Group Mean
1988	27.8				23.2	23.4
1989	29.6				25.8	25.4
1990	29.6				27.3	26.2
1991	30.4				33.6	29.9
1992	32.8				35.3	28.4
1993	36.2				40.2	29.7
1994	32.3				35.1	26.6
1995	39.4				38.3	28.6
1996	41.7				40.1	29.1
1997	45.6				39.1	30.4

* DMU8, DMU13, and DMU15 are subsidiaries of DMU31.

best performing IOUs in this analysis. Their respective average stock prices were greater than the IOU group average over this period. It is important to note that DMU31 is the parent company for DMU8, DMU13, and DMU15; these three subsidiaries were not traded in the stock market. However, these three firms are considered to be best performers as their parent or proxy organization is publicly trade in the stock market.

Firms with average stock prices below the IOU group average in the first several years of the study and improved to move at or above the IOUs group average stock price throughout the remainder of the study period were considered to be improving in performance over time. The firms (DMU6, DMU16, DMU14, and DMU21) shown in Table 50 are ranked in order from most to least performance improvement.

Several firms were observed to be declining in average stock price performance over the horizon. These firms are listed in Table 51. DMU24 and DMU17 have

Table 50

Improving in Performance Over Time

Firm	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Four Years Below Average – Six Years Above Average										
DMU6	21.7	22.1	21.4	24.8	28.4	31.5	27.3	33.0	38.1	39.3
Five Years Below Average – Five Years Above Average										
DMU16	19.1	19.4	19.4	23.8	26.3	30.2	26.9	28.3	28.8	34.6
Four Years Below Average – Four Years Above Average One Year Below Average – One Year Above Average										
DMU14	22.8	24.2	25.3	29.4	34.2	36.6	31.8	34.3	26.4	34.4
Four Years Below Average – Three Years Above Average One Year Below Average – Two Years Above Average										
DMU10	15.3	20.6	22.8	27.3	29.6	34.2	31.1	25.2	30.6	30.8
Eight Years Below Average – Two Years Above Average										
DMU21	12.8	15.6	16.4	16.9	22.3	23.3	24.3	27.6	31.0	35.8
IOU Group Mean	23.4	25.4	26.2	29.9	28.4	29.7	26.6	28.6	29.1	30.4

experienced above average performance as compared with the IOUs group average for nine and eight of the years, respectively. However, their performance has declined in 1996 and 1997. DMU7 and DMU30 have experienced several alternate periods of higher than average and lower than average performance with respect to the IOUs group average from 1988 through 1997.

Table 51

Declining In Performance Over Time

Firm	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Nine Years Above Average – One Year Below Average										
DMU24	28.0	29.8	30.6	38.2	32.3	33.7	28.9	31.4	34.9	25.9
Eight Years Above Average – Two Years Below Average										
DMU17	32.9	36.9	38.6	43.0	32.8	38.6	37.3	39.9	22.8	23.6
Four Years Above Average – Four Years Below Average Two Years Above Average										
DMU7	26.7	28.4	29.9	34.0	24.4	26.8	24.3	27.3	30.9	35.6
Four Years Above Average – Three Years Below Average One Year Above Average – One Year Below Average										
DMU30	38.7	39.1	38.1	40.7	45.1	25.9	23.1	25.4	29.6	29.1
DMU18 **										
Four Years Above Average – Six Years Below Average										
DMU20	35.5	38.6	41.7	47.2	26.1	28.6	22.9	22.2	23.8	21.6
IOUs GRP MEAN	23.4	25.4	26.2	29.9	28.4	29.7	26.6	28.6	29.1	30.4

** DMU18 is a subsidiary of DMU30 and is not traded in the stock market. Since its parent DMU30 has been selected as its proxy, DMU18 also is considered to be declining in performance over this 10-year period.

Comparison of Stock Price Performance With DEA CCR-I Performance

In order to provide for an independent validation check on the former DEA CCR-I input-oriented model performance, the results of the stock price performance and the

DEA CCR-I performance were compared. The performance results for the electric utility firms are summarized in Table 52.

Most Efficient Over Time Comparison

DMU25 was observed to be most efficient over time in both the DEA and stock price comparison. The DEA analysis found DMU10 to be most efficient while the stock price comparison considered it to be improving over time. DMU7 and DMU17, considered to be best performers in the DEA analysis, were found to be declining in performance over time in the stock price analysis.

These two firms, DMU7 and DMU17, were part of separate mergers with their respective holding companies with other firms. The stock market reacted with a downturn in stock prices as a result of these new strategic plans based on perceived uncertainty and risk associated with those ventures.

Improving Over Time Comparison

DMU14 and DMU21 were observed to be improving in performance over time in both the DEA and stock price analysis. It is interesting to observe that DMU8, DMU13, and DMU15--found to be improving over time in the DEA analysis--were observed to be best performers in the stock price analysis. Proxy DMU31 in the stock price analysis represented these three DMUs.

Declining Over Time Comparison

DMU18, DMU20, and DMU24 were found to decline in performance over time in both the DEA and stock price analyses. It is interesting to note that DMU16 and DMU6 were observed to be improving in performance over time in the stock price analysis.

Table 52

Comparison of DEA CCR-I Model Rating and Stock Performance

DEA CCR-I Model Longitudinal Results		Stock Price Performance Results
Most Efficient Over Time		Best Performers Over Time
G&Ts	IOUs	IOUs
DMU19	DMU7	DMU31 (proxy)
	DMU10	DMU13
	DMU17	DMU15
	DMU25	DMU25
Improving Over Time	Improving Over Time	
G&Ts	IOUs	IOUs
DMU3	DMU15	DMU6
DMU12	DMU14	DMU16
DMU5	DMU21	DMU14
DMU11	DMU13	DMU10
	DMU8	DMU21
Declining Over Time	Declining Over Time	
G&Ts	IOUs	IOUs
DMU22	DMU16	DMU24
DMU23	DMU18	DMU17
DMU2	DMU20	DMU7
DMU1	DMU24	DMU30 (proxy)
DMU4	DMU6	DMU18
DMU9		DMU20

Note: DEA CCR-I input-oriented longitudinal analysis included both G&T and IOU firms.

Overall Summary Comparison

Overall six of the 14 IOUs or approximately 43% of the IOUs were found to exhibit the same performance class trend in both the DEA and stock price analyses. Two

DMUs in the most efficient class of the DEA analysis were found to be in the declining performance stock price class. One DMU in the most efficient DEA class was observed to be in the improving performance stock price class.

Two DMUs were found to be improving in performance over time in both the DEA and stock price classes. The other three DMUs in the DEA improving over time class were observed to be in the best-performers-over-time stock-price class.

Three DMUs were found to be declining in performance over time in both the DEA and stock price analyses. The other two DMUs in the DEA declining class were observed to be in the stock-price-improving-performance-over-time class.

It is interesting to observe that IOU firms found in the DEA improving-performance-over-time and declining-performance-over-time classes were situated in a higher class in the stock price comparison. The exception to this finding is the DEA most-efficient-over-time class. The IOU firms found in this class were observed to be one to two classes lower in performance over time in the stock-price comparison. The similarities observed in the stock-price analysis compared favorably with the DEA analysis. The stock price analysis utilized the high and low stock market price or valuation exclusively in the assessment of firm performance. This model is not as robust or inclusive as the DEA analysis. The DEA analysis appeared to be more robust and valid than the latter method. However, The stock price analysis appeared to confirm many of the DEA analysis findings.

CHAPTER 6

CONCLUSION

Efficiency Models

Performance for the firms in this study was a relative efficiency measure as described in Chapter 2. This performance measure was developed using the CCR-I input-oriented data envelopment analysis model. A select key list of input and output variables was determined for an electric utility firm and employed within this model. The relative efficiency of each firm in the sample was determined within this model framework. The relative efficiency performance value for each firm fell within a range from a minimum of zero to a maximum value of one. The model resulted in determining the relative performance of each firm and target recommendations or changes in the respective input variables. The management of the firm may consider these recommendations in improving its performance.

One of the primary goals of this study was to determine a single overall performance measure for use by the management of an organization. This model provided a basis for making this assessment. This model provides management with the ability to select its competitors and to rank itself with its competition.

This model also was utilized to assess firm performance among a full sample of 25 midwestern electric utilities as a cross-sectional analysis for the years 1988, 1992, and

1997. This full sample of 25 electric utilities was composed of investor-owned electric utilities and rural electric generation-and-transmission cooperative utilities. Some of these firms were combination gas and electric utilities and some were fully integrated generation, transmission, and distribution electric utilities. This model process enabled comparison of these diverse groups as described in Chapter 3.

The cross-sectional analysis resulted in determining those firms or decision-making units (DMUs) that were most efficient, relatively speaking, and those that were relatively inefficient. The cross-sectional analysis found three firms to be relatively inefficient and 22 firms to be relatively efficient as described in Chapter 4. The target improvements suggested by the model for management's consideration also provided a process for benchmarking and continuing performance improvement for those organizations that choose to utilize this performance assessment tool and process.

This same model was utilized to find firm relative efficiency over the 1988-1997 horizon. A three-year moving-average window was incorporated into this analysis. It was possible to determine firm performance for each year in the horizon as well as to assess trends in firm performance over time. The longitudinal analysis enabled the researcher to determine trends in firm performance. It was possible to compare trends in performance among all firms in the sample. In comparing performance trends, the researcher identified firms whose performance remained the same over the horizon. Five firms or DMUs were observed to have performance trends that remained relatively efficient at 100% from 1988 through 1997. Nine firms' trends in performance were observed to be improving over this same horizon. Eleven firms' performance trends were observed to be declining over the 1988 through 1997 period. All of these trends, firm performances, and the recommended target improvements for these respective firms were discussed more fully in Chapter 4.

It also was possible to assess performance differences between the two subgroups in the 25-firm sample. The investor-owned utility (IOU) subgroup and rural electric generation-and-transmission cooperative (G&T) subgroup were identified and compared in both the cross-sectional and longitudinal analyses in this study. Target improvements also were recommended for firm management consideration. The relatively inefficient firms and recommendations offered in the cross-sectional analysis were also identified and made in the longitudinal analysis of this study. The most relatively inefficient firms identified in the cross-sectional analysis also were found to be the most relatively inefficient firms in the longitudinal analysis.

The performance histograms and cumulative relative frequency distributions considered in this study were skewed toward the upper most relatively efficient performance value of 100%. No relative efficiency value was found below 70%. The results of this analysis conformed to Troutt et al.'s (1996) findings with respect to maximum efficiency ratio models. These findings suggest that the management of the firms will take the initiative to make rational improvements in operations and management of the firm to maximize performance.

Limitations

The 25-firm sample selected for this study was a judgment sample as referred to by Babbie (1994) and not a random sample. The results, therefore, of this study can not be generalized to electric utilities, whether they are IOUs and/or G&Ts. The results found are valid and applicable only to those firms included in the sample and respective subgroups. While this fact is true, the findings in this study are deemed to be important and worthwhile. Although they cannot be applied directly to other firms and organizations, they do provide additional information on measurement and assessment of electric utility performance. The findings, however, provide firm management with ideas and alternatives for consideration in conducting other studies and in operating their organizations.

Contributions

This study provides additional background, investigation, analyses, and direction for other researchers and managers of electric utilities in assessing firm performance. This study demonstrates that a single firm performance measure can be developed and applied to the electric utility industry to assess the firm and its competitors' performances. Under the assumption of constant returns to scale, the study model provided target improvements for the relatively inefficient firms to enhance their performances. These targets provide firms' management with valuable information and insight to the potential areas and directions for making decisions and resource allocation adjustments. Successful implementations of these measures enable the firms to achieve greater profitability and continuous improvement.

Theory Development

Previous research studies reviewed in Chapter 2 and shown in Table 4 considered various key input variables for the respective organizations utilized in their respective samples. However, the input variables selected did not represent a complete selection of the critical inputs utilized by the firm required to explain the transformation process. The input variables in this study as shown in Table 4 account for the total costs of the firm. The expense components necessary to track and explain both the fixed and variable expenses of the firm on an annual basis are tracked. Such treatment enabled the researcher to assess fixed costs as well as variable costs of production and operation. Key system characteristics are also included in this study that allowed the researcher to evaluate and assess the size and investment capacity of the respective firms with respect to both its generation mix and transmission system delivery.

The key output variables considered by prior studies are not adequate to account for the key outputs for electric utilities. This study considered total kilowatt-hours of energy sold, maximum kilowatt system demand, total electric revenue, and net generation in kilowatt-hours for each respective firm on an annual basis. The use of total revenue as a key output with the total expenses as inputs enabled the researcher to determine net margins and various component unit costs and revenues or rates among the sample sets. The other studies' variable sets were much smaller and deficient to account for this capability.

Firms considered in this study consisted of both the electric production and transmission delivery system side of the business for investor-owned utilities and rural electric generation-and-transmission firms. The other studies are concerned primarily with the study and evaluation of organizations of like kind. While this is commendable for research, the inclusion of mixed organizations in the sample served to provide representative sample organizations that a firm and its management considered as its competitors in a industry market environment undergoing transformation and change. In addition, this study is more pervasive and inclusive than prior studies. This study considered a cross-sectional study of utility firms in 1988, 1992, and 1997 and a longitudinal study of the same firms over the 1988 through 1997 horizon. Other studies found in the literature search section of this report undertook either cross-sectional analyses or longitudinal analyses separately. This study undertook both types of analyses to investigate firm and subgroup performance. It was demonstrated in this study that both types of analyses should be used in evaluating firm performance. Each type provides different insights as to individual and competitor performance and improvements. However, the results of both types of analysis reinforce and support one another.

In order to provide reliability and validity checks on the DEA analyses in this study, a separate maximal decision efficiency model, the MER model, was implemented to test and compare with the DEA CCR model results. The other studies did not utilize this type of verification and validation analyses in their approaches. An external market analysis and comparison utilizing common stock prices and performance was utilized in this study as an independent check on the DEA CCR model approach and results. The results of this independent market performance evaluation supported the results and findings of this study. The other studies did not provide this level of independent validity analyses.

A single relative efficiency measure was developed for measuring and assessing firm and competitor performance. Target improvements were developed within the model as a means for moving relatively inefficient firms to the most efficient frontier.

Industry Practice

This study has direct application in the electric utility industry and is relevant today. The electric utility industry is being de-regulated, re-regulated, and is concurrently moving to a more competitive environment. Firms in competition with one another need to be able to measure and assess their performance in relation to one another. Management needs models, tools, information, and insight to help focus and direct its attention and efforts to continuously improve its performance. The key to survival and competitive advantage is being able to diagnose, measure, assess, and proactively manage its firm and resource allocations toward its best advantage. This study was concerned with finding ways and means to assist firm management with these objectives and goals.

This study incorporated the DEA CCR input-oriented model utilizing a robust set of input and output variables that account for the fixed and variable electric production and operation costs of the firm and its demand, energy, and electric revenue. These variables enable management and the firm to study and evaluate its input resource levels and to assess its own performance. Management of the firm has control over the allocation, use, and distribution of its resource levels in meeting its output requirements and goals. The model incorporated in this study determined recommended target changes in the respective resource inputs for management to consider to improve the performance and relative efficiency of its own firm. Management has the ability to study and consider relative changes in its resource inputs and to evaluate the relevant impacts on its firm as well as its competitors. Such a model enables management a more direct way to consider the consequences and implications of resource decisions in its strategy.

The use of the CCR-I input-oriented model approach to firm performance measurement provides management of the firm with the ability to benchmark its own firm with respect to itself and with its competitors over time. Such a capability provides management with supplemental information and the identification of specific performance issues. Management then has the ability to examine and further evaluate these particular issues for the future welfare of the firm and its customers. The use of such a model and information enables management to pursue a course of continuous improvement to ensure its survival and continued success.

Research Extensions

The existing model and variable set should be extended into the future by updating the annual data set and repeating the analyses. The continued application and use of this process and effort would begin to provide an ongoing measurement and evaluation process for management of the firm to use in making resource allocation decisions and planning.

The CCR-I input-oriented model approach utilized in this study was undertaken assuming constant returns-to-scale for the firms in this sample. The returns-to-scale should be investigated to further refine this study and its results. The results of the literature search presented in Chapter 2 investigated several other DEA models, including the BCC model and maximum efficiency ratio models, such as the FMER model. It would be interesting and informative to study the existing 25 firms in the 1988 through 1997 horizon to determine if these other models may account more explicitly for firm performance or performance differences.

The FMER model as developed by Troutt and Zhang (1993) appears to offer several additional opportunities in exploring the performance of both relatively efficient and inefficient firms. In utilizing this model to validate the CCR-I model, it was observed that the FMER model appeared to be more discriminating in assessing firm relative efficiency performance. In that analysis, a few firms were observed to be fully efficient while more firms were observed to be relatively inefficient. It certainly would be of interest to perform a similar set of analyses on a cross-sectional and longitudinal basis for these 25 firms. It would appear that such joint use of the two models to measure and assess firm performance levels would afford management greater opportunity to investigate and resolve specific performance related input and output variable adjustments.

It is further interesting to observe that with continued de-regulation and movement to competition in this industry, several other possible changes are being considered for the future. There appears to be renewed interest in mergers, acquisitions, and consolidations. New competitive organizational entities are emerging as a result of changing regulatory and legislative measures. Some of these are the birth of the independent power producer (IPP), the electric wholesale generator (EWG), independent system operators (ISOs), and the state-wide and area-wide development of power exchanges and transmission-pooling arrangements. These new types of organizations are enabling existing conventional electric firms, as well as others, to alter and rethink their business mission, roles, strategies, and customer base. It is possible for such firms to consider sell-off of their generation and/or transmission assets to other third parties or to enter into mutual contracts and agreements with other entities. These types of possible options and alternatives enable individual firms and firm alliances to actively think outside of the box and seriously consider making adjustments as suggested by the target model results to enhance and improve their performance. Such actions and options historically might not have been possible or even considered heretofore. This suggests that researchers and those in search of theory development and enhancement have a great opportunity. There appears to be a need to assist managers in finding ways to model and evaluate changing industry structural patterns and providing those directly involved with additional insight. These directions enable management to have an enhanced opportunity for continuous improvement and provide insights for assessing future strategic decisions.

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APPENDICES

APPENDIX A

Electric Utility Deregulation - An Overview

Electric Utility Deregulation – An Overview

The electric utility industry has experienced many changes in its regulatory environment over the past century. In fact, the United States Congress has enacted six major laws concerning the electric utility industry. These six federal laws are shown in Table 1, entitled "Significant Electric Industry Legislation" (Binz, Feiler, & McFadden, 1997, p. 26).

The Public Utility Holding Company Act of 1935 (PUHCA) and The Federal Power Act of 1935 (FPA)

The PUHCA and FPA legislation were passed in order to regain control of the electric utility industry and to begin to restore competition to the industry by limiting the formation, size, market power, and dominance of large electric utility companies. These legislative acts also placed the large electric utilities under the jurisdiction of the Securities and Exchange Commission for interstate electric business matters.

The Public Utility Regulatory Policies Act of 1978 (PURPA)

> Forty-three years after PUHCA and FPA, PURPA was passed in Congress. PURPA opened the door to competition in the U.S. electricity supply market. Under Title I, utilities and State regulators were required to consider energy conservation in their resource planning. Title II required utilities to purchase electricity from qualifying facilities (QFs) and defined QFs as either (1) generating plants that use cogeneration technology or (2) generating plants of less than 50 megawatts capacity that use renewable technologies. An important provision of the legislation was that it required utilities to pay their own avoided generating cost

Table 1

Significant Electric Industry Legislation

The Public Utility Holding Company Act of 1935 (PUHCA)

PUHCA was enacted to break up the large and powerful trusts that controlled the nation's electric and gas distribution networks. PUHCA gave the Security and Exchange Commission the authority to break up the trusts and to regulate the reorganized industry in order to prevent their return. Several statutory exemptions to PUHCA's regulations removed impediments to the development of a competitive generation market: The Public Utility Regulatory Practices Act of 1978 and the Energy Policy Act of 1992.

The Federal Power Act of 1935 (FPA)

This act was passed at the same time as the PUHCA. It was passed to provide for a Federal mechanism, as required by the Commerce Clause of the Constitution, for interstate electricity regulation. Prior to this time, electricity generation, transmission, and distribution was almost always a series of intrastate transactions.

The Public Utility Regulatory Policies Act of 1978 (PURPA)

PURPA was passed in response to the unstable energy climate of the late 1970s. PURPA sought to promote conservation of electric energy and the generation of electricity from more efficient technologies renewable sources of energy. PURPA created a new class of non-utility generators, small power producers, and qualified cogenerators, from which utilities are required to buy power.

The Energy Tax Act of 1978 (ETA)

This act, like PURPA, was passed in response to the unstable energy climate of the 1970s. The ETA encouraged conversion of boilers to coal and investment in cogeneration equipment and solar and wind technologies by allowing a tax credit on top of the investment tax credit. It was later expanded to include other renewable technologies. However, the incentives were curtailed as a result of tax reform legislation in the mid-1980s.

The Clean Air Act Amendments of 1990

These amendments established a new emissions-reduction program. The goal of the legislation was to reduce annual sulfur dioxide emission by 10 million tons and annual nitrogen oxide emissions by 2 million tons from 1980 levels for all man-made sources.

table continues

Table 1 (continued)

Generators of electricity will be responsible for large portions of the sulfur dioxide and nitrogen oxide reductions. The program (instituted under the Clean Air Act Amendments of 1990) employs a unique, market-based approach to sulfur dioxide emission reductions, while relying on more traditional methods for nitrogen oxide reductions.

<u>The Energy Policy Act of 1992 (EPACT)</u>

This law created a new category of electricity producer, the exempt wholesale generator, which circumvented PUHCA's impediments to the development of non-utility electricity generation. The law also allowed FERC to open up the national electricity transmission system to whole suppliers.

Source: EIA/DOE, "The Changing Structure of the Electric Power Industry," 1992. (cited in Binz et al., 1997, p. 26)

(or the avoided cost of acquiring the energy from another utility) for power purchased from QFs. (Energy Information Administration, 1997b, p. 3)

The states had a difficult time in trying to determine the value of avoided costs, and, thus, opened generation capacity to competitive bidding. The results of the competitive bid solicitation process provided the mechanism for determining the utilities avoided costs. This practice resulted in creating a new set of incentives and opportunities to stimulate new institutional, technical, and economic diversity in the generation of electricity. PURPA allowed organizations other than public utilities to sell electric power (Energy Information Administration, 1997b, p. 3).

<u>The Energy Tax Act of 1978 (ETA)</u>

The ETA was passed to provide additional incentives beyond the investment tax credit to organizations for the conversion of boilers to coal and investment in cogeneration equipment and renewable technologies.

The Clean Air Act Amendments of 1990 (CAAA)

Acid rain is formed largely from emissions of sulfur dioxide (SO_2) and nitrogen oxide (NOx) which are produced by the burning of fossil fuels as a part of the electric power production process.

> The SO_2 reduction provisions of Title IV of the CAAA90 (hereafter referred to as Title IV) are noteworthy and creative because they represent the first large-scale attempt to set overall emissions levels by using marketable licenses (allowances) and a choice of compliance methods to control emissions rather than using regulations that specify what actions must be undertaken (command and control). An allowance permits the emission of 1 ton of SO_2. Title IV gives electric utilities several options for reducing emissions, thus introducing flexibility into compliance plans. (Energy Information Administration, 1997a, p. 1)

Further:

> The primary goal of the Acid Rain Program, which will be instituted in 2010, is to reduce annual SO_2 emissions from electric utilities to a level that is 10 million tons below the 1980 level. Emission allowances serve as the mechanism for compliance. Each affected unit is allocated its allowances based on its baseline fuel consumption. The baseline is calculated from the average yearly fuel consumption for the period 1985-1987. In Phase I, allowances are allocated at the rate of 2.5 pounds of SO_2 times the number of mmBtu consumed in the baseline. In Phase II, allowances are allocated at the rate of 1.2 pounds of SO_2 times the number of mmBtu consumed in the baseline. (Energy Information Administration, 1997a, p.

61)

The legislation also requires a reduction of 2 million tons of NOx emissions from utility boilers. In its effort to reduce both SO_2 and NOx emissions, the CAAA was to be implemented in two separate phases. The first phase (Phase I) was to be for the period 1995 through 1999, and the second phase (Phase II) was for the period 2000 and beyond. The Phase I annual limits were set at the rate of 2.5 pounds per million Btu of SO_2 times the fuel consumed in million Btu in the baseline. The NOx levels for Phase I were set at 0.50 and 0.45 pounds per million Btu of fuel consumed in the baseline for dry bottom, wall-fired, and tangentially fired boilers, respectively. Phase II SO_2 levels were reduced to the rate of 1.2 pounds per million Btu of fuel consumed in the baseline. The EPA asserted that it would review NOx levels previously set in Phase I. It also was determined that cell-fired and cyclone-fired boilers exempt in Phase I would come into compliance in Phase II (Energy Information Administration, 1997a, p. 61).

<u>The Energy Policy Act of 1992 (EPACT)</u>

This legislation established a new class of electricity suppliers as an exempt wholesale generator (EWG). The EWG is exempt from the normal and customary cost-of-service regulation requirements that public electric utilities follow. This legislation also amended the Federal Power Act and required that utilities provide wholesale power transmission service to third parties at cost-based rates, even if so doing requires them to expand their transmission capacity. A third provision empowered the Federal Energy Regulatory Commission (FERC) with the responsibility for implementing open-access transmission to foster competition in the wholesale power market. FERC, in discharging its responsibilities, has the authority to approve wholesale power agreements including prices and regulatory review of mergers and acquisitions (Energy Information Administration, 1996, p. 3).

In order to fulfill its responsibilities, FERC required utilities to file nondiscriminatory transmission tariff schedules when seeking approval for market-based wholesale prices. FERC hoped that this highly visible action and requirement would encourage utilities to compete fairly, equitably, and in a nondiscriminatory manner. On April 24, 1996, FERC passed the following two major landmark orders:

1. Order No. 888 - Promoting Wholesale Competition Through Open Access Nondiscriminatory Transmission Services by Public Utilities and RM97-7-001 Recovery of Stranded Costs by Public Utilities and Transmitting Utilities, and
2. Order No. 889 – Open Access Same-Time Information System (formerly Real-Time Information Networks) and Standards of Conduct.

In passing these orders, FERC had the following three objectives in mind: to further the cause of fair and open access to the transmission network; to provide a mechanism for recovery of "stranded costs"; and to improve the operation of a competitive electricity market through the creation of a "same-time" information network (Energy Information Administration, 1997b, pp. 3-4).

Competition and Industry Restructuring

Variations in Electricity Prices

There exists within the U.S. a wide variation in the prices for electricity. Deregulation is intended to promote competition for the supply, transportation, and delivery of electricity throughout the country. The move to competition should reduce barriers to entry and provide an open competitive market where supply and demand will enable market-based prices to prevail. There also is a wide variation in the prices of utilities' customer classes, especially between their respective wholesale and retail customers. Large industrial customers usually are considered as wholesale customers primarily due to their high demand and energy requirements. Retail customers are all of the remaining customers of the electric utility.

Market Forces Impact Wholesale Electric Services

Large industrial customers are attempting to become involved in the wholesale electric supply market. Such customers who are located in high-cost states are lobbying and seeking competitively priced power to meet their requirements. International global competition is putting tension on all major suppliers to lower their costs in order to compete and maintain market share.

> Industrial consumers have been even more aggressive than their residential counterparts. Since energy costs are approximately 5 percent of most manufacturers' total operating costs (and as much as 30 percent in such energy-intensive industries as aluminum processing and steel making), manufacturers have significant incentives to reduce their energy bills. Raytheon is a multibillion-dollar company and one of the largest employers in Massachusetts. Like many U.S. manufacturers since the late 1970s, Raytheon has been losing market share to lower-cost domestic and international competitors. It has threatened to move much of its manufacturing out of state unless Boston Edison grants it markedly lower rates. Companies in many other industries have adopted similar tactics, including switching to lower-cost suppliers by municipalizing. (Weiner, Nohria, Hickman, &

Smith, 1997, p. 23)

Sudden loss of jobs, revenues, taxes, and other flow of funds can cause severe hardship on communities and states that lose substantial customers. To the extent that large industrial customers are successful in reducing their electric costs, other customers served from the same power supplier will be expected to make up the difference in higher electric rates.

The high-cost states will attempt to reduce their costs to the national average. From where will the electric supply at the lower rates come? The existing low-cost states with surplus capacity will seek to sell their electricity to the higher-cost states. Such a move will enable the firms in low-cost states to increase their market share and profits. The customers served in the low-cost states will likely see their electricity costs increase in order to attract new capacity to meet their growing energy requirements.

The source of power supply enabling a competitive market to develop will likely be the present low-cost power supply available primarily in the Midwest. The same organizations that are the primary targets of acid rain and NOx regulations and stiffer requirements will be encouraged to operate at full capacity to supply the competitive market. The Northeast States have voiced opposition, claiming that the pollution situation will get worse in these areas and the fallout in emissions will create more severe environmental conditions in their own backyard (Shields, 1997). They are calling on FERC to intervene in this matter.

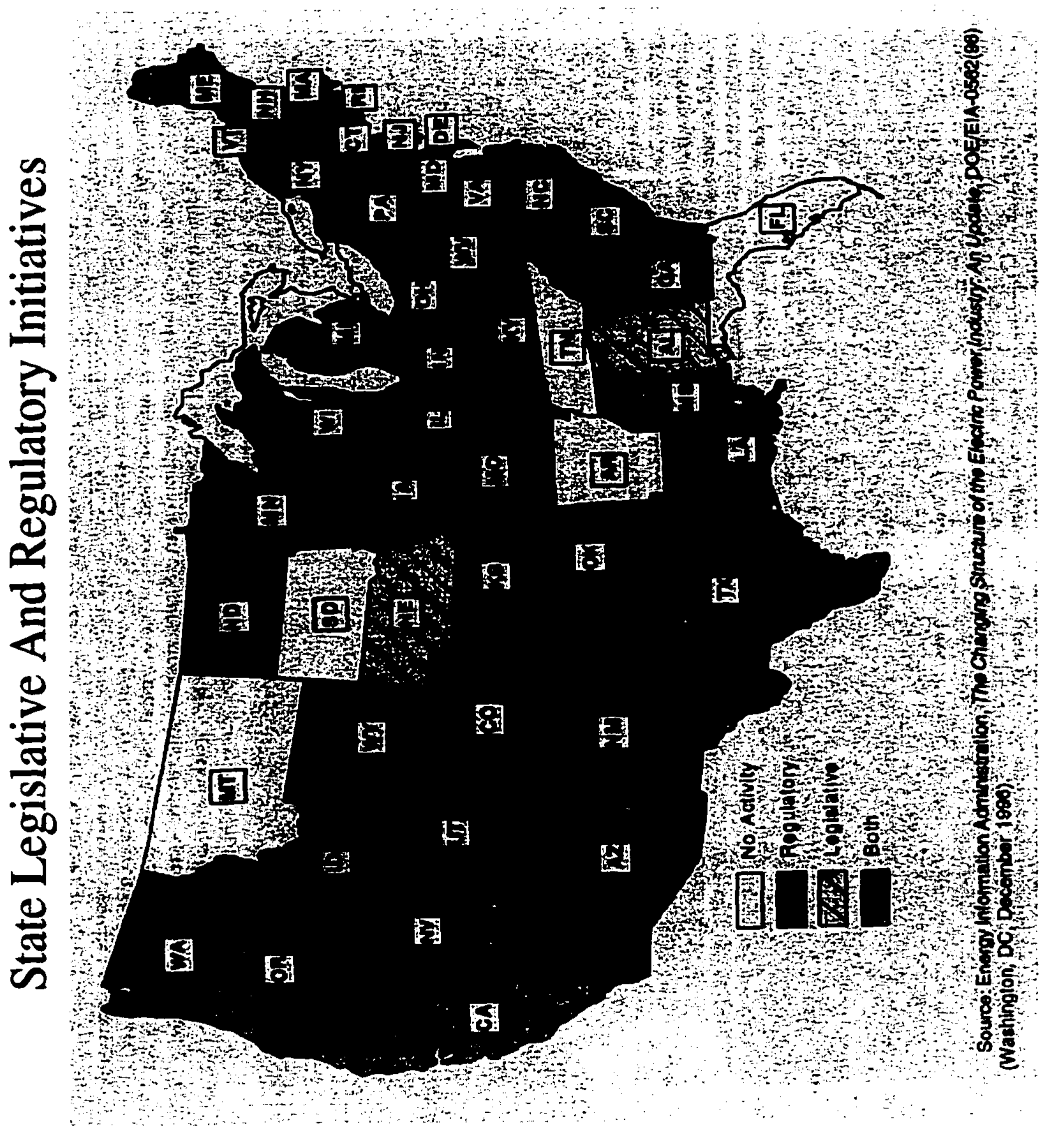
With the push to free and open competition, many are concerned that fewer and larger electric utilities will become the rule rather than many suppliers being available with no one exercising substantial market power. FERC is currently reviewing its oversight role in the review and approval of all utility mergers and acquisitions. Reliability continues to be a major concern with the nature of the transmission systems and network as it exists. In order to handle the transactions contemplated, major enhancements will be necessary to upgrade the electrical transmission networks. Responsibility for investment, engineering, construction, managing of the network and reliability are all outstanding issues yet to be addressed.

State Legislative and Regulatory Initiatives

Figure A1 shows an overview of the status of state legislative and regulatory initiatives for each of the 48 states in the U.S. as of December 1996. It is interesting to observe that only five states are undertaking no activity:Montana, South Dakota, Arkansas, Tennessee, and Florida. Nebraska and Alabama are in the process of pursuing legislative initiatives. Eighteen states are in the midst of regulatory reviews: Washington, Idaho, Utah, Wyoming, North Dakota, Iowa, Missouri, Wisconsin, Michigan, Indiana, Kentucky, West Virginia, Maryland, Delaware, Vermont, Louisiana, Georgia, South Carolina, and North Carolina. The remaining 24 states, as shown, are in the process of both legislative and regulatory review of open-access competitive electricity environment. The interest and motivation for moving to open-access competition are being seriously considered across the U.S. from both a state legislative and regulatory perspective.

Electricity As A Commodity

Electricity, as a product that is virtually sightless, tasteless, and indistinguishable across suppliers, is readily achieving recognition as a commodity. Electricity can be purchased, sold, and transacted much like wheat, barley, corn, and other commodities. With the movement to commodity status comes the ability to trade as a marketable commodity hour-to-hour as well as to develop futures for trading purposes. Electricity



SOURCE: DOE/EIA -0614 Electricity Prices In A Competitive Environment: Marginal Cost Pricing Of Generation Services And Financial Status Of Electric Utilities (August 1997); p. 5.

Figure A1. State legislative and regulatory initiatives.

spot prices are volatile, meaning that severe weather and power interruptions cause wide swings in price and availability.

Evolution of Electricity Commodity Market

With the birth and growth of a electricity commodity market, new classes of competitors have entered into this developing business. The new classes of competitors are marketers and brokers who have entered the business as middlemen with the hopes of building new business and enjoying profits in a new environment. These marketers and brokers have to file for an application with FERC to become brokers and to do business as wholesale organizations. It is interesting to see that the utilities also are separating their unregulated business interests from their traditional electric utility business and entering into this new market opportunity.

With the growth and transition of the competitive electricity market and the pressures of the environment, many companies are choosing to divest from their generation business and move into other areas. Some firms are growing larger with the idea that economies of scale and gains in efficiency can help them become leaders in the new competitive environment.

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