NRRI-84-15

A DECISION SUPPORT SYSTEM FOR UTILITY PERFORMANCE EVALUATION

Luc Anselin
Assistant Professor of City and Regional Planning

J. Stephen Henderson
Senior Institute Economist

THE NATIONAL REGULATORY RESEARCH INSTITUTE
2130 Neil Avenue
Columbus, Ohio 43210

April 1985

This report was prepared by The National Regulatory Research Institute (NRRI) with funding provided by participating member commissions of the National Association of Regulatory Utility Commissioners (NARUC). The views and opinions of the authors do not necessarily state or reflect the views, opinions, or policies of the NRRI, the NARUC, or NARUC member commissions.

EXECUTIVE SUMMARY

The need to construct operational instruments to evaluate the managerial performance of electric utilities has recently received considerable attention from the regulatory community. In a previous National Regulatory Research Institute (NRRI) report (Anselin, Pike, Smith (1981), The Measurement of Electric Utility Performance: Preliminary Analysis), an overview of several traditional methodologies to achieve this was presented (management audits, financial and engineering indexes, econometric studies), and a new technique based on multicriteria decision analysis was suggested. In this report, the decision analytic method for performance evaluation is considered in more detail, and compared to the more traditional approaches of a total factor productivity index (TFP) and econometric cost function estimates.

Utility performance evaluation is considered as part of a decision support system, i.e., the combination of an information system (data base) and a set of operational decision rules (performance indexes). As part of this decision support system, an extensive data base was constructed from several sources, containing data on 210 variables for 123 privately owned electric utilities over the period 1964-1981.

Multicriteria evaluation techniques, such as the analytic hierarchy process and concordance analysis, and economic techniques, such as a total factor productivity (TFP) index and the residual analysis of econometric short- and long-run cost functions are discussed in detail with respect to their methodological and theoretical foundations. They are also implemented empirically on a common data base, and compared with respect to the resulting performance rating of the companies.

In general terms, the information provided by the different performance indexes can be classified into four distinct categories, each of which measure a different aspect of overall performance. The groupings are: (1) traditional and multilateral (across companies) dynamic TFP index; (2) a multilateral static TFP index and residual analysis based on long-run cost functions; (3) residual analysis based on variable cost functions (short-run); (4) subjective multicriteria performance indexes. None of these four categories can be considered as "best" since they differ considerably in terms of underlying theoretical foundations, data needs, and cost of implementation. They also typically result in contradictory conclusions with respect to the performance rating of a particular company. In other words, while the different measures within the same category lead to similar conclusions, the results based on measures in different categories are dissimilar.

This does not preclude the consideration of different techniques as tools in tracking the comparative performance of a number of companies under the jurisdiction of a commission. In fact, it is rather encouraging in this respect that there is little empirical evidence for the claim that the performance measures are not related to managerial efficiency, but rather to exogenous factors beyond a utility's control.

It therefore is suggested that a performance measure should be integrated in the full regulatory context, and that a collection of measures can be used as short-cut indicators of several aspects of company performance. In order to be useful in the context of incentive regulation or rate hearings, it would be necessary to supplement them with more detailed information such as that provided by a management audit. Also, their adoption may involve considerable institutional adjustment and changes in regulatory practice.

TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES--Continued

FOREWORD

Utility performance evaluation continues to be a difficult subject, but it is not one that is impervious to objective analysis. This study is in the vein of attempts to construct operational utilities. It employs in detail the decision analytic, multicriteria approach and compares it with the more traditional approaches of total factor productivity indexes and econometric cost function estimates.

This study is primarily for the technically oriented reader, but policy applications are not ignored. We believe it to be an important advance in the measurement of utility performance and offer it as a fresh contribution to that debate.

Douglas N. Jones
Director, NRRI
April 19, 1985

ACKNOWLEDGMENTS

The authors wish to thank Standard and Poor's Compustat Services Inc. for providing, free of charge, part of the data used in this study. Also, we wish to acknowledge the useful comments and suggestions given by the participants in the May 1984 Workshop/Seminar, particularly Mr. Michael Foley (NARUC), Mr. Enver Masud (Iowa State Commerce Commission), and Dr. Orman Panaanen (New Mexico State University). The graduate research assistants who carried out part of the data collection and other support efforts associated with this project deserve recognition as well. They are Martin Cristo, Paul Infanger, Kyubang Lee, and Adam Prager. Finally, we wish to thank Jan Hilt, Karen Myers, and Shirley Simonton for their efforts in typing this manuscript.

CHAPTER 1

INTRODUCTION

The need to construct operational instruments to evaluate the managerial performance of electric utilities has recently received considerable attention from the regulatory community. In particular, given the concerns about cost control and the interest in incentive regulation, it is important to be able to assess and enforce the existence of "efficient" management. An "ideal" measure to evaluate utility performance should be objective (in the sense of uncontested by the different parties involved), easy to construct, readily available, and specific to managerial actions (i.e., free from so-called exogeneous effects, outside of management control). In an operational context, it is also important that the performance index, when incorporated in regulatory actions, does result in changes in the managerial performance of the utility in the desired direction, and does not create unexpected (and unwanted) side effects.

In a previous NRRI report by Anselin, Pike, and Smith (1981), The Measurement of Electric Utility Performance: Preliminary Analysis, an extensive literature survey and discussion of several traditional methodologies to measure utility performance were carried out. Three commonly used techniques were considered in that report: management audits, econometric techniques, and engineering indexes. Also, a less familiar methodology was introduced, based on multicriteria decision analysis. In the present report, the decision analytic techniques are studied more closely. To some degree, it can be considered to be an extension of the previous work in that several ideas suggested there are implemented empirically and compared in more detail from an operational point of view.

The particular point of departure taken here is to consider utility performance evaluation as part of a decision support system, i.e., the combination of an information system (data base) and a set of operational decision rules (performance indexes). The main objective of the study is to further analyze, discuss, assess, and compare two types of techniques: (1) the traditional economic indexes, based on a total factor productivity measure and the residual analysis of econometric cost functions; and (2) the decision analytic techniques, based on a subjective but structured assessment of the relative importance of a range of performance indicators. Although part of the empirical work deals with the rating and ranking of electric utilities based on actual data, this rating is not a primary objective of the study. Therefore, throughout the study, the identity of the companies involved is not revealed. In addition to avoiding possible controversy (related to the accuracy of the data, the presence of particular situations, the interpretation of the results, etc.) this allows the primary attention to be focused on the methods themselves, the underlying theoretical foundations and assumptions, and the potential for implementation in a regulatory context.

In order to be able to compare the different techniques empirically in a consistent way, an extensive data base was constructed from several sources, containing data on 210 variables for 123 privately owned electric utilities over the period 1964-1981. The data base is described in detail in appendix A to the report (a more extensive discussion of the data base is also contained in Anselin et al., Data Base Description, which was released as Work Note DSS84-1 in January 1984 and revised in May 1984).

The report itself consists of three main parts, which are to some extent self-contained. In Part I (chapters 2-4), the conceptual framework of the decision support system is outlined and the multicriteria techniques are discussed in detail. In addition to a methodological treatment, an empirical application is carried out. In Part II (chapters 5 and 6), the more traditional economic techniques, such as TFP indexes and the use of econometric cost functions are treated from a theoretical point of view as well as implemented empirically. In Part III (chapters 7 and 8), the two types of approaches are compared from a methodological point of view, and also in terms of the resulting company ratings, based on an empirical implementation on a common data set.[1]

In addition to the discussion contained in this report, the current study also requested and generated considerable feedback from the regulatory community. In order to assess the operational usefulness of the different techniques, a seminar/workshop was organized on May 21-22, 1984 in Columbus, Ohio. More than forty commission staff members from over twenty different states participated. This generated the primary input used in the implementation of the subjective multicriteria performance indexes. Also, several speakers (not associated with the NRRI project staff) were invited and presented additional perspectives on performance evaluation and its incorporation in regulatory practice, in the form of discussion papers, and by participating in a panel discussion. A brief description of these activities is presented separately, as appendixes H and I to this report.

Several of the results contained in this report were disseminated in preliminary form at several points in time during the term of the project. Three work notes made available the discussion of the data base (WN DSS84-1, Anselin et al., May 1984), the conceptual framework and the theory behind the multicriteria techniques (WN DSS84-3, Anselin, May 1984), and the results of the empirical implementation of the subjective techniques (WN DSS84-5, Anselin, August 1984). Dr. Anselin presented part of these results in an address to the Southeastern Association of Regulatory Utility Commissioners, at its meeting in Nashville, Tennessee in May 1984. Finally, both Dr. Anselin

---

[1]Chapters 5 and 6 were written by Dr. J. Stephen Henderson, the rest of the report was written by Dr. Luc Anselin.

and Dr. Henderson each presented a paper at the Fourth NARUC Biennial Regulatory Information Conference in September 1984 in Columbus, Ohio. These papers (Anselin, "A Decision Support Framework for Regulatory Evaluation of Electric Utility Performance"; Henderson, "Estimating Short Run Cost Functions for Electric Utilities") have been published in the Conference Proceedings (NRRI, 1984).

PART I

DECISION ANALYTIC TECHNIQUES

CHAPTER 2

A DECISION SUPPORT SYSTEM FOR REGULATORY PERFORMANCE EVALUATION--THE CONCEPTUAL FRAMEWORK

Introduction: The Problem and Approach

In this chapter, the initial conceptual framework for a decision support system for electric utility performance evaluation is outlined, with a focus on the multicriteria decision techniques in particular. Performance evaluation is seen against the background of cost control and the enforcement of "efficient" management, i.e., that with the given inputs a maximum output is obtained, or, more appropriately for the electric utility industry, that the output demanded (mostly assumed to be exogenous) is reached with the "optimal" combination of inputs at the lowest possible cost. To obtain a measure for the extent to which costs are controlled, an appropriate index for the overall efficiency of the operation of the electric utility is necessary--to assess the performance of its management in an absolute sense (at one point in time or over a period of time), as well as relative to that of other utilities operating in a similar environment. In the next chapter, the construction of such an index, using several possible multicriteria decision techniques, is considered more closely. In this chapter, the emphasis is on the conceptual framework.

It should be noted that in this study the major emphasis is on the design of an evaluation tool, a decision support system, which consists of two main parts: a data base and a set of operational decision rules. Also, the primary focus is on the comparison of several methodologies to carry out performance evaluation, and not on the "ranking" or "rating" of specific utilities per se. In this respect, the flexibility of the decision support framework is stressed, in order to take into account the lack of homogeneity among utilities (the "comparability" issue) and among regulatory commissions (as reflected in the different priorities mentioned in a survey of commissions in Anselin et al., 1981) as well as for the framework to operate in a dynamic and often highly political environment.

In particular, the focus is on multicriteria decision analytic techniques, even though the other approaches discussed in this report, such as total factor productivity measures and econometric cost function analysis can easily be encompassed within the general framework outlined here.

A Conceptual Framework for Utility Performance Evaluation

In this section, a general abstract framework is outlined, that forms the conceptual basis for a decision support system for regulatory evaluation of utility performance. The framework has a modular structure, as schematically shown in figure 2-1, where each of the modules represents a set of actors, concerns, methods, results or actions. In general terms, it consists of four major parts, each of which can be considered as different phases in the regulatory process of evaluating performance. The first part forms the general background and results in the "regulatory perspective." The second part contains a formal representation of this perspective in terms of the structure of a relevant data base and the analysis of the relevant preference structure. The third part contains the methodology to analyze the available information in order to obtain a ranking or rating of the utilities considered. The final part depicts how the resulting ranking or rating is translated into specific regulatory actions. Each of these major parts is briefly discussed below.

A critical factor for successful application of an evaluation exercise is to consider the problem in the proper decision context. In

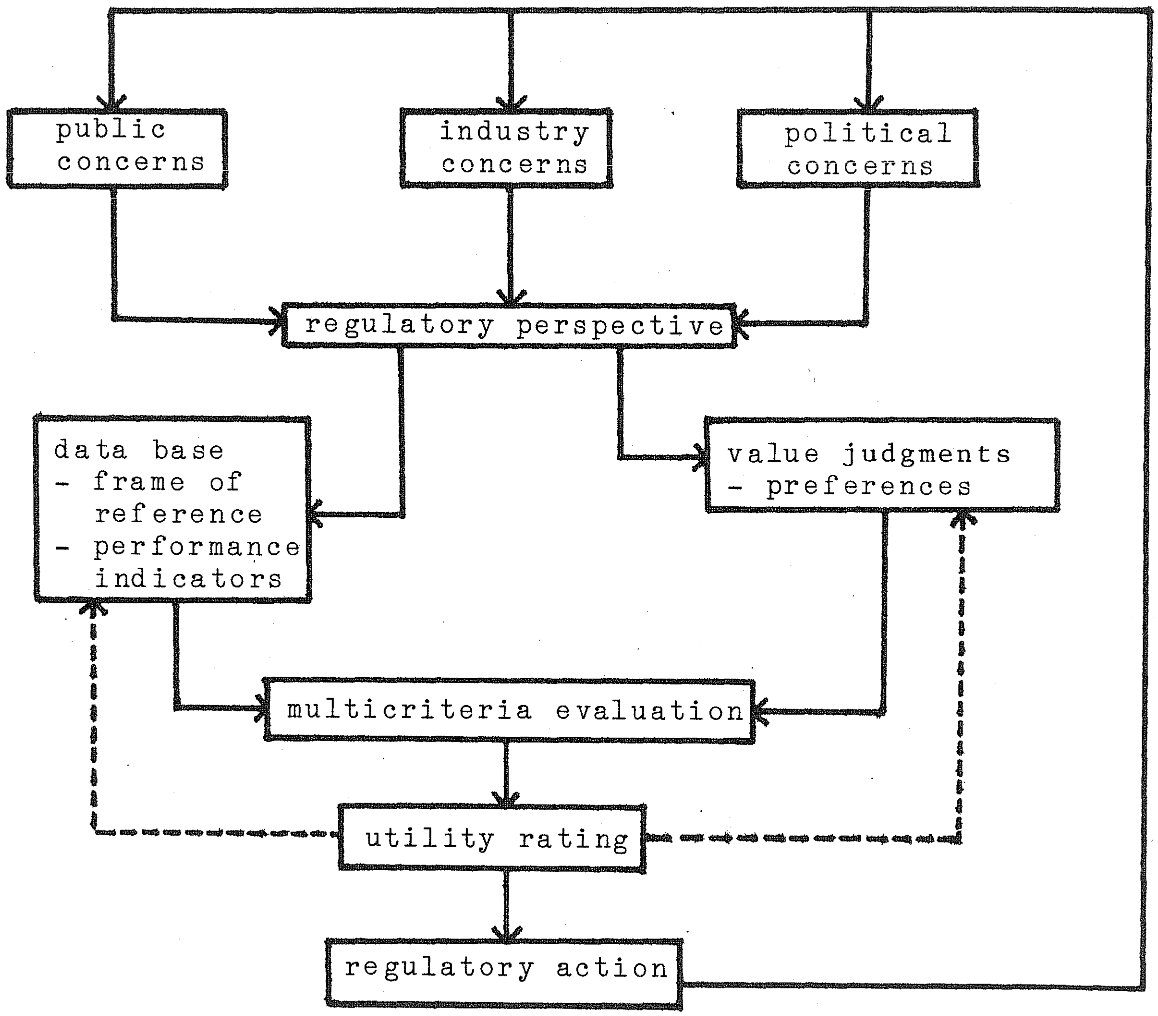

Fig. 2-1. The general conceptual framework

the framework outlined here, this is termed the "regulatory perspective," which is obtained from the combination of several concerns and the awareness of problems and issues, as expressed by the public at large, industry groups, political representatives, etc. It also forms the set of constraints (legal, budgetary, political, time) within which the evaluator or decisionmaker (a commissioner and/or a commission technical staff) has to operate. The regulatory perspective will typically vary from state to state and from situation to situation. It is important for a decision support system designed to evaluate utility performance to be flexible with respect to this variety in concerns and priorities. This is achieved here by making the regulatory perspective the basis for the determination of the overall structure of the data base and for the expression of value judgments, which form the second phase in the modular structure.

The two main aspects of the data base, i.e., the frame of reference and the set of relevant indicators (variables), are directly related to the decision context, or regulatory perspective. The frame of reference determines how many and which companies will be considered and what the time dimension of the analysis will be, both in terms of extent (i.e., dynamic evaluation versus static evaluation) and of frequency (yearly, quarterly, monthly). The relevant variables form the raw information necessary to implement the evaluation technique considered. It should be noted that the existence of resource constraints and/or problems with obtaining relevant and current information are considered to be part of the decision context (the regulatory perspective). In that sense, they may limit the extent of the data base as well as the type of methodology in which it can be applied (e.g., the quality of measurements--ratio scale, ranking--determines the multicriteria techniques that can be used). The other aspect in the second phase of the evaluation process consists of a formal analysis of the value judgments expressed by or inferred from the decisionmaker(s) or evaluators(s). This may consist of an explicit derivation of a utility or preference function, or a less complex expression of weights, priorities, rankings, etc. These value judgments pertain to the choice of the evaluation method and the awareness of the evaluation criteria used.

The data or indicator values are combined with the formal preference structure in the third phase, utilizing a multicriteria evaluation technique (or another performance measurement approach) to result in a rating or ranking of the performance across several utilities at one point in time, or for one company across time. The iterative and interactive nature of the multicriteria methods allows for a feedback loop, in the sense that the information obtained from the performance rating may lead to considering additional indicators, a different time period, etc., or may result in a modification of the preferences and/or weights used in the analysis. This inherent flexibility emphasizes the use of these techniques as decision aids or tools, in that their main object is to clarify the different dimensions involved and to help the decision maker or evaluator in reaching a conclusion in a consistent and structured fashion.

Finally, the rating or ranking obtained may form the basis for regulatory action, for example, leading to a management audit, or resulting in the formulation of specific incentive targets, or a decision in a rate case. This regulatory action will feed back into the general environment and influence public, industry and political concerns, which may in their turn influence the regulatory perspective or decision context. The whole results in a dynamic and flexible framework.

CHAPTER 3

MULTICRITERIA METHODS FOR PERFORMANCE EVALUATION: A BRIEF OVERVIEW

Multicriteria Evaluation Analysis and Performance Indexes

A performance, productivity, or efficiency index (in general terms) provides a measure of how the transformation process of inputs (labor, capital, materials, fuels) into outputs (electric power generation, transmission, distribution) is carried out by a firm (or, more narrowly, by a decision-making unit). In the context of the regulated electric utility, where production levels (output, service area) and rate of return can be considered as being largely exogenous, the interest focuses on the managerial performance with respect to the total cost of service. In other words, the ideal performance index should provide a measure of the extent to which an "optimal" (minimal) cost level is achieved, as a result of managerial decisions only, in isolation from other factors (regional fuel costs, regional wage levels, historical accidents, climatic elements, population density, terrain, etc.).[1]

---

[1]The degree of exogeneity of some of these variables (in particular the fuel costs and wage rates) is not necessarily uniform across the industry and has been the topic of substantial debate. The reader should note that in this report two different viewpoints have been implemented. On the one hand, the company-specific average fuel cost has been included in the list of financial and engineering ratios (and hence assumed to be at least partly endogenous) that are used to form the subjective performance indexes reported on in chapter 5. This is based in part on the results of the survey of commission staffs carried out in the previous NRRI report on this subject (Anselin et al. (1981)). On the other hand, following common practice in econometric analysis, the fuel cost and labor cost variables in the cost functions of chapters 6 and 7 are taken to be exogenous.

One of the basic issues in obtaining an overall performance rating or ranking of electric utilities is the necessity to combine several sources of information in a meaningful way into a summary measure. In addition to the more traditional use of statistical and econometric techniques (as discussed in chapters 5 and 6), this problem can also be approached from a decision analytic viewpoint, as an application of multicriteria evaluation analysis (for detailed overviews of these techniques, see for example Bell et al. (1977), Changkong and Haimes (1983), Cohon (1978), Fishburn (1978), Hinloopen et al. (1983), Keeney and Raiffa (1976), Rietveld (1980), Saaty (1982), Voogd (1983), Wierzbicki (1983), and Zionts (1978)). The more recently developed multicriteria analysis involves not only choosing the appropriate variables, measures, and units, but also assessing weights and priorities among these measures, in order to achieve a summary index.

When only one indicator of performance is considered (e.g., total cost per kilowatt-hour or revenue per kilowatt-hour), or when there is a clear common unit of measurement that can be used to convert several variables into an overall index (e.g., through the use of prices and monetary units), it becomes fairly straightforward to rank utilities according to this one criterion or index, either on their relative performance, or on the evolution (change) of their individual performance over time. A well-known example of this is the use of a total factor productivity index, discussed later in this report, in which a measure is obtained of the change in the number of units of aggregate output that can be produced with an aggregate unit of input. In order to obtain such an index, it is necessary not only that the relevant inputs and outputs be included (i.e., the identification of the relevant indicators), but also that assumptions be made about the proper aggregation mechanism and the calculation of prices and unit costs. Although based on a considerable body of microeconomic theory, these assumptions often involve considerable judgment by the analyst and may not always reflect the proper behavioral framework for a regulated utility (e.g., the existence of considerable economies of scale, or reactions to rate of return regulation--Averch-Johnson effect--of "satisficing" behavior and X-inefficiency, etc.). An alternative way of obtaining an overall performance or efficiency index is through the application of shadow prices derived within an optimization framework that uses a notion of an efficiency frontier, in the so-called data envelopment analysis (DEA) developed by Charnes and Cooper (see Banker (1980), Banker et al. (1981), Bessent et al. (1982), and Charnes et al. (1978, 1981, 1982)). Although this technique allows the incorporation of inputs and outputs for which no clear market prices exist (e.g., quality and reliability of service), the determination of the shadow prices directly from the data is basically a "black box" approach for which the decision maker(s) or evaluator(s) does not necessarily have a clear understanding of the underlying assumptions and limitations.

The multicriteria evaluation approaches focus more specifically on the issues of commensurability and trade-off assessment--in other words, on how to convert the different variables into comparable units (e.g., to simultaneously compare number of employees, annual generation, service reliability, etc.) and on how to assess the relative weights or priorities of the resulting indicators. The techniques are viewed as flexible decision tools in which the subjective aspects of the evaluation are made more explicit, and the preferences, priorities, and other judgments of the decision maker(s) or evaluator(s) are incorporated in a consistent and structured framework. The evaluation problem is viewed as that of constructing a multi-attribute preference ordering of a set of utilities according to a number of criteria. These criteria either measure overall performance directly and contribute to the overall index in different degrees (reflected in the weights) or measure particular subcategories of performance (such as quality of service, financial and technological efficiency), which in their turn may contribute to the overall performance in different degrees. The full process can be conceptualized in a structured framework as a hierarchy of indexes (or measures) where each measure contributes to a certain degree to the higher order measures. From this point of view, the multicriteria techniques can be considered as a complement to an engineering or financial "ratio" analysis of utility performance, in that they provide a tool to meaningfully summarize the information provided, in a flexible manner, in line with the particular "regulatory perspective" at hand.

Several procedures exist to carry out the multiple criteria evaluation in an operational way. They vary with respect to the extent of required direct involvement of the decision maker(s), the degree of mathematical sophistication, the quality of measurement needed and the computational difficulty. The approaches include simple and straightforward a priori specification of weights, the use of pairwise comparisons along an ordinal scale (leading to discordance and concordance matrices), or along a psychometric scale (as in the analytic hierarchy process), as well as the use of multiple interviews with the decision maker(s) to elicit their preference function(s) in multiple dimensions (multi-attribute utility functions). In the next section, a brief overview of a number of techniques is provided, illustrated by a simple hypothetical example, to allow the reader to follow the transition from the methods to their application in a regulatory setting.

Overview of Techniques

When several measures of performance are considered, e.g., earnings per share, power plant investment per unit of output, average rates, deviation of actual from forecasted costs, etc., it is seldom the case that the utilities considered achieve the same rank ordering across all measures. In fact, usually some utilities perform better on some of the criteria and less well on others so that the overall evaluation has to be constructed from several conflicting partial rankings. Two major methodological issues are important as a result of this: the standardization or normalization of all variables into comparable units, and the assessment of the relative importance of the different partial indicators with respect to the overall measure.

This section consists of three parts. First, the standardization issue is considered in more detail, several methods are outlined, and the data for the illustrative example are presented. Second, the analytic hierarchy process is discussed in detail and illustrated with the example. Finally, the same is carried out for the use of concordance and discordance methods. It should be noted that the methods presented here do not represent an exhaustive overview of possible multicriteria approaches, but are selected to illustrate a variety of issues--related to measurement, flexibility, ease of use--important within the context of regulatory evaluation of electric utility performance.[2]

The Basic Information: Impact or Evaluation Matrix

In order to focus the discussion on an applied regulatory context, a simple sample is used throughout, constructed from actual performance measures (technical and financial ratios) from the 1979 Annual Report of the Intercompany Performance Comparison Group (1980), which lists several indicators for twenty-one midwestern and northeastern utilities over a number of years. Four companies are considered (A-D), characterized by eleven partial performance indicators (ratios), and grouped into three main categories--"finance," "service," and "production." For finance, the four indicators used are "growth in earnings per share (4-year average)" (F1), "ratio of operating income to plant" (F2), "ratio of income available for common equity to common equity value" (F3), and "growth in ultimate customers" (F4). For service, the three indicators selected are "administrative and general expense per customer" (S1), "customer service and informational expense, per customer" (S2), and "customer accounts expense, per customer" (S3). Finally, the four indicators selected for production are "service area load factor (P1), "conventional steam station net

[2]For a more detailed review, see also the previous NRRI report on this subject (Anselin et al (1981)).

heat rate" (P2), "total capacity use factor" (P3), and "transmission and distribution expense per customer" (P4). The choice of these particular indicators and their classification is purely illustrative, and is only "realistic" to the extent that it is based (in general terms) on the results of a survey of commission staffs carried out in 1981 (see Anselin et al. (1981)). A more extensive set of indicators is used in the empirical application in chapter 4. Here the main intention is to illustrate the techniques and to show how they can be applied. The base information is organized in an impact matrix or evaluation matrix, which in our example lists the companies as the column headings and the indicators as the rows. The actual values for the four companies are presented in table 3-1, together with the maximum (M), minimum (m), and median values for the reference group, that is, all the companies for which results are contained in the IPCG report.

TABLE 3-1

IMPACT OR EVALUATION MATRIX, RAW DATA

Indicator*	A	B	C	D	M	m	median
F.1.(+)	10.0	10.2	3.7	6.1	10.2	-6.5	2.28
F.2.(+)	9.46	10.24	10.12	8.99	12.82	6.62	9.57
F.3.(+)	14.99	12.51	12.91	9.91	14.99	8.42	10.92
F.4.(+)	1.6	1.9	1.7	1.6	3.4	0.4	1.5
S.1.(-)	46.97	56.90	53.27	69.75	69.75	32.36	49.60
S.2.(-)	4.87	2.12	4.24	2.20	4.87	1.23	3.29
S.3.(-)	18.76	16.23	20.34	21.30	40.18	11.97	19.00
P.1.(+)	56.50	64.60	58.50	63.60	75.40	52.50	63.45
P.2.(-)	10390	11530	10250	10280	11530	9880	10530
P.3.(+)	46.89	49.93	57.78	45.92	71.48	26.77	45.35
P.4.(-)	44.31	57.25	52.61	54.99	66.16	35.41	49.38

*Note that for some of the financial ratios, the interpretation of the indicator as positive (+) or negative (-) may depend on the particular viewpoint taken (e.g., the viewpoint of the stockholder vs. the customer).

In addition, to illustrate the way in which the data can be transformed into more easily interpreted lower quality information (e.g., ranks, or purely qualitative judgments), the data are shown as ranks within the industry group, and within the four companies considered, as well as in terms of a binary statement of whether the company ranks above the industry median (=1) or not (=0). This information is presented in table 3-2.

TABLE 3-2

IMPACT OR EVALUATION RANKS

Indicator	Overall				Within Comparison				Above (1) or Below (0) the Median			
	A	B	C	D	A	B	C	D	A	B	C	D
F.1.	2	1	9	6	2	1	4	3	1	1	1	1
F.2.	11	5	8	12	3	1	2	4	0	1	1	0
F.3.	1	5	4	16	1	3	2	4	1	1	1	0
F.4.	10	5	7	9	4	1	2	3	1	1	1	1
S.1.	8	17	14	20	1	3	2	4	1	0	0	0
S.2.	20	5	17	6	4	1	3	2	0	1	0	1
S.3.	10	6	13	17	2	1	3	4	1	1	0	0
P.1.	15	9	13	10	4	1	3	2	0	1	0	1
P.2.	7	20	4	5	3	4	1	2	1	0	1	1
P.3.	9	6	3	10	3	2	1	4	1	1	1	1
P.4.	6	18	14	16	1	4	2	3	1	0	0	0

The example given above illustrates a common situation--where there is no clearly dominant or dominated company. In other words, no company rates as best on all criteria, nor is there a company that ranks lowest on all indicators considered. When the information is presented as in table 3-1, it becomes very difficult (especially in realistic situations with a larger number of indicators and/or companies) to carry out a holistic evaluation or ranking directly, without resorting to an implicit (in the mind of the evaluator) simplification. This may take the form of converting the data into ranks and summming the ranks, or of considering only the "best" performance for each indicator and adding up the number of times a company scores highest, or of still other ad hoc procedures. While these approaches may be appropriate in certain situations, they implicitly assume the equality of importance of the indicators, which does not seem reasonable in a large number of practical situations (for example, as reflected in the survey results reported in Anselin et al (1981)). Also, a lot of information may be lost in the process of converting the financial and other ratios into a lower order measure, such as a rank or a binary categorization. As a result, it is often more appropriate to carry out a procedure that formally and explicitly compares the (relative) importance of the different indicators or criteria. In order to implement this, it is necessary to express the data in the evaluation matrix (such as table 3-1) in comparable units, by constructing a normalized or standardized impact matrix.

Several approaches exist to obtain standardized values, based on statistical principles as well as on ad hoc considerations. A statistically straightforward procedure is to rescale each value such that each row in the impact matrix (for each indicator) has a mean of zero and a unit standard of deviation. This can be carried out by subtracting the sample mean from each value and dividing this result by the sample standard deviation. Alternatively, several procedures exist that transform the original data into a scale or index with positive values, less than 1 (or 100), or between 0 and 1 (or 100), with the new minimum as 0 and the new maximum as 1. Often, this implies that the data first have to be rescaled to be positive (by adding the largest absolute negative value to them), for example, when negative growth rates are present. The new normalized performance measure can be found by dividing all values by their observed maximum (which does not guarantee that the worst performance equals 0), or by dividing the difference between the original value and the minimum by the range (the maximum less the minimum). The latter is illustrated as "Rule 1" in table 3-3 for the data contained in the impact matrix of table 3-1.

Also, a relative standardized value can be obtained by dividing each value by the row sum (for each indicator), so that the resulting measures add up to one ("Rule 2" in table 3-3), or by the square root of the sum of squares of the row elements, so that the new measures have the same (unit) row length. It should be noted that all indicators or criteria considered should be expressed in the same direction; that is, a larger value indicates a better performance. For ratios related to cost criteria (for example, the indicators S.1-S.3), this implies that the standardized values have to be converted into their complements (i.e., subtracted from 1, or 100).

TABLE 3-3

NORMALIZED IMPACT MATRIXES

	Rule 1				Rule 2			
Indicator	A	B	C	D	A	B	C	D
F.1.	96.9	100.0	0.0	36.9	33.3	34.0	12.3	20.3
F.2.	37.6	100.0	90.4	0.0	24.4	26.4	26.1	23.2
F.3.	100.0	51.2	59.1	0.0	29.8	24.9	25.7	19.7
F.4.	0.0	100.0	33.3	0.0	23.5	27.9	25.0	23.5
S.1.	100.0	56.4	72.3	0.0	26.4	25.0	25.5	23.1
S.2.	0.0	100.0	22.9	97.0	21.2	28.1	22.8	27.9
S.3.	50.1	100.0	18.3	0.0	25.2	26.3	24.5	24.1
P.1.	0.0	100.0	24.7	87.7	23.2	26.6	24.1	26.2
P.2.	89.1	0.0	100.0	97.7	25.2	24.3	25.3	25.3
P.3.	8.2	33.8	100.0	0.0	23.4	24.9	28.8	22.9
P.4.	100.0	0.0	35.9	17.5	26.3	24.2	24.9	24.6

Still a different approach is to assess so-called value functions or utility functions, through a series of interviews with the evaluator. These functions are based on the choice between "lotteries" of outcomes, within the framework of Von Neumann-Morgenstern utility theory (see e.g., Bell et al. (1977), Edwards (1977), Hauser and Urban (1979), Keeney and Raiffa (1976), and Raiffa (1970)). This approach also can be used to simultaneously assess the valuation of the outcome (for an indicator) and the relative importance of the indicator with respect to the overall objective. Although mathematically more elegant than the procedures outlined so far, and especially appropriate in situations of nonlinear outcomes (or nonlinear valuation of the outcomes), the assessment of the value function is a tenuous and time consuming process. It also necessitates a high degree of mathematical sophistication from the evaluator or assessor. In addition, when a large number of indicators are considered, the approach tends to become unwieldy (for a discussion of practical issues and limitations, see for example, Edwards (1977), Hershey et al. (1982), Hobbs (1980), Newman (1977), Rowe and Pierce (1982b)).

The Analytic Hierarchy Process

The analytic hierarchy process (AHP) technique, originally developed by Saaty (1977, 1980, 1982) is one of the most flexible and easily implemented multiobjective-multicriteria decision techniques. It has found many applications in a wide range of management and planning problems, such as transportation planning, resource allocation, conflict resolution, strategic business planning and marketing, and urban planning (see, Saaty (1979, 1980), Saaty and Vargas (1982), Wind and Saaty (1980), Batty and Spooner (1982), Anselin and Arias (1983)). Specific applications in the energy field have dealt with energy rationing (Saaty and Mariano (1979)), regional energy planning (Blair (1979)), long-range planning for an electric power utility (Saaty (1980)), nuclear waste management (Saaty and Gholamnezhad (1982)), and relative performance evaluation of utilities (Anselin (1982)). The AHP technique is characterized by the description of a decision problem as a hierarchy and by the application of a specific measurement scale to obtain vectors of normalized weights or priorities, using pairwise comparisons.

In the context of this study, the construction of an overall performance index for a set of electric utilities can be organized as a system of subproblems, linked together in a hierarchical structure (schematically presented in figure 3-1). In this structure, overall performance is viewed as the focus, which is obtained through a combination of several criteria, each criterion with its own relative importance, weight, or priority with respect to its contribution to the overall focus. In the hierarchy, the top or the focus is the overall performance of the utilities considered, and the next level consists of the criteria used to measure the overall performance. For example, and in line with the illustration presented above, three broad criteria could be considered to be the most relevant in this respect: finance (that is, financial structure, income, and so forth), service (that is, customer relations, expenses, and so forth), and production (that is, technical considerations). Schematically, we can view it as the two highest levels in figure 3-1. We can now consider each of the criteria as a cluster (or grouping) to which several "indicators" contribute, each with its own relative weight or priority with respect to the particular criterion. In addition, a more flexible structure can be considered, in which some indicators contribute to more than one criterion. Schematically, this is presented in the interrelations between level 2 (the criteria) and level 3 (the indicators) in figure 3-1. To the extent that no direct observations exist for the indicators, or that the concepts involved are still at too abstract a level, a next level can be introduced, in which subindicators are related to the particular indicators to which they contribute. This process can be carried out until a structure is reached that is satisfactory to the evaluator in that it encompasses all the complexities and interrelations of the different indicators, criteria, etc. The last step in structuring the problem as a hierarchy is to consider the set of utilities as being compared with respect to each of the indicators or subindicators. Note that the choice of the set of utilities to be compared is not addressed here, and is left to the individual decision maker or evaluator. To obtain this, a preliminary analysis, either quantitative (using cluster analysis or econometric techniques) or qualitative has to be carried out to determine a set of utilities sufficiently similar with respect to the operating environment.

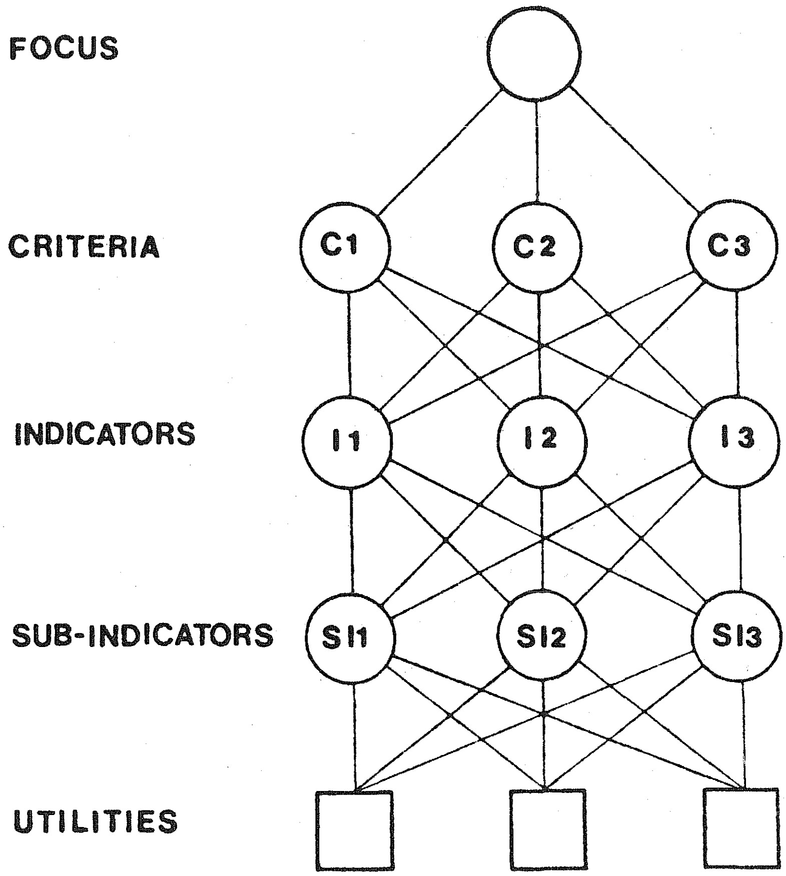

Fig. 3-1. Hierarchical structure of the evaluation process

However, the comparison is not necessarily limited to a cross section, since one utility can be analyzed with respect to its performance change over time. The result would then be an indicator of the performance in each time period relative to the other time periods.

In order to proceed from the hierarchical structure of the problem to a set of weights or priorities that reflect the relative strength of each element at a level in the hierarchy, with respect to the next higher level, a particular measurement scale is used, presented in table 3-4 (see also Saaty (1977) for a detailed discussion of the properties of the scale). This scale takes into account the psychological observation that people are limited to seven plus or minus two factors for simultaneous comparison (Miller (1956)). The scale is used to construct a pairwise comparison matrix, which expresses the strength with which one element, activity, or, in our example, utility dominates another as far as that criterion or indicator is concerned. As a result, the simultaneous ranking is broken down into a set of pairwise comparisons. Moreover, the strength of the AHP procedures lies in the fact that the matrix of pairwise comparisons is constructed without imposing strong requirements for consistency or transitivity of preference. In fact, a test for consistency can be carried out to allow the evaluator(s), in an iterative way, to change the values used.

The information contained in the matrix is transformed into a vector that reflects priorities or relative weights by finding the largest eigenvalue and associated eigenvector, normalized to have its elements sum to one. The overall priority vector is obtained by weighting the values found at each level in the hierarchy by their priority with respect to the next higher level, until the focus (or top of the tree) is reached (a detailed illustration of this process is presented in the appendix to the previous NRRI report on this topic (Anselin et al. (1981)), and a fully computerized implementation of the process is outlined in Anselin (1983)). The resulting vector (with values summing to one) reflects the relative priority of the utilities (or time periods) compared with respect to their overall performance.

TABLE 3-4

THE SCALE AND ITS DESCRIPTION

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	

Source: Saaty (1977), p. 246

The properties of the scale are such that the values obtained can be interpreted numerically (as a ratio scale) and not just as ranks. However, it should be kept in mind that the evaluation vector that is obtained depends to a crucial extent on the linearity of the approach, which may not always be appropriate. For example, in a simple application to variables that show extreme values the inherent nonlinearity will be largely ignored and may lead to misleading conclusions (see also the discussion in Johnson (1980)).
Another potential problem is that there is more than one way to obtain a vector of priorities from a pairwise comparison matrix (see Saaty (1980)). On the other hand, several experimental studies in psychology and management science have found that a linear approach is fairly robust in a wide variety of actual situations (for discussions see, e.g., Cook and Stewart (1975), Dawes and Corrigan (1974), Hobbs (1980), Newman (1977), Rowe and Pierce (1982a), Schoemaker and Waid (1982), Waid and Schoemaker (1981)).

The use of the AHP method as such to carry out electric utility performance evaluations has certain limitations. In particular, when a large number of companies is compared, the size of the pairwise comparison matrices necessary to carry out the evaluation for each indicator (lowest level in the hierarchy) becomes unwieldy. Also, to the extent that the data on the financial and other ratios contained in the impact matrix (such as in tables 3-1 or 3-3) are of a precise, quantitative nature, there is a loss of information resulting from converting the base data to pairwise comparisons.

Therefore, we propose to use AHP primarily as a means to organize the criteria and indicators and to obtain their relative weights. These weights can then be used to construct a performance index by weighted summation of the standardized elements of the evaluation matrix (table 3-3). The resulting index will be between one hundred (if the company rates best on all indicators) and zero (if the company rates as worst on all), and can be used in a cross-sectional framework as well as to compare the evolution of aggregate performance (as defined by the criteria and indicators considered) over time.

This approach is now illustrated using the data for the example presented above. First, the three criteria, finance, service and production, are compared with respect to their importance for the overall focus (performance evaluation). The resulting 3x3 pairwise comparison matrix and 3x1 priority vector are given in table 3-5, together with the values for the dominant eigenvalue (λ), the consistency index (CI), and consistency ratio (CR), (for a detailed illustration and interpretation, see Anselin et al. (1981)). Next, the specific indicators are considered with respect to the criteria, which for finance and production results in a 4x4 matrix, and for service in a 3x3 matrix. The results are presented in table 3-6. The whole is summarized in figure 3-2, which also shows the resulting overall weights for each indicator (obtained from multiplying the partial weight of the indicator-criterion by the partial weight of criterion-focus). The overall weights can now be used to construct the performance indexes. They are presented in table 3-7 (with the resulting ranking in parentheses) for three cases: the first and second columns show the indexes for the two normalization Rules 1 and 2, respectively, as given in table 3-3 using the AHP weights, and the third column shows the resulting index (for Rule 1) when the indicators are given equal weight.

TABLE 3-5

PRIORITIZATION OF CRITERIA WITH RESPECT TO THE FOCUS

Criteria	Pairwise Comparison Matrix			Priority Vector
	F	S	P	
Finance	1	5	3	.627
Service	1/5	1	1/4	.094
Production	1/3	4	1	.280

λ_{max} = 3.086 CI = .043 CR = .007

TABLE 3-6

PRIORITIZATION OF INDICATORS WITH RESPECT TO THE CRITERIA

	Pairwise Comparison Matrix				Priority Vector
Finance	F1	F2	F3	F4	
F1. Earnings/share	1	2	1/2	4	.289
F2. Operating income/plant	1/2	1	1/3	3	.173
F3. Income available/ common equity	2	3	1	4	.458
F4. Growth in customers	1/4	1/3	1/4	1	.079
Service	S1	S2	S3		
S1. Administrative and general expenses	1	8	2		.578
S2. Customer and informational expense	1/8	1	1/8		.057
S3. Customer accounts expense	1/2	8	1		.364
Production	P1	P2	P3	P4	
P1. Load factor	1	8	7	3	.581
P2. Heat rate	1/8	1	1	1/6	.059
P3. Capacity use factor	1/7	1	1	1/6	.062
P4. Transmission and distribution expense	1/3	6	6	1	.297

F:	$\lambda max = 4.087$	CI = .029	CR = .032
S:	$\lambda max = 3.054$	CI = .027	CR = .047
P:	$\lambda max = 4.100$	CI = .033	CR = .037

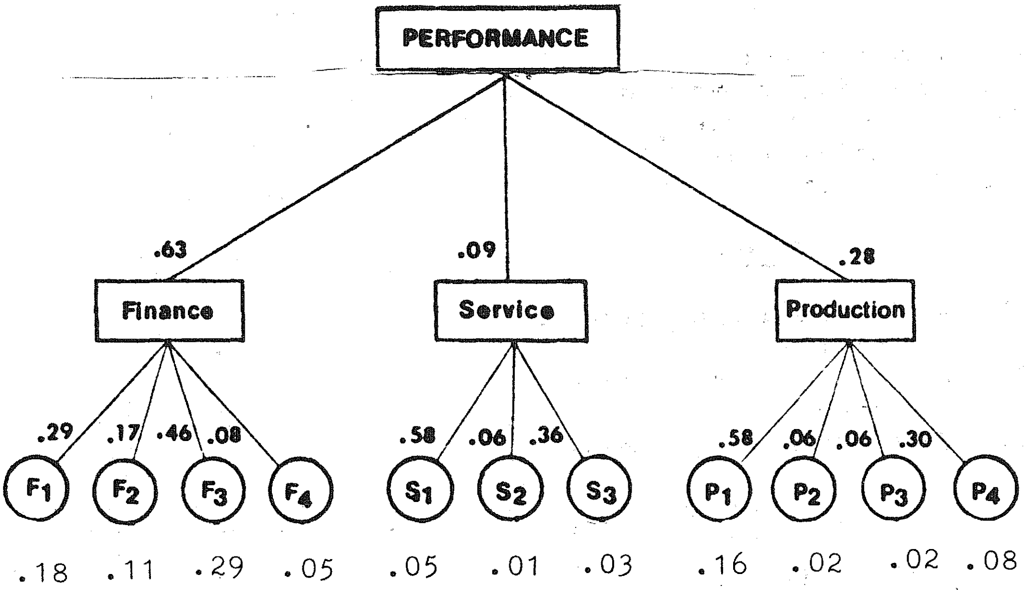

Fig. 3-2. Detailed structure of the performance evaluation indicator weights

TABLE 3-7

PERFORMANCE INDEXES

	1	2	3
A	67.0 (2)	27.6 (1)	52.9 (2)
B	72.3 (1)	27.1 (2)	67.4 (1)
C	44.0 (3)	23.0 (3)	50.6 (3)
D	25.0 (4)	22.4 (4)	30.6 (4)

While the results in themselves are purely illustrative, it should be noted that both the weights used and the normalization rule applied affect the indexes obtained. The resulting ranking is fairly robust with respect to C and D, while A and B change positions when the relative normalization rule (Rule 2) is used. A full sensitivity analysis would provide information on the critical weights and critical judgments, which can be altered if necessary, resulting in an iterative, fully flexible, and structured decision tool.

Concordance and Discordance Analysis

A second type of multicriteria evaluation method is based on the use of so-called concordance and discordance matrixes (also called the Electre method). This approach is outlined here to illustrate the situation where the values in the impact matrix and/or the relative importance of the indicators are not necessarily expressed in a ratio or interval scale. More recently, these methods have been developed into so-called qualitative evaluation techniques, applicable in a wide range of situations where, because of lack of data or political considerations (with respect to the indicator weights), the information used is fuzzy and less precise (for overviews and specific techniques, see, e.g., Hinloopen et al. (1983), Nijkamp (1982), Nijkamp and Voogd (1979), Rietveld (1980), Roy (1977), Voogd (1982, 1983)).

The concordance method is based on the pairwise comparison of scores in the evaluation matrix, company by company, and indicator by indicator. The procedure is carried out in three steps. First, for each pairwise comparison i,j (e.g., A-B, A-C, etc.) the criteria or indicators (k) are grouped into two categories, those for which i performs better than j, the so-called concordance set, and its complement, the discordance set, which contains those indicators for which j is better than i. For the data in the example used before, the appropriate concordance set is illustrated in table 3-8 (showing the dominance of the row company over the company in the column). For example, from table 3-1, A performs better than B with respect to indicators F3, S1, P2, and P4, but B performs better than A with respect to F1, F2, F4, S2, S3, P1, and P3.

TABLE 3-8

CONCORDANCE SET

	A	B	C	D
A		F3 S1 P2 P4	F1 F3 S1 S3 P4	F1 F2 F3 S1 S3 P3 P4
B	F1 F2 F4 S2 S3 P1 P3		F1 F2 F4 S2 S3 P1	F1 F2 F3 F4 S1 S2 S3 P1 P3
C	F2 F4 S2 P1 P2 P3	F3 S1 P2 P3 P4		F2 F3 F4 S1 S3 P2 P3 P4
D	F4 S2 P1 P2	P2 P4	F1 S2 P1	

The second step of the approach consists of quantifying the degree of dominance, by computing the sum of the weights (obtained separately) associated with the criteria that are contained in the concordance set of each pairwise comparison. Several types of weights can be used, for example, weights obtained through the application of AHP, equal weighting, point allocation, etc. Alternatively, a purely parametric qualitative analysis can be carried out, which considers all possible combinations of ranks (the so-called regime method or permutation method, see, e.g., Hinloopen et al. (1983), Nijkamp (1982), Paelinck (1976, 1977)). For two situations, AHP weights and equal weighting, the resulting concordance matrixes are presented in table 3-9. For example, A performs better than B with respect to F3, S1, P1, and P4, and the sum of the AHP weights for these four indicators (from figure 3-2) is 0.44. For ease of presentation, this value is multiplied by 100, yielding 44, the entry in row A, column B of table 3-9.

TABLE 3-9

CONCORDANCE MATRIXES

	AHP Weights				Equal Weights			
	A	B	C	D	A	B	C	D
A		44	63	76		36.4	45.5	63.6
B	56		54	90	63.6		54.5	81.8
C	37	46		65	54.5	45.5		72.7
D	24	10	35		36.4	18.2	27.3	

The third and final step consists of summarizing the information contained in the concordance matrixes by computing a concordance index (or degree of relative dominance), which is obtained for each company by subtracting the column sum from the row sum. The ranking of companies that results (highest concordance index is best) is given in columns 1 and 2 of table 3-10, for the two weight systems used in table 3-9. For the AHP weights the ranks are in conformance with the results for the full AHP approach for Rule 1 and for equal weighting. The use of equal weights in the concordance method, however, results in a different rank for A and C, which switch places.

TABLE 3-10

CONCORDANCE AND DISCORDANCE DOMINANCE INDEX
(Resulting ranks in parentheses)

	C-AHP	C-EQUAL	DIS
A	66 (2)	-9.0 (3)	-8.1 (3)
B	100 (1)	99.8 (1)	-2.3 (4)
C	-4 (3)	45.4 (2)	-20.8 (2)
D	-162 (4)	-136.2 (4)	-31.2 (1)

Rather than using the degree of relative dominance, the discordance method considers the discrepancies between the scores (in a pairwise fashion). Specifically, the largest discrepancy (for i inferior to j), or the average discrepancy, standardized to be between 0 and 1 (or 100) and possibly weighted can be shown in a discordance matrix. Table 3-11 illustrates this for the former case, using the values standardized with Rule 1. For example, using the information from Rule 1 in table 3-3, and from the concordance set in table 3-8, company A is inferior in performance to company B according to criteria F1, F2, F4, S2, S3, P1, and P3. This is found in the first column and row B in table 3-8 (since B is better than A according to these criteria). The difference in score between A and B on these criteria (from table 3-3) is 3.1 for F1, 62.4 for F2, 100 for F4, S2 and P1, and it is entered in row A, column B of table 3-11. The other values are obtained in a similar fashion.

TABLE 3-11

DISCORDANCE MATRIX (RULE 1)

	A	B	C	D
A		100.0	91.8	97.0
B	100.0		100.0	97.7
C	96.9	100.0		74.1
D	100.0	100.0	100.0	

Again, the information in the discordance matrix is summarized in a so-called discordance index, which is obtained for each company by subtracting the column sum from the row sum. A ranking can thus be obtained, where now the largest negative value is best (see column DIS of table 3-10). The resulting ranking in our example is different from the ones previously obtained.

The concordance and discordance methods are especially useful in the situation of weak measurement. However, they do not always result in unambiguous rankings, as illustrated in our example. Consequently, the results have to be interpreted cautiously. Nevertheless, they can be used as part of a larger sensitivity analysis or a parametric analysis of the information contained in an evaluation matrix, and as such may be used in combination with other techniques. It should be noted that the concordance method is sensitive to the choice of the weights used, while the discordance matrix is mostly sensitive to the choice of the normalization rule.

Some Considerations on Weight Assessment and Evaluation Functions

Whether a fully structured multicriteria evaluation is carried out, or a more ad hoc approach is used, a crucial issue remains the assessment of the criteria weights. These should reflect as closely as possible the preference structure of the evaluator, in a consistent fashion. As already mentioned at different instances in this chapter, a large number of techniques exists to assess the weights. These techniques can be categorized as being either holistic (i.e., all the weights are assessed in one step) or partial (i.e., the problem is divided in a number of subproblems, each assessed separately). Examples are direct weight assessment, point allocation, the use of AHP, unit weighting, regression techniques, and indifference analysis. Several empirical studies have been carried out in the literature to compare the appropriateness of various techniques. Although there does not seem to be a consensus, elements such as problem complexity, training of the evaluator, and familiarity with the techniques seem to point to the need to use simple, but theoretically consistent (i.e., not ad hoc) techniques (for discussions of these issues, see, e.g., Cook and Stewart (1975), Einhorn (1975), Hobbs (1980), MacCrimmon and Wehrung (1977), Rowe and Pierce (1982a, b), Schoemaker and Waid (1982)). In particular, there seems to be growing evidence to reject the use of equal weighting in order to avoid the issue of explicitly assessing the relative importance of evaluation criteria. In this respect, techniques such as AHP, which are fairly simple and easily implemented, can form a useful alternative. An empirical application of several weight assessment techniques in a regulatory context is presented in the next chapter.

Finally, if the indicators are considered to be equally important (after solid verification that this is indeed the case), several simple techniques can be applied to obtain so-called "fair" ranks. The idea behind this is that (only in the case of equal weighting) the different criteria can be considered as "judges" and the problem becomes one of combining the opinions of the different judges into an overall ranking. This problem has historically received a lot of attention in mathematics and statistics, and several simple procedures have been developed (see e.g., Armstrong et al. (1982), Cook and Seiford (1982), Goddard (1983)). One of the most commonly used is the so-called Borda-Kendall method of rank sums, in which the alternatives are ranked in increasing order of the sum of the ranks obtained on all criteria (or, "from all judges"). In the example used here, this results in the ranking expressed in table 3-12. In addition, these rank sums can be used in a statistical test, the Kendall W coefficient of concordance, on whether there is a statistically significant difference in the rankings on the different criteria, or whether that difference is due to random effects only (for details, see Daniel (1978), p. 326-331). In the example used here, the corresponding W statistic is 3.49 (with an χ^2 statistic of 115.1 with 3 degrees of freedom). As a result, the null hypothesis of equal ranking can clearly be rejected. In other words, there is a statistically significant difference between the rankings obtained according to the different criteria.

TABLE 3-12

BORDA-KENDALL RANK SUMS

	Sum	Rank
A	28	3
B	22	1
C	25	2
D	35	4

Relevance of a Decision Analytic Approach for Electric Utility Performance Ranking

Although to this date very few applications of multicriteria approaches to measuring efficiency or performance have been discussed in the literature, this should not preclude these methods from serious consideration. In fact, in several respects problems that are associated with other procedures are avoided. The subjective (and potentially controversial) nature of the subject is explicitly taken into account, thereby avoiding the possible "bias" of the analyst or auditor and the mechanical nature and lack of subtlety of some of the econometric approaches. Also, the potential mass of information that engineering and financial ratios provide can be reduced to a more manageable size, and directly understandable concepts (such as weights, priorities, preferences) are used to construct an overall index. The methods are flexible enough to be adaptable to specific situations and time periods, which avoids some of the rigidity of the other approaches.

There are some drawbacks, however. Because of the flexibility of these procedures there is no unique index, and in different situations or at different points in time the weights and the resulting index may vary. The techniques also need substantial involvement of the decision maker (a commissioner or commission staff). The time, opportunity, and other costs associated with this involvement should be taken into account. Although the methods take conflicts and differing weights explicitly into account, the requirement for openness and frank discussion associated with this may not always be politically feasible, thereby leaving the determination of weights and other procedures open to possible manipulation. Finally, the results are only as good as the initial data base. The methods in themselves do not assure that the right or even relevant indicators are chosen. The value of the overall index depends critically on the degree to which the indicators and subindicators that are used indeed reflect the notion of productivity and cost performance. Moreover, a theoretical drawback may be that there is not necessarily a direct relation with the notion of optimality or any other more absolute standard.

In sum, the multicriteria methods presented here show considerable promise for application to relative performance measurement of electric utilities, in particular as a quick way of summarizing a large amount of information. It should be kept in mind however, that their usefulness depends in a critical way on the availability and quality of a broad data base of appropriate indicators of performance. In addition, whatever indexes are obtained should not be used in isolation or in an absolute way, but should rather be considered as an indication of potential problem areas. More detailed and individualized utility-specific studies such as management audits, may then lead to additional information and possibly may suggest appropriate policy decisions. As such, they can form a useful and flexible decision tool within an overall decision support system for performance evaluation. In the next chapter these ideas are illustrated in a small pilot study that involved several commission staff members directly.

CHAPTER 4

APPLICATION OF SOFT TECHNIQUES TO UTILITY PERFORMANCE EVALUATION

In order to assess the potential for application of the multicriteria techniques in a regulatory context and to evaluate their differences and similarities in situations that are relevant to commissions, a 2-day seminar/workshop was organized by NRRI on May 21-22, 1984 in Columbus, Ohio (the program of the seminar/workshop is in appendix B to the report). The seminar/workshop was attended by more than forty commission staff members from over twenty states (a full listing of the participants is given in appendix C). The pilot study consisted of an evaluation exercise of the performance of a small number of electric utilities, using actual data and several techniques to assess the relative weights and priorities of the evaluation criteria. The information gained through this provides the basis for the calculation of various performance scores or indexes and thereby facilitates the analysis of the effect of the different techniques on the resulting performance evaluation.

The remainder of this chapter consists of four sections. First, the design of the evaluation experiment is outlined in detail. Second, the results for the criteria weights are discussed, followed by an analysis of the different performance scores. The final section consists of a brief assessment of the various techniques.

Design of the Evaluation Experiment

As was discussed in detail in chapter 3, an evaluation based on multicriteria decision analysis first necessitates the selection of the relevant criteria or indicators and the construction of achievement profiles for each object to be evaluated, in an evaluation or impact matrix. Two main methodological issues are involved in the actual analysis: the standardization or normalization of all variables into comparable units, and the assessment of the relative importance of the different partial indicators with respect to the overall measure. In the pilot study reported here, the focus was on the latter task, since it involves the direct input and expression of value judgment (in a highly structured manner) by the analyst. More specifically, the interest was in three main issues: (1) assessing how the use of different techniques to measure the relative importance of evaluation criteria affects the resulting company performance scores; (2) measuring how the techniques are perceived by commission staff members in terms of transparency, applicability and ease of use; (3) evaluating how commission staff members rate the use of multicriteria techniques compared to more traditional methods such as total factor productivity indexes and econometric residual analysis.

In order to achieve a reasonable compromise between an acceptable degree of realism and the time constraints imposed by the workshop format, the number of companies for which the evaluation was carried out was limited to ten. The companies were selected a priori and taken to be similar with respect to a number of characteristics, usually considered to be exogenous to the issue of management performance, such as location, climate, size, fuel mix, etc. All companies were purely electric and located in the Midwest. Also, for the companies selected there was available a complete set of observations on a large number of variables, necessary to carry out a total factor productivity analysis and several econometric studies, in addition to the multicriteria evaluation discussed here (the full description of the data base is presented in appendix A to the report). Even though the observed performance data for 1982 (and the annual percentage growth rate between 1981 and 1982) were presented to the workshop participants, the actual identities of the companies were not disclosed, in order to focus on the techniques and to eliminate the effect of varying familiarity among the participants with the operations of specific utilities (e.g., utilities that may be within the participant's commission jurisdiction could possibly be evaluated on criteria other than the limited set provided, thereby potentially biasing the results).

A total of thirty-six performance indicators were used as the basis for the evaluation exercise, sixteen of which were static values for 1982 and twenty of which were annual percentage growth rates. The indicators were chosen as the result of an intensive analysis of several actual performance studies available in published form, in combination with the conclusions of a previously carried out survey of commission staffs (see Anselin et al. (1981)). Their detailed definition and operational variable names are given in table 4-1. Although, by necessity, the list of indicators was not intended to be exhaustive, most participants expressed satisfaction with its extent and degree of completeness. In fact, of forty-one respondents, thirty-one participants considered the list of indicators as realistic (two as unrealistic, while eight had no opinion), and twenty-four participants found it detailed enough (nine found it too detailed, four not detailed enough, and four had no opinion). Twelve participants made specific comments about the list of indicators used, mostly suggesting more detail on particular items and/or the use of alternative units of measurement. Also, of these twelve, four mentioned the need to include quality of service indicators, variables for which data were not available in the same uniform format as needed for the comprehensive data base. The performance profiles for the ten companies were presented in the form of an evaluation or impact matrix. Table 4-2 shows the original data and table 4-3 gives the standardized values. The normalization of each indicator is achieved by subtracting the minimum score from the original value and dividing by the score range (maximum less minimum). As discussed at length in chapter 3, this is only one of a number of possible ways of achieving normalized scores. It was chosen here because of its transparency (the lowest value becomes zero, the highest becomes one hundred) and widespread use

TABLE 4-1A

INDICATORS USED IN THE NRRI PERFORMANCE MEASUREMENT WORKSHOP

ABBREVIATION	VARIABLE NAME
AVG RES PRICE	AVERAGE RESIDENTIAL PRICE
AVG RES PRICE CHGE	AVERAGE RESIDENTIAL PRICE (CHANGE)
AVG REV PER KWH	AVERAGE REVENUE PER KWH
AVG REV PER KWH CHGE	AVERAGE REVENUE PER KWH (CHANGE)
RETURN PER KWH	RETURN PER KWH
RETURN PER KWH CHGE	RETURN PER KWH (CHANGE)
RES SALES CHGE	RESIDENTIAL SALES (CHANGE)
COMM SALES CHGE	COMMERICAL SALE (CHANGE)
INDUS SALES CHGE	INDUSTRIAL SALES (CHANGE)
INT CVRGE RATIO	INTEREST COVERAGE RATIO
INT CVRGE PARTIO CHGE	INTEREST COVERAGE RATIO (CHANGE)
OPERATING RATIO	OPERATING RATIO
OPERATING RATIO CHGE	OPERATING RATIO (CHANGE)
LG TM DEBT ASSETS	LONG TERM DEBT TO ASSET RATIO
LG TM DEBT ASSETS CHGE	LONG TERM DEBT TO ASSET RATIO (CHANGE)
OPER INC NET PLNT	OPERATING INCOME TO NET PLANT RATIO
OPER INC NET PLNT CHGE	OPERATING INCOME TO NET PLANT RATION (CHANGE)
INC ASSETS	INCOME TO ASSETS RATIO
INC ASSETS CHGE	INCOME TO ASSETS RATIO (CHANGE)
RTRN ON EQUITY	RETURN ON EQUITY
RTRN ON EQUITY CHGE	RETURN ON EQUITY (CHANGE)
EARN PER SHARE CHGE	EARNINGS PER SHARE (CHANGE)
CAPCTY UTILZTN	CAPACITY UTILIZATION
CAPCTY UTILZTN CHGE	CAPACITY UTILIZATION (CHANGE)
RESRV MARGIN	RESERVE MARGIN
RESRV MARGIN CHGE	RESERVE MARGIN (CHANGE)
HEAT RATE	HEAT RATE
HEAT RATE CHGE	HEAT RATE (CHANGE)
AVG FUEL COST	AVERAGE FUEL COST
AVG FUEL COST CHGE	AVERAGE FUEL COST (CHANGE)
O & M EXP NET PLNT	OPERATION AND MAINTENANCE EXPENSES TO NET PLANT
O & M EXP NET PLNT CHGE	OPERATION AND MAINTENANCE EXPENSES TO NET PLANT (CHANGE)
T & G EXP CUST	TRANSMISSION AND MAINTENANCE EXPENSES PER CUSTOMER
T & G EXP CUST CHGE	TRANSMISSION AND MAINTENANCE EXPENSES PER CUSTOMER (CHANGE)
ADM & GEN EXP CUST	ADMINISTRATIVE AND GENERAL EXPENSES PER CUSTOMER
ADM & GEN EXP CUST CHGE	ADMINISTRATIVE AND GENERAL EXPENSES PER CUSTOMER (CHANGE)

TABLE 4-1B

LIST OF VARIABLE DEFINITIONS:
NRRI PERFORMANCE MEASUREMENT WORKSHOP
(All growth variables are calculated as 100 times $(X_{82}-X_{81})/X_{81}$, that is, the percentage rate of growth from 1981 to 1982.)

Variable	Definition
Average residential price	Residential revenue/residential sales
Average revenue per kWh	Total electric operating revenue/total sales
Return per kWh	Net income available for common/total sales
Interest coverage ratio	Gross income after taxes (before interest charges)/total interest charges
Operating ratio	Operations, maintenance, depreciation and tax expenses/gross revenue
Long term debt to asset ratio	Long term debt/assets from balance sheet
Operating income to net plant ratio	Electric operating income (after expenses)/ net electric plant
Income to assets ratio	Gross income after taxes (before interest charges)/assets (book value from balance sheet)
Return on equity	Net income available for common/book value of common equity
Capacity utilization	Total sales/system capacity including net purchases from other utilities
Reserve margin	Peak load/system capacity (as above)
Heat rate	Calculated from Compustat as total fuel cost/ (net generation x average fuel cost per million Btu)
Average fuel cost	Total cost of fuel consumed/total Btu content
Operating and maintenance expenses to net plant factor	Operation plus maintenance expenses/Net electric plant
Transmission and distribution expenses per customer	Transmission and distribution operating and maintenance expenses/total customers
Administrative and general expenses per customer	Administrative and general expenses/total customers

TABLE 4-2

EVALUATION MATRIX, RAW DATA

	A	B	C	D	E	F	G	H	I	J
AVG RES PRICE	.062	.068	.054	.084	.067	.074	.074	.063	.058	.080
AVG RES PRICE CHGE	.154	.074	.199	.071	.021	.128	.236	.230	.159	.112
AVG REV PER KWH	.050	.065	.044	.068	.059	.060	.063	.054	.046	.068
AVG REV PER KWH CHGE	.145	.099	.226	.173	.053	.147	.248	.109	.198	.125
RETURN PER KWH	.006	.006	.007	.009	.008	.008	.003	.009	.012	.011
RETURN PER KWH CHGE	.134	.091	.258	.354	-.011	.137	.000	.183	.695	.165
RES SALES CHGE	-.013	-.019	-.011	-.002	.014	-.002	-.010	-.005	.011	-.005
COMM SALES CHGE	.053	-.009	.037	.023	.027	.016	.010	.009	.042	.025
INDUS SALES CHGE	-.045	-.111	-.064	-.407	-.158	-.176	-.087	-.081	-.061	-.067
INT CVRGE RATIO	1.855	1.154	2.112	1.888	1.836	1.413	1.858	1.458	2.124	1.877
INT CVRGE RATIO CHGE	.037	-.116	.022	-.024	-.060	-.034	.053	-.007	.124	.052
OPERATING RATIO	.839	.800	.826	.792	.838	.811	.865	.816	.790	.770
OPERATING RATIO CHGE	.019	-.003	-.034	-.006	.052	.011	.025	.005	.010	.008
LG TM DEBT ASSETS	.382	.422	.384	.415	.409	.507	.413	.409	.372	.434
LG TM DEBT ASSETS CHGE	-.043	.011	-.014	-.038	-.001	.024	-.052	-.003	-.004	.060
OPER INC NET PLNT	.059	.062	.066	.062	.048	.062	.072	.044	.051	.059
OPER INC NET PLNT CHGE	.021	-.106	.336	-.100	-.267	-.061	.026	-.085	-.068	-.059
INC ASSETS	.081	.059	.080	.075	.074	.082	.064	.071	.076	.084
INC ASSETS CHGE	.015	-.085	-.015	-.003	-.114	-.047	-.004	-.001	.111	.017
RTRN ON EQUITY	.125	.097	.141	.108	.119	.122	.081	.128	.163	.129
RTRN ON EQUITY CHGE	.059	-.077	.066	-.040	-.174	-.084	-.017	.004	.303	.004
EARN PER SHARE CHGE	.036	-.134	-.038	-.049	-.135	-.100	.131	.057	.330	.148
CAPCTY UTILZTN	.425	.426	.438	.392	.333	.467	.457	.389	.386	.441
CAPCTY UTILZTN CHGE	.026	-.071	-.129	-.215	-.063	-.012	-.033	-.029	-.092	-.026
RESRV MARGIN	.193	.254	.167	.329	.216	.306	.194	.314	.249	.243
RESRV MARGIN CHGE	-.187	.668	.316	.722	.054	.008	-.052	.536	.131	-.101
HEAT RATE	10164.2	10335.1	9663.6	10642.6	11139.3	10818.8	10750.7	10070.0	10286.9	10228.5
HEAT RATE CHGE	-.049	-.003	.005	-.004	.002	.001	-.004	-.005	.003	-.004
AVG FUEL COST	1.554	1.938	1.499	1.679	1.420	1.685	1.624	2.163	1.450	1.756
AVG FUEL COST CHGE	.150	.017	.033	.051	.116	.004	.020	-.048	.120	.071
O & M EXP NET PLNT	.222	.190	.217	.160	.164	.194	.341	.139	.125	.129
O & M EXP NET PLNT CHGE	.168	-.143	-.001	-.151	.032	-.028	.174	-.086	-.056	-.011
T & G EXP CUST	.074	.069	.069	.062	.080	.066	.078	.080	.063	.079
T & G EXP CUST CHGE	.169	.080	.127	.006	.162	.112	.083	.141	.122	.208
ADM & GEN EXP CUST	.102	.087	.088	.068	.105	.079	.066	.067	.091	.060
ADM & GEN EXP CUST CHGE	.208	.057	.153	.109	.190	.125	.166	.116	.112	.131

TABLE 4-3

EVALUATION MATRIX, STANDARDIZED SCORES

	A	B	C	D	E	F	G	H	I	J
AVG RES PRICE	73.4	52.7	100.0	0.0	54.8	32.7	34.0	71.1	87.0	10.8
AVG RES PRICE CHGE	38.0	75.4	17.1	76.6	100.0	50.0	0.0	2.7	35.7	57.4
AVG REV PER KWH	72.6	13.8	100.0	3.1	38.3	36.0	19.9	56.6	91.0	0.0
AVG REV PER KWH CHGE	52.8	76.2	11.6	38.6	100.0	51.9	0.0	71.1	25.9	63.1
RETURN PER KWH	33.9	30.2	40.4	63.7	54.8	52.2	0.0	74.3	100.0	98.0
RETURN PER KWH CHGE	20.6	14.5	38.1	51.8	0.0	21.0	1.6	27.6	100.0	24.9
RES SALES CHGE	19.2	0.0	25.3	51.6	100.0	51.7	28.0	41.5	90.7	43.9
COMM SALES CHGE	100.0	0.0	73.4	51.9	58.4	40.5	30.8	29.3	81.6	54.5
INDUS SALES CHGE	100.0	81.7	94.7	0.0	68.8	63.9	88.5	90.1	95.6	93.9
INT CVRGE RATIO	72.3	0.0	98.7	75.7	70.3	26.7	72.5	31.4	100.0	74.5
INT CVRGE RATIO CHGE	63.6	0.0	57.6	38.4	23.4	34.0	70.2	45.2	100.0	70.0
OPERATING RATIO	27.2	67.8	40.2	76.4	28.2	55.9	0.0	50.7	78.1	100.0
OPERATING RATIO CHGE	38.6	63.8	100.0	67.5	0.0	47.9	30.9	54.9	49.2	50.9
LG TM DEBT ASSETS	92.5	63.4	90.9	68.1	72.8	0.0	69.9	72.3	100.0	54.1
LG TM DEBT ASSETS CHGE	92.2	43.6	66.3	87.2	54.8	32.1	100.0	56.3	57.7	0.0
OPER INC NET PLNT	52.5	63.2	79.1	65.7	14.8	64.0	100.0	0.0	23.4	52.6
OPER INC NET PLNT CHGE	47.8	26.8	100.0	27.7	0.0	34.1	48.6	30.1	33.0	34.5
INC ASSETS	86.8	0.0	84.6	65.8	61.7	92.4	18.1	45.9	67.0	100.0
INC ASSETS CHGE	57.2	12.7	44.1	49.4	0.0	29.6	48.9	50.3	100.0	57.9
RTRN ON EQUITY	53.6	19.8	73.1	32.9	46.0	50.4	0.0	57.6	100.0	58.1
RTRN ON EQUITY CHGE	48.8	20.3	50.3	28.0	0.0	18.9	32.9	37.3	100.0	37.4
EARN PER SHARE CHGE	36.7	0.2	20.6	18.5	0.0	7.4	57.0	41.1	100.0	60.8
CAPCTY UTILZTN	68.7	69.3	78.4	43.5	0.0	100.0	91.9	41.4	38.9	80.5
CAPCTY UTILZTN CHGE	100.0	59.5	35.7	0.0	63.3	84.5	75.6	77.4	51.3	78.5
RESRV MARGIN	83.9	46.4	100.0	0.0	69.7	14.3	83.0	9.2	49.5	53.1
RESRV MARGIN CHGE	100.0	6.0	44.7	0.0	73.5	78.5	85.2	20.5	65.1	90.6
HEAT RATE	66.1	54.5	100.0	33.7	0.0	21.7	26.3	72.5	57.8	61.7
HEAT RATE CHGE	100.0	14.0	0.0	16.3	4.9	6.9	15.5	18.6	3.8	16.3
AVG FUEL COST	82.0	30.3	89.3	65.1	100.0	64.3	72.5	0.0	96.0	54.8
AVG FUEL COST CHGE	0.0	67.1	59.1	49.9	17.1	73.7	65.7	100.0	15.4	39.8
O & M EXP NET PLNT	55.5	70.0	57.7	84.0	82.2	68.2	0.0	93.7	100.0	98.6
O & M EXP NET PLNT CHGE	1.9	97.8	53.9	100.0	43.7	62.3	0.0	80.3	70.9	57.1
T & G EXP CUST	33.6	62.8	61.6	100.0	0.0	77.2	11.9	1.2	95.6	9.4
T & G EXP CUST CHGE	19.7	63.4	39.9	100.0	23.1	47.5	62.1	33.2	42.6	0.0
ADM & GEN EXP CUST	6.1	39.6	38.3	81.6	0.0	59.3	87.2	86.2	32.5	100.0
ADM & GEN EXP CUST CHGE	0.0	100.0	36.3	65.5	12.3	55.1	28.0	61.0	63.5	51.3

in evaluation practice. All indicators were rescaled where necessary (i.e., the complement from 100 was taken), so that the direction of of measurement is uniform (i.e., a higher value means better performance).

The actual performance evaluation experiment was carried out using four techniques, of which one was holistic and the others were based on the construction of a weighted summation index and a multicriteria modified Electre analysis. The full survey form is present in appendix D to the report.

The first phase in the analysis consisted of a direct ranking and scoring (on a scale from 0 to 100) of the performance of the ten companies, using the information in the evaluation matrix only. That is, each analyst had to construct a performance index directly from the data. This forced the analyst to implicitly summarize the information provided, without a structured analysis of the criteria and indicators, or without using a formal stepwise procedure to simplify the unstructured data. In the other three phases of the pilot experiment, the focus was not on the performance index itself, but on the assessment of the weights, which then were used to construct the index (through weighted summation or other aggregation procedures).

In the second phase of the analysis, the participants were asked to determine the value of the indicator weights directly, without having a particular structure provided to carry out the trade-offs involved. It was indicated that not all indicators necessarily had to be rated, and the only limitation to the weights was to be within a range of 0 to 100.

The last two phases of the experiment provided a more structured approach. In phase three, the structure was obtained in the form of a point allocation rating at two levels of generality. The indicators were grouped into three main categories or criteria: "service" (with nine indicators), "finance" (with thirteen indicators), and "production" (with fourteen indicators). First, one hundred importance points had to be allocated among the three criteria. Next, one hundred importance points had to be distributed over the indicators within each criterion.

The final phase of the evaluation exercise was based on an application of the analytic hierarchy process technique (AHP, discussed in detail in chapter 3). The set of performance indicators was formally structured in an evaluation hierarchy, with five levels of generality: an overall focus ("performance assessment"), criteria ("service," "finance," and "production"), time dimension ("static," and "dynamic"), indicators, and subindicators. The latter are outlined in more detail in table 4-4. It should be pointed out that the actual process of structuring a hierarchy out of a set of criteria is in itself one of the most important aspects of an evaluation. It is therefore not claimed that the structure used in this exercise is the most appropriate to assess utility performance. In fact, given the format of the workshop, the hierarchy was by design kept fairly simple, and a number of other formulations could be advanced for use in actual applications.

The weights were obtained by carrying out a series of pairwise comparisons of the relative importance of the elements at one level in the hierarchy with respect to the notion at the next higher level, using a psychometric scale developed by Saaty (1977). This evaluation was facilitated by first ranking the elements in terms of importance, and then using this information to fill out the upper triangular part of the pairwise comparison matrix (for a full example, see chapter 3 and the examples in section 4 of appendix D). In the workshop, the evaluation was preceded by a brief illustrative example in order to better familiarize the participants with the technique and the particular measurement scale used. In addition, no more than three elements of the hierarchy were used in any set of pairwise comparisons, thereby considerably decreasing the potential for inconsistency in the rating. In total, twenty-three pairwise comparison matrixes had to be filled out, of which twelve were 3x3 matrixes (the remainder were 2x2). The actual indicator weights were obtained from a computer analysis in which the information contained in the pairwise comparison matrixes was first transformed to a set of importance weights. These weights were then combined in accordance with the hierarchical structure of the evaluation to form the final indicator weights.

TABLE 4-4

EVALUATION HIERARCHY

CRITERIA	TIME DIMENSION	INDICATORS	SUBINDICATORS
- Service			
	- Static		
		- average residential rates	
		- revenue	- average revenue/kWh
			- return/kWh: available for common/kWh
	- Dynamic		
		- sales growth	- sales growth: residential
			- sales growth: commercial
			- sales growth: industrial
		- change in average residential rates	
		- revenue	- change in average revenue/kWh
			- change in return/kWh
- Finance			
	- Static		
		- coverage ratios	- after-tax interest coverage ratio
			- operating ratio: operating expenses/ gross revenue
			- long-term debt/assets
		- return	- operating income/net plant
			- net income/assets
			- return on equity: available for common stock/book value
	- Dynamic		
		- coverage ratios	- change in after-tax interest coverage ratio
			- change in operating ratio
		- return	- change in operating income/net plant

TABLE 4-4--Continued

CRITERIA	TIME DIMENSION	INDICATORS	SUBINDICATORS
			- change in net income/ assets
			- change in return on equity
		- growth in earnings per share	
- Production			
	- Static		
		- capacity use	- average: capacity utilization average kWh/system capacity)
			- peak: reserve margin (peak load/ system capacity)
		- fuel use	- steam station heat rate
			- average fuel cost ($ per million Btu's)
		- expenses	- operating and main-tenance expenses/ net plant
			- transmission and distribution expenses/customer
			- administrative and general expenses/ customer
	- Dynamic		
		- capacity use	- change in average capacity use
			- change in reserve margin
		- fuel use	- change in heat rate
			- change in fuel cost
		- expenses	- change in operating and maintenance
			- change in trans-mission and dis-tribution
			- change in administra-tive and general

The evaluation exercise was preceded by a 90-minute presentation on the use of multicriteria techniques in electric utility performance evaluation. On average, it took the participants about 30 minutes to carry out phase 1 of the analysis, 20 minutes for phase 2, 15 minutes for phase 3, and 40-45 minutes for phase 4. Finally, it may be of interest to note that the background of the participants showed a variety of disciplines, and encompassed engineering (13 participants), economics (12), accounting (8), planning (3), finance (2), mathematics (2), and law (1).

Analysis of the Criteria Weights

In this section, the criteria weights that resulted from the evaluations carried out by the participants in phases 2-4 of the workshop survey are discussed. In order to facilitate comparison, the three sets of weights were standardized into common units, such that they sum to 100 across criteria. For the direct weight, this entailed that each value had to be divided by the total sum, which varied by partipant, since there were no constraints (besides the range 0-100) imposed on the weights used. This implies the simplifying assumption that the trade-off process carried out in the mind of the evaluator is linear in the criteria. This assumption is explicit in the point allocation technique and AHP. For the former, the normalized weights were obtained by multiplying the indicator points by the share of the category to which it belonged, while for the latter no standardization is necessary. In addition to this simple normalization, the weights for the three main categories "service," "finance," and "production" were calculated for each technique by summing the weights for the respective indicators.

The results are presented in tables 4-5 to 4-9. Table 4-5 shows the basic descriptive statistics for the criteria weights in the three methods: the mean (M), rank (R), standard deviation (SD), range (RA),

TABLE 4-5

CRITERIA CATEGORY WEIGHTS

Criteria	Phase 2		Direct Weights			
	M	R	SD	RA	CV	C1
Service	27.5	3	11.4	74.6	41.7	189.7
Finance	30.9	2	11.9	58.8	38.5	168.7
Production	41.6	1	13.9	77.4	33.4	299.9
	Phase 3		Point Allocation			
	M	R	SD	RA	CV	C1
Service	37.1	1	13.8	70.0	37.0	232.6
Finance	26.2	3	12.5	60.0	47.7	237.6
Production	36.9	2	13.8	70.0	37.3	231.5
	Phase 4		AHP			
	M	R	SD	RA	CV	C1
Service	39.6	1	24.4	67.3	61.7	498.2
Finance	25.8	3	22.8	72.9	88.5	452.6
Production	34.5	2	22.2	67.1	64.2	385.0

TABLE 4-6

DIRECT WEIGHTING

Indicator	M	SD	RA	CV	C1	C2
Average residential rates	4.1	2.0	9.8	49.8	80.4	43.9
Change in average residential rates	3.1	1.8	5.9	56.7	43.4	35.5
Average revenue/kWh	5.9	7.5	45.5	126.7	*	*
Change in average revenue/kWh	4.3	6.4	40.9	148.0	*	*
Return/kWh	2.4	2.2	8.3	89.4	66.3	65.5
Change in return/kWh	1.7	1.5	4.7	84.4	44.7	62.6
Residential sales growth	1.8	1.4	5.4	79.3	41.3	59.3
Commercial sales growth	1.8	1.3	4.5	69.6	34.8	53.5
Industrial sales growth	2.2	1.7	8.0	78.4	45.9	54.3
After-tax interest coverage ratio	2.6	2.0	7.1	78.7	56.0	59.9
Change in after-tax interest coverage ratio	1.5	1.5	5.7	101.0	54.5	51.5
Operating expenses/gross revenue	2.9	1.9	8.2	64.7	51.7	58.1
Change in operating expenses/ gross revenue	2.4	1.7	5.9	72.3	42.4	43.9
Long-term debt/assets	2.7	1.8	8.0	64.9	42.7	46.5
Change in long-term debt/assets	2.0	1.6	4.5	81.6	44.9	44.3
Operating income/net plant	2.7	1.8	6.4	67.1	43.8	47.4
Change in operating income/ net plant	2.0	1.6	5.1	81.6	45.1	44.5
Net income/assets	2.4	1.4	5.7	61.2	31.4	33.2
Change in net income/assets	1.8	1.6	5.7	86.5	46.5	44.7
Return on equity	3.5	2.2	9.1	62.2	73.8	85.5
Change in return on equity	2.2	1.6	5.7	74.3	40.5	40.5
Growth in earnings per share	2.2	1.9	8.0	85.5	54.3	56.1
Average capacity use: average kWh/system capacity	3.8	2.1	8.9	56.2	76.3	*
Change in average capacity use	2.9	2.1	7.9	74.8	62.8	77.0
Reserve margin: peak load/ system capacity	3.8	2.2	11.8	59.1	81.9	*
Change in reserve margin	2.4	1.7	6.9	72.3	43.1	47.9
Steam station heat rate	4.0	2.6	11.8	64.7	*	*
Change in steam station rate heat	2.7	2.2	8.9	80.1	65.1	77.9
Average fuel cost	4.2	2.7	14.7	64.3	*	*
Change in average fuel cost	2.9	1.9	6.6	64.5	49.2	62.0
Operating & maintenance expenses/net plant	3.6	1.8	8.8	50.9	53.2	74.8
Change in O & M expenses/ net plant	2.6	1.8	6.3	70.8	45.4	52.7
Transmission & distribution expenses, per customer	2.6	1.5	6.3	57.1	31.1	36.8
Change in T & D expenses per customer	2.3	1.9	7.9	81.5	51.3	56.2
Administrative & general expenses, per customers	2.2	1.3	5.9	60.3	28.6	28.0
Change in administrative & general expenses per customer	1.8	1.6	5.9	90.9	49.5	47.0

*Indicates a value larger than 100

TABLE 4-7

POINT ALLOCATION WEIGHTS

Indicator	M	SD	RA	CV	C1	C2
Average residential rates	8.6	9.3	42.0	107.4	*	*
Change in average residential rates	3.2	2.7	10.0	83.9	*	77.2
Average revenue/kWh	9.6	10.1	48.0	106.0	*	*
Change in average revenue/kWh	3.8	5.3	32.0	138.0	*	*
Return/kWh	2.5	2.4	10.5	97.3	80.9	75.5
Change in return/kWh	1.6	1.7	6.3	109.6	61.0	78.3
Residential sales growth	2.1	2.0	6.0	98.3	63.1	70.5
Commercial sales growth	2.3	2.2	7.5	95.3	69.3	70.1
Industrial sales growth	2.9	2.9	10.5	97.7	*	91.0
After-tax interest coverage ratio	2.9	3.5	16.7	122.1	*	*
Change in after-tax interest coverage ratio	0.7	1.0	4.0	134.9	71.8	65.3
Operating expenses/gross revenue	2.7	2.5	10.0	90.4	82.3	89.5
Change in operating expenses/ gross revenue	1.4	1.6	7.0	109.7	59.2	56.1
Long-term debt/assets	2.5	2.4	10.0	96.2	78.0	83.1
Change in long-term debt/assets	1.0	1.2	6.0	120.0	64.2	58.6
Operating income/net plant	2.5	3.8	20.0	149.9	*	*
Change in operating income/ net plant	1.0	1.4	7.0	137.8	70.3	65.2
Net income/assets	1.8	2.0	10.0	109.4	66.1	65.9
Change in net income/assets	0.7	0.9	3.0	122.8	70.4	63.5
Return on equity	5.2	5.9	22.8	113.9	*	*
Change in return on equity	1.4	1.4	4.5	100.3	53.6	49.7
Growth in earnings per share	2.1	2.4	10.0	115.1	83.6	86.5
Average capacity use: average kWh/system capacity	4.2	3.3	15.0	79.4	*	*
Change in average capacity use	1.9	2.5	14.0	129.1	95.0	*
Reserve margin: peak load/ system capacity	4.0	3.0	12.5	75.1	*	*
Change in reserve margin	1.8	2.1	12.0	114.1	71.4	73.3
Steam station heat rate	4.2	3.4	15.0	80.2	*	*
Change in steam station rate heat	2.1	2.6	14.0	122.7	97.0	*
Average fuel cost	5.3	3.5	12.5	66.5	*	*
Change in average fuel cost	2.0	1.7	6.0	85.0	48.9	50.1
Operating & maintenance expenses/net plant	3.2	2.8	15.0	88.6	*	*
Change in O & M expenses/ net plant	1.9	2.6	14.0	137.4	*	*
Transmission & distribution expenses, per customer	2.2	1.8	7.0	83.1	50.1	53.3
Change in T & D expenses per customer	1.2	1.6	6.0	126.0	66.6	60.4
Administrative & general expenses, per customer	1.8	1.6	6.0	88.2	48.3	46.8
Change in administrative & general expenses per customer	1.3	1.1	6.0	118.0	62.4	54.1

*Indicates a value larger than 100.

TABLE 4-8

AHP WEIGHTS

Indicator	M	SD	RA	CV	C1	C2
Average residential rates	15.9	16.1	55.7	101.1	*	*
Change in average residential rates	6.5	8.6	36.3	132.5	*	*
Average revenue/kWh	6.3	8.8	33.7	140.2	*	*
Change in average revenue/kWh	2.4	3.6	18.9	151.0	*	*
Return/kWh	3.4	4.2	19.1	122.4	*	*
Change in return/kWh	1.8	2.4	8.6	132.8	63.1	66.6
Residential sales growth	1.0	1.6	7.9	156.7	54.2	70.4
Commercial sales growth	0.8	1.0	4.8	123.0	46.4	67.1
Industrial sales growth	1.4	1.6	5.8	113.3	42.1	56.3
After-tax interest coverage ratio	4.2	7.1	29.6	169.2	*	*
Change in after-tax interest coverage ratio	1.0	1.5	7.0	149.9	51.9	48.8
Operating expenses/gross revenue	4.1	7.5	30.1	182.5	*	*
Change in operating expenses/ gross revenue	1.0	1.5	6.4	141.1	49.6	46.4
Long-term debt/assets	2.8	3.2	10.9	111.6	94.0	*
Change in long-term debt/assets	1.3	3.6	19.1	287.9	*	*
Operating income/net plant	1.5	1.8	7.2	116.8	45.2	43.8
Change in operating income/ net plant	0.7	0.7	2.5	109.2	48.0	43.0
Net income/assets	2.5	5.2	24.3	211.5	*	*
Change in net income/assets	0.8	1.1	4.9	131.9	47.9	43.7
Return on equity	2.1	2.6	11.5	124.0	67.7	70.7
Change in return on equity	0.7	0.9	4.0	130.4	49.5	44.8
Growth in earnings per share	3.0	3.7	15.4	122.8	*	*
Average capacity use: average kWh/system capacity	3.9	4.0	13.4	102.5	*	*
Change in average capacity use	3.9	6.8	32.3	175.4	*	*
Reserve margin: peak load/ system capacity	2.7	4.4	21.8	162.0	*	*
Change in reserve margin	2.0	3.2	14.1	164.4	*	*
Steam station heat rate	4.0	5.5	27.2	137.7	*	*
Change in steam station rate heat	2.0	2.4	9.0	118.8	58.6	63.1
Average fuel cost	3.7	3.7	13.1	101.3	*	*
Change in average fuel cost	2.5	4.5	23.1	180.1	*	*
Operating & maintenance expenses/net plant	2.4	3.0	15.3	120.8	82.9	95.5
Change in O & M expenses/ net plant	2.7	6.0	30.0	224.9	*	*
Transmission & distribution expenses, per customer	1.4	1.5	5.9	106.1	39.2	35.4
Change in T & D expenses per customer	1.4	2.6	11.9	182.5	79.5	82.1
Administrative & general expenses, per customer	1.2	1.8	7.1	155.0	55.6	52.0
Change in administrative & general expenses per customer	0.8	1.2	4.0	143.4	50.1	42.7

*Indicates a value larger than 100

TABLE 4-9

MEAN INDICATOR WEIGHTS AND RANKS

Indicator	Direct W	Direct R	Points W	Points R	AHP W	AHP R
Average residential rates	4.1	4	8.6	2	15.9	1
Change in average residential rates	3.1	10	3.2	9	6.5	2
Average revenue/kWh	5.9	1	9.6	1	6.3	3
Change in average revenue/kWh	4.3	2	3.8	8	2.4	18
Return/kWh	2.4	20	2.5	15	3.4	10
Change in return/kWh	1.7	35	1.6	28	1.8	22
Residential sales growth	1.8	33	2.1	20	1.0	30
Commercial sales growth	1.8	31	2.3	17	0.8	33
Industrial sales growth	2.2	26	2.9	11	1.4	25
After-tax interest coverage ratio	2.6	18	2.9	12	4.2	4
Change in after-tax interest coverage ratio	1.5	36	0.7	35	1.0	31
Operating expenses/gross revenue	2.9	11	2.7	13	4.1	5
Change in operating expenses/ gross revenue	2.4	23	1.4	29	1.0	29
Long-term debt/assets	2.7	15	2.5	16	2.8	12
Change in long-term debt/assets	2.0	30	1.0	33	1.3	27
Operating income/net plant	2.7	16	2.5	14	1.5	23
Change in operating income/ net plant	2.0	29	1.0	34	0.7	36
Net income/assets	2.4	22	1.8	27	2.5	16
Change in net income/assets	1.8	32	0.7	36	0.8	32
Return on equity	3.5	9	5.2	4	2.1	19
Change in return on equity	2.2	28	1.4	30	0.7	35
Growth in earnings per share	2.2	25	2.1	21	3.0	11
Average capacity use: average kWh/system capacity	3.8	6	4.2	6	3.9	8
Change in average capacity use	2.9	13	1.9	23	3.9	7
Reserve margin: peak load/ system capacity	3.8	7	4.0	7	2.7	13
Change in reserve margin	2.4	21	1.8	26	2.0	21
Steam station heat rate	4.0	5	4.2	5	4.0	6
Change in steam station rate heat	2.7	14	2.1	19	2.0	20
Average fuel cost	4.2	3	5.3	3	3.7	9
Change in average fuel cost	2.9	12	2.0	22	2.5	15
Operating & maintenance expenses/net plant	3.6	8	3.2	10	2.4	17
Change in O & M expenses/ net plant	2.6	19	1.9	24	2.7	14
Transmission & distribution expenses, per customer	2.6	17	2.2	18	1.4	24
Change in T & D expenses per customer	2.3	24	1.2	31	1.4	26
Administrative & general expenses, per customer	2.2	27	1.8	25	1.2	28
Change in administrative & general expenses per customer	1.8	34	1.1	32	0.8	34

and coefficient of variation (CV). It should be noted that the category weights are obtained explicitly (i.e., directly from the evaluator) only in the point allocation method, and are computed in the other cases. Service turns out to be the most important criterion in point allocation and AHP (with mean values of 37.1 and 39.6 respectively), but ranks lowest using direct weights, where production is most important (with a mean value of 41.6). Also, the importance rankings for the criteria categories are the same in point allocation and AHP, but completely different from those obtained through direct weighting. The highest variation among respondents (measured by the SD and CV) is clearly found for AHP, while the values for the first two methods are more similar in this respect. In addition to listing these purely descriptive characteristics, table 4-5 presents the results of a chi-square test (C1) on the hypothesis of equal weighting, i.e., a value of 33.3 for each category. In all cases, this hypothesis can clearly be rejected. Tables 4-6 to 4-8 give the detailed results for the indicator weights, respectively for the direct weighting approach, the point allocation, and AHP, and table 4-9 presents this information in summary form in order to allow a more direct comparison of the different techniques.

For the direct weighting method, the five most important criteria were: average revenue/kwh (5.9) and its change (4.3), average fuel cost (4.2), average residential rates (4.1), and steam station heat rate (4.0), for a combined weight of 22.5. However, considerable variation of the values across respondents was found for average revenue/kWh and its change (the most important criterion), for change in after-tax interest coverage ratio (on average the least important), change in administrative and general expenses per customer (low importance) and return/kWh (high importance). For all indicators, the mean for the static measure was found to be higher than that for the corresponding rate of change. Two tests are reported on the hypothesis of equal weighting. The first (C1) is a chi-square test on the hypothesis of an equal weight of 1/36 for each indicator, measured in terms of its variation across respondents. The second (C2) considers the hypothesis of equal weighting within each category, or, in other words, of a weight of 3.70 for the indicators in the service group, of 2.56 for those in the finance group, and of 2.38 for those in the production group. The critical level, at p=0.05, for a chi-squared statistic with 38 degrees of freedom is 53.38, which is to be compared to the values listed in the table (a * is listed when the statistic has values larger than 100). The null hypothesis cannot be rejected at the 0.05 significance level for 22 out of the 36 indicators for C1 and for 19 indicators using C2. However, as is to be expected, it is clearly rejected for all the more important indicators mentioned above.

The top five rated criteria with the point allocation method are: average revenue/kWh (9.6), average residential rates (8.6), average fuel cost (5.3), return on equity (5.2), and steam station heat rate (4.2). While four out of these are the same as for direct weighting, their values are higher, and combine to 32.9. In addition, the weights show a higher degree of variation across respondents, and this for all indicators, except average revenue/kWh and its rate of change. In contrast to the previous method, here the two null hypotheses of equal weights can be clearly rejected for all but two of the indicators, change in average fuel cost, and administrative and general expense per customer, which rank 22nd and 25th respectively).

Before the weights obtained from the AHP application could be analyzed across respondents, it was necessary to eliminate some evaluations that clearly violated the consistency test on the pairwise comparisons. Of the 23 comparisons to be carried out, 12 could result in inconsistencies (measured as a value of the consistency test of higher than 0.10), since the other 2x2 matrixes involved only one assessment. A cut-off point of 4 was taken to eliminate those answers that showed too high a degree of internal inconsistency. For the 40 participants who carried through the fourth step in the evaluation, a total of 27 responses were used in the analysis to obtain the mean weights. Of these, four had a total absence of inconsistencies and ten had one. The resulting top five indicators are: average residential rates (15.9), and its change (6.5), average revenue/kWh (6.3), after-tax interest coverage ratio (4.2), and operating expenses/gross revenue

(4.1), for a total combined weight of 37.0. While this is considerably higher than for the other two methods, this seems primarily due to the value for the most important indicator. As was found for the aggregate category weights, the variation of the individual indicator weights across respondents is considerably higher for the AHP technique. Also, the two null hypotheses on equal weighting can clearly be rejected (the appropriate chi-squared statistic critical value, with 26 degrees of freedom, is 38.89).

In order to summarize this information more clearly, the mean indicator weights and their ranks, for the three methods, are given in table 4-9. Although there is considerable variation among the actual values obtained, a small group of indicators consistently ranks quite high: average revenue/kWh, average residential rates, average fuel cost, and heat rate. The rate of change of an indicator is consistently valued as less important than the static value. A rank correlation analysis (using the Spearman rank correlation coefficient) between the importance ranks of the indicator weights (across indicators) reveals the strongest relation between the weights obtained from the direct weighting method and the point allocation, 0.840, followed by direct weighting and AHP, 0.778, while AHP and point allocation had a coefficient of 0.721. While these coefficients are acceptably high to reject the notion of strongly conflicting evaluations among the methods, the variation among the magnitudes of the individual indicator weights is important enough to deserve further attention. This, however, is beyond the scope of the current report.

Analysis of the Company Scores and Rankings

In this section, the company performance scores or performance indexes which can be constructed using the indicator weights are considered more closely. Two types of indexes can be distinguished, based either on a weighted summation or on a "soft" multicriteria analysis. Weighted summation is a simple linear process that consists of multiplying the weights by the standardized values of the corresponding variables, and summing the results. It should be noted that this is only one out of a much larger number of possible aggregation methods (linear and nonlinear), which is chosen here primarily for ease of exposition. The multicriteria technique illustrated here, a variant of the Electre approach (for detailed discussion, see chapter 3), is based on the formulation of a "concordance index" and a "discordance index," reflecting the degree to which one alternative (company) dominates the other alternatives, and is dominated by the other alternatives, respectively. While the concordance index uses only ordinal measurement (outranking principle) and information on the criteria weights, the discordance index uses the latter in combination with the discrepancy between the values in the standardized impact matrix.

Most of the following discussion is based on the mean weights obtained as a result of the workshop. It should be noted, however, that several other procedures exist for constructing an "average" or "consensus" weighting for an evaluation that is carried out by multiple participants (i.e., the construction of a group preference function). The average values are chosen here for reasons of simplicity and ease of exposition. In an actual application, the assessment of the group weights from the individual evaluations is a process which necessitates considerable discussion, negotiation and feedback among the participants (e.g., using a Delphi technique). These requirements could not be taken into account within the scope of the workshop. However, in the interest of completeness, the full results on the subjective performance indexes that resulted from each of the participant's weights have been listed in appendix E (tables E-1 through E-4).

A summary idea about the variation in the weighted summation company scores obtained from the the individual participant weights can be gained from table 4-10. There is listed, in addition to the mean

TABLE 4-10

COMPANY SCORES BY METHOD

Company	A	B	C	D	E	F	G	H	I	J
Holistic										
Mean	71.7	44.8	80.2	46.6	48.2	49.5	51.5	54.7	78.5	57.1
St. Dev.	16.9	22.8	17.6	26.5	23.2	21.9	22.5	23.6	22.2	26.8
Range	81.0	84.0	78.0	100.0	90.0	82.0	83.0	86.0	89.0	95.0
C.V	23.5	50.8	22.0	56.9	48.1	44.3	43.6	43.1	28.3	47.0
Direct										
Mean	57.8	43.8	64.2	46.5	43.1	48.0	41.5	48.8	68.6	54.1
St.Dev.	4.2	4.6	5.4	5.4	6.0	3.4	6.1	2.9	5.5	4.4
Range	17.6	23.2	24.7	29.1	32.1	15.7	41.0	18.5	24.6	27.1
C.V.	7.2	10.4	8.4	11.7	13.9	7.1	14.7	5.9	8.0	8.2
Points										
Mean	60.3	42.2	68.8	41.1	46.3	46.8	39.5	49.0	71.9	51.1
St. Dev.	7.0	6.2	10.7	7.7	6.5	4.9	8.1	5.8	8.7	8.3
Range	34.2	30.5	55.5	32.4	29.1	28.3	42.2	30.9	48.5	32.0
C.V.	11.5	14.8	15.5	18.7	14.1	10.6	20.4	11.8	12.1	16.2
AHP										
Mean	60.0	45.1	67.4	41.4	47.9	46.3	38.9	50.9	71.7	51.2
St.Dev.	7.2	7.9	12.9	12.5	7.2	6.0	10.1	7.2	8.7	11.1
Range	33.7	36.5	38.8	48.8	32.8	27.0	38.3	30.8	26.7	37.0
C.V.	12.0	17.6	19.2	30.2	15.0	12.9	26.1	14.2	12.1	21.7

value, the standard deviation (St. Dev.), the range, and the coefficient of variation (C.V.) for the company performance ratings across respondents. In addition to the three weight assessment methods discussed in the previous section, the results of the holistic evaluation (carried out in the first phase of the workshop survey) are also presented. In general, these holistic scores vary considerably more across respondents than do the indexes obtained with the weights. The range for the holistic technique typically is between 80 to 100, and the coefficient of variation is from 2 to 4 times that of the other techniques, which points to considerable conflict among the evaluators with respect to their first impression of the company performance.

A more complete comparison of the performance indexes obtained with the different techniques is provided in table 4-11, in which the company scores and the resulting ranks are listed for sixteen different approaches. In addition to the three categories of weights considered so far (direct weighting, or "direct"; point allocation, or "points"; and AHP), two types of equal weighting are introduced as well, paralleling the hypotheses tested in the previous section ("equal" for a weight of 1/36; "grouped" for the situation of equal weighting within each criteria category). These five sets of (average) weights are used to obtain the concordance and discordance indexes. It should be noted that the values for these are not comparable to the values constructed by a weighted summation. Also, recall from chapter 3 that, whereas for the concordance index a higher value points to a better performance, for the discordance the opposite is the the case (the most negative value corresponds to the best performance). For the weighted summation techniques, the performance indexes obtained show fairly similar values, with the exception of the holistic evaluation. This is confirmed by the information in table 4-12 where the correlation coefficients between the values of the company scores are listed. It should be noted that, due to the small number of observations and the truncated character of the indexes, the strictly statistical properties of the correlations do not fully hold. They are therefore listed mainly for illustrative purposes. The highest values are obtained

TABLE 4-11

COMPARISON OF COMPANY SCORES AND RANKS BY METHOD

I. Scores

Company	A	B	C	D	E	F	G	H	I	J
					Weighted Summation					
Holistic	71.7	44.8	80.2	46.6	48.2	49.5	51.5	54.7	78.5	57.1
Direct	57.8	43.8	64.2	46.5	43.1	48.0	41.5	48.8	68.6	54.1
Points	60.3	42.2	68.8	41.1	46.3	46.8	39.5	49.0	71.9	51.1
AHP	60.0	45.1	67.4	41.4	47.9	46.3	38.9	50.9	71.7	51.2
Equal	55.5	41.9	61.2	49.4	39.9	47.4	43.2	48.1	69.4	55.2
Grouped	55.7	41.1	60.7	48.1	42.5	46.8	40.9	48.4	70.7	54.6
					Concordance Index					
Direct	85.5	-221.3	168.1	-49.2	-319.9	-85.6	-83.9	37.1	285.0	185.0
Points	84.0	-232.1	194.2	-122.0	-331.1	-109.5	-69.4	75.8	307.5	202.8
AHP	86.4	-177.6	221.4	-97.6	-232.9	-127.1	-164.4	38.0	319.5	134.4
Equal	83.3	-222.2	161.1	11.1	-288.9	-94.4	-116.7	5.6	305.6	155.6
Grouped	97.4	-239.6	157.8	-12.9	-235.9	-109.5	-150.6	9.4	333.3	150.5
					Discordance Index					
Direct	-116.5	246.6	-284.2	108.8	347.5	91.3	185.5	45.6	-452.7	-171.9
Points	-107.2	240.8	-300.3	200.1	359.2	112.4	180.5	-28.9	-475.2	-181.5
AHP	-143.1	152.4	315.7	203.7	234.9	135.3	273.5	50.8	-494.9	-97.0
Equal	-116.5	247.1	-275.8	39.0	296.0	105.6	212.6	88.5	-461.6	-135.0
Grouped	-131.1	262.9	-257.1	79.8	221.1	122.8	253.6	70.0	-488.1	-133.8

II. Ranks

Company	A	B	C	D	E	F	G	H	I	J
					Weighted Summation					
Holistic	3	10	1	9	8	7	6	5	2	4
Direct	3	8	2	7	9	6	10	5	1	4
Points	3	8	2	9	7	6	10	5	1	4
AHP	3	8	2	9	6	7	10	5	1	4
Equal	3	9	2	5	10	7	8	6	1	4
Grouped	3	9	2	6	8	7	10	5	1	4
					Concordance Index					
Direct	4	9	3	6	10	8	7	5	1	2
Points	4	9	3	8	10	7	6	5	1	2
AHP	4	9	2	6	10	7	8	5	1	3
Equal	4	9	2	5	10	7	8	6	1	3
Grouped	4	10	2	6	9	7	8	5	1	3
					Discordance Index					
Direct	4	9	2	7	10	6	8	5	1	3
Points	4	9	2	8	10	6	7	5	1	3
AHP	3	7	2	8	9	6	10	5	1	4
Equal	4	9	2	5	10	7	8	6	1	3
Grouped	4	10	2	6	8	7	9	5	1	3

TABLE 4-12

CORRELATION BETWEEN COMPANY SCORES BY METHOD

	Holistic	Direct	Points	AHP	Equal	Grouped
Holistic	1.000	0.830	0.855	0.842	0.830	0.830
Direct		1.000	0.952	0.915	0.927	0.976
Points			1.000	0.988	0.806	0.927
AHP				1.000	0.770	0.915
Equal					1.000	0.939
Grouped						1.000

between AHP and point allocation (0.988), direct weighting and grouped equal weighting (0.976), and direct weighting and point allocation (0.952). The lowest values, as already pointed out, are obtained for the correlations between the holistic evaluation and all others, and between equal weighting and AHP.

Most applications of performance evaluation within a regulatory context are not likely to use the actual values of the various (subjective) performance indexes, but rather would focus on the relative rankings these imply for the companies under consideration (or for one company taken over time). These rankings are presented in table 4-11, and the resulting rank correlations are given in table 4-13. The similarity among the rankings obtained with the different techniques, also reflected in the high values for the rank correlation coefficients, is striking. However, from a strictly statistical standpoint, the hypotheses that they are the same cannot be maintained (as tested with a Kendall W coefficient of concordance). This may in part be due to the small sample size (10 companies) considered.

In a regulatory context, one is primarily interested in being able to identify companies with extreme performance, good as well as bad. In that respect, the different rankings show an encouragingly high degree of agreement. Company I ranks highest on all but the holistic

TABLE 4-13

RANK CORRELATION BETWEEN COMPANY SCORE BY METHOD

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Summation																
1. Holistic	1.00	0.83	0.85	0.84	0.83	0.83	0.84	0.90	0.87	0.82	0.89	0.89	0.93	0.82	0.82	0.87
2. Direct		1.00	0.95	0.92	0.93	0.98	0.87	0.84	0.94	0.92	0.93	0.95	0.92	0.99	0.92	0.94
3. Points			1.00	0.99	0.81	0.93	0.77	0.79	0.84	0.79	0.85	0.88	0.87	0.96	0.79	0.89
4. AHP				1.00	0.77	0.92	0.75	0.76	0.81	0.76	0.83	0.83	0.82	0.93	0.76	0.88
5. Equal					1.00	0.94	0.94	0.88	0.98	0.99	0.96	0.95	0.92	0.88	0.99	0.94
6. Grouped						1.00	0.88	0.82	0.94	0.93	0.95	0.93	0.88	0.94	0.93	0.98
Concordance																
7. Direct							1.00	0.96	0.98	0.96	0.96	0.95	0.94	0.83	0.96	0.93
8. Points								1.00	0.94	0.90	0.93	0.95	0.98	0.90	0.90	0.88
9. AHP									1.00	0.99	0.99	0.99	0.96	0.90	0.99	0.96
10. Equal										1.00	0.98	0.96	0.93	0.87	1.00	0.95
11. Grouped											1.00	0.98	0.95	0.88	0.98	0.99
Discordance																
12. Direct												1.00	0.99	0.93	0.96	0.95
13. Points													1.00	0.90	0.93	0.92
14. AHP														1.00	0.87	0.89
15. Equal															1.00	0.95
16. Grouped																1.00

evaluation (for which it ranks second), and companies C, J, and A consistently rate among the top four. At the other side of the scale, the evidence is less uniform. Companies G, B, and E rank among the last for most techniques, although G achieves two rankings as 6th (holistic evaluation and concordance index with point allocation), and E rates 6th for the AHP method. In all, however, these three companies seem to consistently perform poorly. Provided that all methods are given equal credibility (or weight), the different rankings can be summarized with the Borda-Kendall rank sum. This yields the following overall ranking (with the respective rank sums in parentheses): 1. I (17); 2. C (33); 3. J (53); 4. A (57); 5. H (83); 6. F (108); 7. D (110); 8. G (133); 9. B (142); 10. E (144).

Interpretation of the Results

Even though the participants in the workshop cannot be considered to form a statistically representative sample of the total regulatory community, their perception of the usefulness and appropriateness of the different evaluation techniques that were discussed may provide some insight into the operational value of these approaches. To gauge this in a somewhat organized fashion, a small number of questions were submitted at the end of the workshop.

A major point of interest was the perceived use in the regulatory process for performance indicators as such, or in combination with a structured multicriteria decision analytic technique. Of the forty respondents, 24 rated the use of performance indicators alone as useful, while 8 considered them as not useful, and the 8 others had no opinion. With respect to the usefulness of multicriteria techniques, the assessment was even more positive, with 28 participants rating them as useful, 5 as not useful, and 7 had no opinion. With a specific focus on the analytic hierarchy process technique to assess the relative importance of the criteria weights, 30 of the 38 respondents rated the method as useful, 4 as not useful, and 4 had no opinion. More specifically, 22 participants considered the AHP approach to have the right degree of complexity, while 12 rated it as too complex, and 1 as not complex enough. Also, 25 thought that the structuring process provided insight, while 7 considered it confusing.

Finally, the participants were asked to list and rank the different techniques for utility performance evaluation that were discussed in the course of the Workshop. Four major categories of approaches were listed: the use of econometric cost and production functions, the construction of a total factor productivity index, the use of financial and engineering performance ratios as such, and the application of multi-criteria decision analytic techniques. Table 4-14 presents the summary results of this evaluation. It should be noted that the listing was open-ended, in the sense that no technique was suggested to be ranked a priori. As a consequence, the number of times each method is mentioned is not a constant. Overall, the multicriteria technique was very well received (taking into account that the participants were least familiar with this method) and achieved the highest number of first place rankings, 15, as well as the highest number of times listed, 29. The econometric cost and production functions and the use of TFP each were ranked first 5 times, but were

TABLE 4-14

COMPARATIVE RATING OF PERFORMANCE EVALUATION TECHNIQUES

	Frequency			
Technique	Rank 1	2	3	4
Multicriteria	15	6	7	1
Econometric	5	11	5	1
TFP	5	9	9	2
Ratios	3	1	2	3

not listed equally frequently (22 times for the econometric methods, 25 times for TFP). The use of financial and engineering ratios was only listed 9 times, 3 of which as most important.

In sum, and taking into account the limited context of the workshop, the use of multicriteria "soft" decision techniques to assess the performance of electric utilities has been found to be both operationally feasible and easily acceptable by commission staffs. The techniques provide a flexible means to gain insight into the complexities of the evaluation problem and to isolate potential problem companies (and/or problem areas), as a step in a more elaborate decision support system. A more detailed comparison of these techniques with the more traditional economic and econometric approaches is presented in chapter 7.

PART II

ECONOMIC APPROACHES TO UTILITY PERFORMANCE MEASUREMENT

CHAPTER 5

METHODOLOGY OF TWO ECONOMIC APPROACHES

Two principal economic methods for analyzing performance are total factor productivity indexes and measures based upon cost function estimation. Dynamic and static versions of each of these approaches are discussed in this chapter. The application of each of these methods to electric companies is presented in chapter 6. Other economic methods are discussed in Anselin, Pike, and Smith (1981).

Total Factor Productivity Index

The purpose of economic studies of productivity is to measure increases in output that can not be accounted for by changes in the levels of the inputs used in the production process or by any characteristics of that process. The analysis is typically conducted for a single firm or other entity (such as an industry or the entire U.S. economy) over time. Technical progress or productivity advancement is taken to be the residual growth of output after subtracting the growth of inputs. Hence, if output grows by 10 percent between 2 years and the aggregate physical inputs grew by only 6 percent, the residual or 4 percent would be considered the firm's productivity growth.

Total factor productivity (TFP) analysis was developed by Kendrick (1961) and Denison (1962). The concept is straightforward--the productivity index is the growth rate of output unexplained by the growth of inputs. The difficulty is constructing aggregate measures of outputs (if there is more than one) and inputs. The original approach taken by Kendrick and followed by many others was to use a Laspeyres weighted average of inputs with the weights being base-period prices.[1] To illustrate this, suppose the measure of productivity growth, expressed in terms of natural logarithms (ln), is

$$\ln(TFP_t)-\ln(TFP_{t-1})=\ln(Y_t/Y_{t-1})-\ln(I_t/I_{t-1}) \ , \qquad (5.1)$$

where Y is output in period t, and I is an index of inputs. The term TFP denotes an index that can be interpreted as a ratio of output to inputs. In this formulation we are only interested in the logarithmic difference in this index (that is, the left hand side of equation (5.1)), which is the growth rate described above. The term, TFP, is sometimes used to denote this growth rate directly, and sometimes the logarithmic difference of TFP is called a growth rate. The reader should be aware that different authors use this same term, TFP, differently and that in this study it refers to a ratio of output to inputs. Regardless of how TFP is defined, however, the measure of productivity is always the growth rate of unexplained output.

The Laspeyres input index is defined in terms of a base period as

$$I_t/I_o = \sum_i P_i^o X_i^t / \sum_i P_i^o X_i^o$$

where the P_i^o is the price of input i in time period o, and X_i^t is the quantity of input i used in time period t. In effect, the rate of growth of the aggregate input index is a weighted average of the growth rates of the individual inputs, using base-period cost shares as weights. That is, the input index can be rewritten as

$$I_t/I_0 = w_i X_i^t / X_i^o ,$$

where w_i is the base-period cost share $p_i^o X_i^o / \sum p_i^o X_i^o$.

---

[1] See Ferguson (1972) for an elementary discussion of index numbers, including the Laspeyres and Paasche indexes.

The Laspeyres index number approach is inexact except under special circumstances. Because of this it has generally been supplanted by Divisia index numbers. In practical applications, Divisia indices are approximated by a formula attributed to Tornqvist given by[2]

$$\ln(I_t/I_{t-1}) = \sum_i \bar{w}_i \ln(X_t/X_{t-1}), \tag{5.2}$$

where $\bar{w}_i$ is a weighted average of the cost shares in the two periods, as opposed to the base-period cost shares of the Laspeyres approach. A ranking of utilities on the basis of this TFP measure is, in effect, a comparison of the annual productivity improvements made by each company. It does not compare the actual efficiency of the companies in producing the given output with the actual inputs used. That is, no static comparison of performance can be made using this TFP measure, at least in the way it is normally applied. The following TFP technique, however, is equally adaptable to both static and dynamic measures of performance.

Multilateral Total Factor Productivity

The conventional Divisia index of TFP includes an aggregate input index that is a weighted average of the growth rates of the various inputs. The weights are themselves an average of the cost shares in the 2 years being compared. Thus, for example, if the comparison is between the years 1979 and 1980, the Divisia index of inputs is a weighted average of the growth of each input between the 2 years, with the weights as the average of 1979 and 1980 cost shares. In principle, there is nothing to prevent the same technique from being used to compare companies. A growth rate is nothing more than the

---

[2]See Diewert (1981) for a technical discussion of the Divisia index. The Tornqvist approximation is discussed in Cowing, Stevenson, and Small (1981).

percentage difference between two quantities, except that the comparison happens to be between two adjacent years. To compare a pair of companies, the percentage difference in all inputs and output could be found, using an average cost share as weights in the formation of the aggregate input index. Such a procedure could conceivably be applied to all possible pairs of companies. For even a small number of companies the result would be a very large number of pairwise comparisons. Not only is such an approach expensive and unwieldy, but the set of pairwise comparisons may not even be internally consistent. That is, one index may imply that company A is more productive than company B and another might show that B is better than C. A consistent indexing scheme is one that would then show that company A is better than C when they are directly compared, to be consistent with the indirect comparison implied by the A-B and B-C results. The above set of pairwise comparisons suffers because it may not be be consistent in this sense.

There are at least two ways of dealing with the problem just described. A computationally straightforward solution is to base the TFP index on each company's own cost shares. This is essentially the approach taken by Foley (1984) in the NARUC study of "Electric Utility Financial and Operating Performance Review." In particular, Foley uses a ratio of output (in kilowatt-hours) to constant dollar value of inputs as a TFP index. In effect, this is similar to a Paasche index for which the weights used to form the aggregate input index are the cost shares in the current year.[3] The weights are updated each year. The index number problems associated with both Laspeyres and Paasche index do not need reviewing here. It suffices to say that the Divisia type of index avoids the rather severe assumptions implicitly made about input substitution possibilities by the other two indexes.

A second type of solution to the previously mentioned inconsistency and the one adopted for this study is based on the Divisia formulation. It was proposed by Caves and Christensen (1980) for

[3]See footnote 1 of this chapter.

making binary comparisons of productivity and has been applied to the airline industry by Caves, Christensen, and Tretheway (1981). The formula for this multilateral TFP index is

$$\begin{aligned} \ln TFP_k - \ln TFP_l = {} & \ln(Y_k) - \ln(Y_l) \\ & -\sum_i [(w_{ik}+\bar{w}_i)/2] \ln(X_{ik}/\tilde{X}_i) \\ & +\sum_i [(w_{il}+\bar{w}_i)/2] \ln(X_{il}/\tilde{X}_i) \end{aligned} \tag{5.3}$$

where a bar over a variable denotes the arithmetic mean and a tilde over a variable denotes the geometric mean. The subscripts k and l can refer to time periods or firms. The averages used in formula (5.3) are computed over the entire pooled, time series, cross sectional sample. The weights used to construct the aggregate input index are divided equally--half of the weight reflects specific conditions of a firm in a given year, and half is an average of the conditions over the entire sample. In effect, all firms are compared to a hypothetical average firm producing the geometric mean of output with the geometric mean of inputs. Since all firms are compared to the same representative company, the set of pairwise comparisons is consistent.

This multilateral TFP measure can be used directly to compare the performance of utilities within the same year. Hence, a static comparison of relative productivity can be made using this approach. In addition, annual differences in the index represent the dynamic growth of productivity over time. Both the static and dynamic measures were computed for a sample of 81 electric companies over the time period 1964 to 1981. This application of the multilateral TFP index is presented in chapter 6.

TFP Adjustments

The TFP index approach to productivity measurement is typically modified when applied to regulated public utilities. As described, these measures can adequately trace productivity movements in competitive industries, for which they were developed. Public utilities, however, have three characteristics that are sometimes incorporated into studies of performance. These three factors are returns to scale, capacity utilization, and the effects of rate-of-return regulation on the price of capital. The adjustments associated with each of these are discussed in Cowing, Small, and Stevenson (1981). A brief description is provided in this section for readers unfamilar with these issues.

The traditional TFP index implicitly is based on constant returns to scale. A doubling of output and a doubling of all inputs would result in an index of zero, reflecting no technical progress. If a firm has increasing returns to scale, output increases proportionally more than inputs. In such a case, a doubling of all inputs should result in more than a doubling of output. If output were merely to double, the TFP index should show a negative growth in productivity. That is, in the absence of a returns-to-scale correction, the traditional TFP indices would overstate TFP growth. The usual adjustment is to multiply the aggregate input index by a factor that reflects scale economies. The most commonly used factor is the reciprocal of the economies of scale measured in conjuction with econometric estimates of cost functions. The need for statistical estimation makes this an expensive adjustment that many commissions may find unnecessary. Cost estimation is included in this project on its own merits, however, and so little additional computational expense was needed to make this correction in this study. The particular factor used in this study was

$$\ln (TFP_t) - \ln(TFP_{t-1}) = \ln(Y_t/Y_{t-1}) - \overline{SE}^{-1} \ln (I_t/I_{t-1}) \qquad (5.4)$$

where $\overline{SE}$ measures scale economies as the elasticity of cost with respect to output. This elasticity is unity for constant returns to scale and is less than one if a firm has increasing returns to scale, as is the case for most public utilities. So, for example, if the elasticity is .95, cost increases only 95 percent as much as output because of the positive returns to scale. The reciprocal of this number is greater than one, which when multiplied by the input index has the appropriate effect of reducing the value of the TFP index. The bar over SE denotes that it is calculated as the average of the measures in the 2 years being compared in (5.4).

In the case of the multilateral index, the correction is to multiply each aggregate input index by the corresponding scale economy factor. Since the norm of this index is a hypothetical average firm, the scale economy factor involves the average economies of scale for the entire sample. In particular, the index becomes

$$\begin{aligned} \ln TFP_k - \ln TFP_1 &= \ln(Y_k) - \ln(Y_1) \\ &- \overline{SE}_k^{-1} \sum_i [(w_{ik} + \bar{w}_i)/2] \ln(X_{ik}/\tilde{X}_i) \\ &+ \overline{SE}_1^{-1} \sum_i [(w_{i1} + \bar{w}_i)/2] \ln(X_{i1}/\tilde{X}_i) \end{aligned} \qquad (5.5)$$

where $\overline{SE}_k^{-1} = 1/2\ (SE_k^{-1} + \overline{SE}^{-1})$ and the bar denotes the average of SE over the entire sample. The empirical findings discussed in chapter 6 reflect the adjustments in equations (5.4) and (5.5).

The second type of adjustment that is sometimes incorporated into productivity indices is for capacity utilization. This type of adjustment has not been included in this project because its justification is questionable. The typical reason given by researchers who have used such an adjustment is that the capital intensive nature of electricity production is such that large differences in capital can occur in relatively short time spans. The addition of a new generating plant, for example, can cause a jump in the utility's capital stock from year to year. This creates an apparent reduction in the firm's performance that some economists believe should be corrected by multiplying the capital stock by a capital utilization rate to create a measure of utilized capital.

The arguments in favor of such a correction are not persuasive, in our view. First, the typical correction is to base the utilization rate on that of the generation plant. Such an adjustment may not be appropriate. If, as in this study, the firm's entire capital stock is measured, the utilization of generation facilities to correct for all capital use has no obvious meaning. That is, multiplying transmission and distribution plant by the rate of generation utilization does not yield an understandable result. If only the generation plant is included in the analysis to begin with, the multiplication of generation utilization and generation plant yields a data series that is highly correlated with output. Indeed, only errors in the indexing used to create the real capital stock series would prevent output from being identical to the product of (output in kilowatt hours/capacity in kilowatts) and (dollar value of kilowatts installed). In such a case, increases in output would be used to explain increases in output in the TFP index, a seemingly redundant procedure.

Second, if the problem is an unstable time series of TFP measures, it is not clear that utilized capital represents the best way of smoothing it. A simple moving average might be better. Third, plant, which by necessity must remain idle until demand grows sufficiently to utilize it fully, is nonetheless costing society real resources. This cost does not disappear in reality, even if it apparently does when capital is multiplied by a utilization rate. It is better, in our view, to use an ordinary, uncorrected index of TFP and recognize its inherent tendency to fall suddenly when large increments of new capital are installed.

The third type of correction that a few researchers, notably Cowing, Small, and Stevenson (1981), have used is based upon the Averch-Johnson hypothesis that rate-of-return regulation distorts the cost of capital facing the firm. The correction involves estimating company-specific measures of regulatory tightness and using these to impute a corrected cost of capital. Such a correction was not explored in this study for two reasons. The adjustment is expensive and its effect is likely to be quite modest according to the findings of Cowing et al.

Cost Function Estimation

Although the TFP indexes can be modified to account for scale economies, capacity utilization, and regulatory tightness, the approach can accomodate exogenous factors in only a limited way. The major exogenous forces beyond the control of management that influence the cost of electricity are the prices of the factors of production. These are implicitly included in the TFP index since cost shares are the weights used in forming the aggregate input measure. The price of labor, capital, and fuel were included in this and most studies of the electricity industry productivity.[4] It is the difference in the prices paid for inputs that accounts for most of the difference in electricity prices between regions of the United States. Apart from factor prices, however, the TFP approach cannot correct for other exogenous factors beyond the control of management. Such factors might include climatic conditions since the cost of protecting and maintaining plant and equipment is larger in colder regions. Population density is a factor that might tend to reduce unit costs since the distribution network need not be so extensive. Exogenous productivity determinants such as these can be incorporated into an econometric estimate of a cost function. In this sense, many researchers think that statistical cost functions are superior to TFP approaches, although they suffer from the drawback of being relatively expensive to implement. In the experience of the NRRI project team, however, the biggest cost of a productivity study is assemblying the data. The cost of analysis, whether it is constructing a TFP index or estimating a cost function, is small by comparison.

---

[4]This means the price of of fuel, for example, was treated in this study as being beyond the control of management. From the viewpoint of large regional differences in fuel prices, this appears to be a safe assumption. To check the overall validity of this assumption, the empirical results reported in chapter 6 were reanalyzed using the statewide average instead of the utility's own fuel price. This should eliminate any market power that the utility might have in setting its own fuel price. The empirical conclusions were not changed in any important way.

Long-term Cost Functions

Long-run cost functions can be used in productivity analysis. For the purposes of this project, electric companies are considered to produce a single homogeneous product--electricity. (An alternative specification of a multiple output cost function that distinguishes residential from industrial sales, for example, yields little additional explanatory power in the case of electricity companies. A study of telephone costs, however, might usefully distinguish multiple services.) The production process is considered to use three inputs, labor (l), capital (k), and fuel (f). For simplicity, we suppose that the firm wishes to minimize the costs of producing a given output, y. The firm takes as given the prices of the three inputs. The outcome of the cost minimizing decision process is the cost function. Here we treat the case of the long run in which the firm chooses the optimal combination of all three imputs, including capital. Then, we discuss the implications of shorter time frames during which the capital stock is fixed. The cost function may be generally written as

$$C = C(y, p_l, p_k, p_f, Z), \tag{5.6}$$

where p_i is the price of input i and Z is a subset of other exogenous variables.

Statistical estimation of cost function (5.6) requires that an error term be added. It is convenient to deal with logarithms of cost for reasons made clear later. We can write

$$\ln C^a_{it} = \ln C^p_{it} + e_{it}$$

where C^a_{it} is the actual cost for any firm i in year t, C^p_{it} is predicted cost for firm i in year t, e_{it} is the error term, and ln is the natural logarithm. Predicted cost is the cost function in equation (5.6).

Two types of productivity indices can be based on the estimated cost function. A static index can be formed from an analysis of the residuals for any year t. In particular, the negative of the residuals or

$$-e_{it} = \ln C^p_{it} - \ln C^a_{it} \tag{5.7}$$

is a measure of the percentage difference between predicted and actual cost. A firm would be considered to be more productive for higher values of this index since, in such a case, actual costs are less than those predicted by the cost function estimated over many firms in the electricity industry. The production technology of such a firm, in some sense, can be considered superior to that of the industry's average. This type of index can be formed by estimating a logarithmic cost function for each yearly cross-section of firms and using the negative of the residuals as the productivity index.

A dynamic performance index showing the firm's improvement in cost management can be developed from the estimated cost function by comparing the firm's actual cost in year t with that which could have been expected on the basis of the previous year's estimated cost function. The TFP index in this case can be written as

$$TFP_{it} = \ln C^{p}_{i,t-1}(y_t, p_t, z_t) - \ln C^{a}_{it} \tag{5.8}$$

where the $C^{p}_{i,t-1}$ refers to the estimated cost function of period t-1, and the variables in parentheses refer to the current values of output, the vector of input prices, and exogenous factors in year t. For any given year t, a TFP index measures the improvement in cost performance, aside from that which can be anticipated from a knowledge of last year's technology.

Regulators may be interested in both the static and dynamic indexes of performance. Both of these dimensions can be incorporated into incentive regulation or into the regulatory staff's management information system.

Variable Cost Functions

The terminology, "variable," or "short-term" cost function, has been applied to a variety of ideas in the economics literature.

Berndt, Morrison, and Watkins (1981) distinguish three generations of the concept. The first generation consists of models based on partial adjustment behavior, the practical application of which usually involves a regression model with a lagged dependent variable as one of the predictors. The second generation examines restricted cost relationships in which one or more factors of production are considered to be fixed. It is this second generation of cost models that is considered here. For completeness, the third generation advances the ideas of the first by linking the partial adjustment to explicit dynamic optimization, a topic beyond the scope of this report.

The short-term cost function examined here is based upon the traditional textbook treatment of fixed and variable costs. The firm is considered to have certain inputs to the production process that can not be easily varied. Capital facilities and equipment are the usual examples. With capital fixed in the short run, the problem facing the firm is to optimize those inputs which can be varied. Here, three inputs are considered: labor and fuel are variable, while capital is fixed. Variable cost consists of expenditures on the two variable inputs or

$$CV=p_l L+p_f F$$

where L denotes labor, F denotes fuel, p is the price of the input, and CV is variable cost. Total cost includes that spent on capital or

$$C=CV + p_k K,$$

where K denotes capital. After the firm has optimized its variable costs, we can represent its choices as

$$CV=f(Y,p_l,p_f,K). \tag{5.9}$$

Equation (5.9) represents the minimum variable cost for producing the output level y, given the input prices p_l and p_k, and the level of the capital stock, K. The effect of each of the first three arguments in (5.9) is expected to be positive. That is, to produce more output should require more variable cost so the effect of Y on CV should be positive. Likewise, an increase in the price of any variable factor should increase variable cost.

The final term in equation (5.9) should exert a negative influence on variable cost, as long as the firm is not too far from its long-run equilibrium stock of capital. The reason is that more capital should enable the firm to use fewer variable inputs and produce the same output. As demand begins to approach capacity, the existing capital stock must be utilized at a higher and higher rate. For a given set of electricity generation stations, for example, this normally means that more fuel intensive technologies are pressed into service in order to meet peak demand. Additional capital normally saves fuel, so that variable costs can be expected to decrease when a new generation plant is added. The same argument applies also to other phases of electricity production. Distribution maintenance costs should decrease as capital is added.

Indeed, the major reason for adding plant is the corresponding reduction in variable costs (to produce a given output). If added capital resulted in an increase in variable costs, the company would assuredly have too much capital. This is because a reduction in the capital stock would simultaneously reduce variable costs, and also would directly save the cost of the capital itself, while producing the same output. Hence, observing capital with a positive effect on variable cost would be evidence of overcapitalization.

The variable cost function can yield more precise information about the firm's capital choices than the case just described, however. At any given time, a firm (whether regulated or not) is not likely to be in its long-run equilibrium configuration of capital, labor, and fuel. Typically, most firms have some plant that might be termed excessive from a static viewpoint, but that is needed to avoid lost sales when demand grows in the future. Long-run equilibrium occurs when the firm's capital stock is that which would have been chosen in the long run to produce the current level of output. The conventional manner of describing this relation between long and short run is shown in figure 5-1, which depicts the long-run average cost curve as the envelope of a succession of short-run average cost curves.

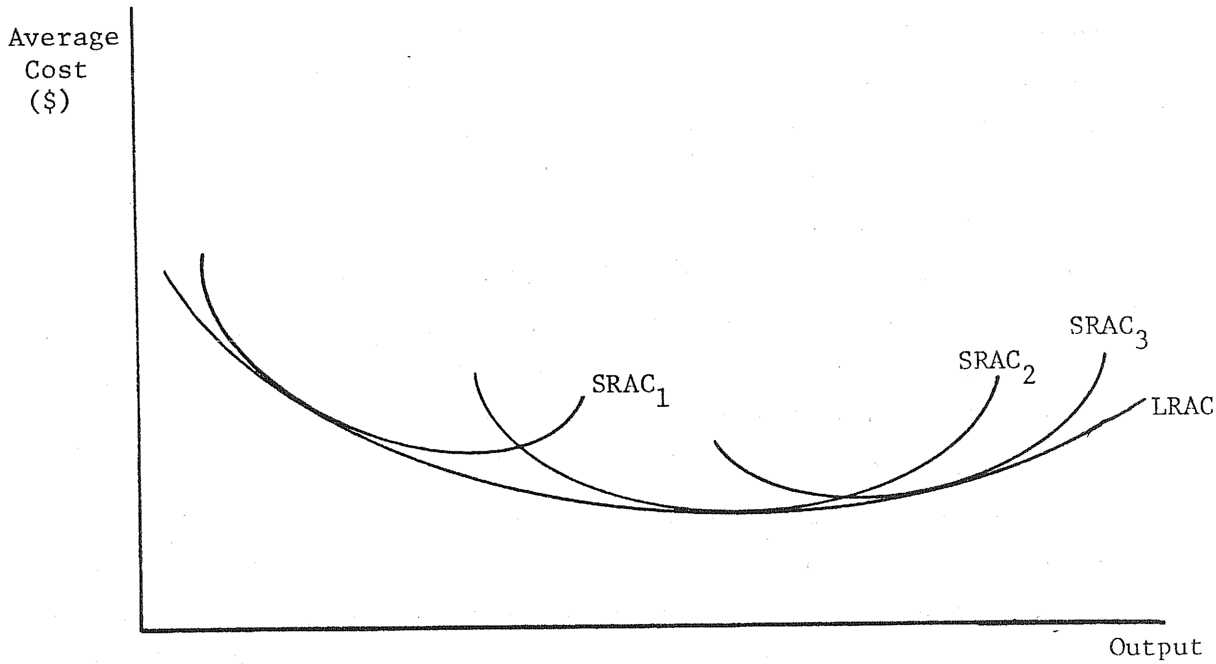

Fig. 5-1. Long- and short-run cost curves

Each of the three short-run average cost (SRAC) curves corresponds to a different level of the capital stock. The short-run cost is as low as that in the long run only if the existing stock of capital happens to equal that which would have been chosen in the long run to produce the given level of output. In the figure this happens at a point of tangency between the short-and long-run curves. Interestingly, this tangency point can be found if we know the variable cost function, equation (5.9). Since total cost is $C=CV+p_kK$, the firm's optimal long-run choice of capital is to adjust the stock of capital until the derivative of total cost with respect to capital is zero. That is,

$$\frac{\partial C}{\partial K} = \frac{\partial (CV)}{\partial K} + p_k = 0,$$

this requires that

$$\frac{\partial(CV)}{\partial K} = -p_k. \qquad (5.10)$$

Hence, for the firm to be in long-run equilibrium requires not only that the effect of capital on variable costs (i.e. the derivative) be negative, but that it equal the negative of the price of capital. If the derivative is smaller than this (that is, the absolute value of the derivative is larger than the price of capital), the firm has less than its long-run capital needs. If the derivative is greater than the negative of the cost of capital, (which includes the case that the derivative is positive), the firm has more than its long-run supply of capital. Hence, equation (5.10) forms a testable hypothesis that can be examined empirically. The statistical estimation of the variable cost function is reported in the chapter 6 of this report.

A secondary advantage of the variable cost function for empirical application is that it avoids the issue of whether electricity producers are responding to a distorted price of capital. That is, the traditional Averch-Johnson hypothesis that rate-of-return regulation induces firms to overcapitalize can be interpreted to mean that the firms are minimizing costs, but are using a perceived capital price that is less than the actual price. In this interpretation, regulation causes a reduction in the firm's perception of the cost of capital, which in turn causes the firm to use more capital than is socially optimal. Ordinary, long-run cost estimation uses the cost of capital as a predictor variable. Consequently, when this technique is applied to electricity production, the issue of an appropriate adjustment to the cost of capital may arise. The variable cost function approach avoids this whole controversy since capital price is not used as a regressor to begin with.

CHAPTER 6

EMPIRICAL APPLICATION OF TWO ECONOMIC APPROACHES

This part of the report is devoted to applying the various performances measures outlined in the previous chapter to the electricity industry.

This chapter has three sections. Issues relating to the data base used in this study are covered in the first. The econometric details associated with cost function estimation are outlined in the second. In all, seven economic performance measures were examined for this study: the convention TFP index, which is a dynamic measure; the multilateral TFP approach, which produces both static and dynamic indexes; the long-run cost function, which produces both static and dynamic indexes; and the variable cost function, which produces both static and dynamic indexes. These seven indexes are compared in the third section of this chapter. Only summary statistics are presented in this chapter. The reader should note that econometric cost estimation requires a relatively large sample size in order to have sufficient degrees of freedom for statistical significance. The sample consists of 81 invester-owned electric companies over the years 1964 to 1981. The data required for the TFP measures is a subset of that required for the statistical estimation; consequently, all of the economic measures were computed for the entire sample. Hence, the summary statistics presented in this chapter are based on 81 companies.

Data Base

The NRRI has assembled an extensive data base on investor-owned electric companies as part of this project. The data, sources, and a list of companies are described in appendix A. The NRRI was fortunate to have two machine-readable sources that provided most of the information. One was a Temple-Barker-Sloan tape of FERC Form 1 data covering the years 1964 to 1978 for almost all investor-owned companies. The second was a current Compustat II tape of annual utility data that was graciously provided by Standard and Poor's Compustat Services, Inc. to the NRRI, free of charge, for this specific project. Although the Compustat II tape includes 1983 data for some items, 1981 was the most recent year for which most items were available on the annual tape. Consequently, the NRRI sample extends to 1981.

Because of the availability of these two primary sources, 135 companies were selected for the NRRI data base. These are listed in appendix A. Due to the need to supplement these sources with information from printed documents, however, the variables listed in appendix A are included in our data set with varying degrees of completeness. During this 1-year project, complete information was obtained on the 81 companies that form the sample discussed in this chapter. Although the appendix lists 210 variables, only 7 are used in the economic approaches to productivity measurement discussed in this chapter.

Labor was measured as the sum of the number of full-time workers and one-half of the number of part-time workers. The price of labor was found by dividing labor expenses, including salaries, wages, and pension benefits, by the number of workers. The price of fuel was the average price paid by the utility for coal, oil, gas, and uranium for all generating plants.[1] The quantity of fuel was found by dividing fuel expenses by this average price (in dollars per million Btu). The cost of capital was a weighted average of the cost of debt, preferred equity, and common equity. The cost of debt was estimated as the

---

[1]Nuclear fuel expenses are reported by Compustat as part of average fuel price. This source covered the years from 1973 to 1981. Average fuel price during the 1964 to 1972 period were gathered from construction plant data that did not include nuclear plants. Any error is likely to be small since few utilities were running nuclear plants then.

prevailing interest rate for the utility's Standard and Poor's bond rating classification. That of preferred equity was computed as the preferred dividend requirements per dollar of preferred stock. Common equity cost was estimated using a simple discounted cash flow model.

An inflation adjusted measure of the capital stock was developed as follows. The real capital stock in any year is the previous year's real stock plus new investment measured in 1980 dollars. Specifically,

$$K_t = K_{t-1} + NI_t/HW_t \qquad (6.1)$$

where K_t is the real capital stock in year t, NI_t is the net investment in year t, and HW_t is the Handy-Whitman index for year t (adjusted to 1980 dollars). The process of computing K_t began in 1949, 15 years prior to the beginning of the sample used in the variable cost estimation. Separate capital stock series were found for each company, for six categories of facilities--steam generation, hydro generation, nuclear generation, transmission, distribution, and general plant. The process was initialized by assuming a 3 percent steady growth of capital from 1920 to 1949. The initial 1949 real capital stock, then, was computed as the product of the reported book value in 1949 and a weighted average of the Handy-Whitman index over the previous 30 years. The formula is

$$K_{49} = B_{49} \frac{1-b}{1-b^{30}} \sum_{t=1}^{30} b^{t-1}/HW_t, \qquad (6.2)$$

where B_{49} is book value in 1949, and b is 1.03. The current price of capital in any year t is

$$p_k^t = (r_t + d_t)\ HW_t \qquad (6.3)$$

where r is the utility's weighted average cost of capital, d is the firm's depreciation rate (estimated as the ratio of depreciation expenses and the book value of the capital stock), and HW_t is the current value of the Handy-Whitman index. Capital expenses, then, were simply the product of the real capital stock and its price.

Output is measured as total kWh sales, reflecting this study's interest in the utility's overall cost, as opposed to focusing on the generation phase. The only exogenous determinant, other than input prices, was the number of heating degree days in the company's service area.[2] The cost is expected to be higher in colder climates, reflecting the additional cost of building, maintaining, and protecting plant in harsh winter weather.

Econometric Cost Function Estimation

The translog cost function can be considered to be a general, second-order approximation to any cost function. In addition, it possesses several properties that make it convenient for empirical application. For this study, costs were specified to be a translog function of output, inputs prices, and exogenous factor(s). This can be written as

$$\ln(C) = a_o + \sum_d a_d \ln(d) + \sum_{de}\sum a_{de} \ln(d)\ln(e),$$

$$\text{for } d,e = p_1, p_f, Y, Z \text{ and either } K \text{ or } p_k, \qquad (6.4)$$

where y is output, Z is an exogenous factor, and a's are coefficients to be estimated empirically.

Equation (6.4) can be used to represent either a long-run or variable cost function. In the long-run application, cost (C) includes the annual expenditures on capital, $p_k K$, and the indexes d and e range over a list of variables that includes the price of capital, p_k, but not the quantity of capital, K. For the variable cost application, cost includes only labor and fuel expenditures, while the indexes d and c include the physical capital, but not its price.

The statistical efficiency of the parameter estimates can be improved by jointly estimating factor share equations along with the cost function in equation. Knowing the cost function, the cost share of any factor i can be found, by the envelope theorem, as the

---

[2]Population density was statistically insignificant and consequently eliminated.

logarithmic derivative of the cost function with respect to the input price. These can be written as

$$S_i = \frac{P_i X_i}{C} = \frac{\partial \ln(C)}{\partial \ln p_i} = a_i + a_{il}\ln(p_l) + a_{if}\ln(p_f)$$

$$+ a_{ik}\ln(p_k) + a_{iy}\ln(Y) + a_{iz}\ln(Z) \qquad (6.5)$$

where the subscript i ranges over all variable factors, and the term $\ln(p_k)$ is replaced by $\ln(K)$ in the case of the variable cost function.

The cost function must be homogeneous of degree 1 in variable input prices, which implies that the (variable) cost of producing output Y will exactly double if all (variable) input prices double. It also insures that the factor share equations in (6.5) add to unity. This condition can be imposed on the estimation procedure by requiring the parameters to meet the following restrictions,

$${}_i\ a_i = 1, \quad {}_j\ a_{ij} = 0 \quad \text{for } i = L, F, K, Y, \text{ and } Z.$$

Since the factor shares do indeed sum to unity in the data, one of these share equations must be dropped to avoid singularity in the estimation procedure. The econometric model, then, consists of the translog cost equation (6.4) and factor share equations from (6.5) for one fewer than the number of variable factors, to which additive error terms are appended. The resulting equation system was estimated using three-stage least squares (3SLS). The identity of the dropped factor share equation is not important since iterative 3SLS converges to maximum likelihood estimation.

Empirical Findings

Each of the seven economic performance indicators was calculated for each of the 81 companies in the sample, for each year. There are four dynamic indexes that measure year-to-year performance improvement. These are computed as year-to-year changes of some corresponding static measure, as described in the previous chapter. Consequently, although the sample contains 18 years (1964 to 1981) of observations for the static measures, only 17 were available for the dynamic measures. To simplify matters, the initial year was dropped for the static indexes, so that 17 observations are reported here for all seven measures. The three measures based on the TFP methodology were calculated directly from the corresponding equations (5.4) and (5.5) in chapter 5. The four indexes based on cost functions required a preliminary step in which the short- and long-run cost functions were estimated, using the cross section of 81 companies, for each of the 18 years. Each of these year-by-year cost functions, equation (6.4), was jointly estimated with its associated factor share equations (6.5). The static and dynamic indexes were then computed according to equations (5.7) and (5.8). The amount of numerical detail generated in the course of this project is somewhat overwhelming, as the reader may appreciate. To reduce the reader's burden, we present only summaries of the results.

The estimated coefficients of the translog, long-run cost function for selected years are given in table 6-1. The similar short-run coefficients are listed in table 6-2. In general, the R-squares for the cost models were quite high, 96 percent or better, indicating that almost all of the variation in cost is explained by the independent variables. Most of the explanatory power comes from the first order terms in the equation. Adding the interactive and higher order terms increases the explanatory power only modestly. For the purposes of productivity analysis, a high explanatory power is the most desirable property of an estimated cost function. Since differences between predicted and actual cost are the basis of the performance index, accurate prediction is important. In this sense, the estimated equations are very good.

Although the overall predictive power of the equations is quite high, estimates of some individual coefficients are very imprecise in

TABLE 6-1

COEFFICIENT ESTIMATES FOR TRANSLOG LONG-RUN COST MODEL: SELECTED YEARS

	1964		1972		1980	
Coefficient	Parameter	Std. Error	Parameter	Std. Error	Parameter	Std. Error
a_o	.796	4.60	6.318	3.979	5.518	5.022
a_l	.414	.113	.395	.067	.152	.127
a_k	.343	.110	.374	.091	.675	.148
a_f	.242	.106	.231	.096	.173	.183
a_y	1.286	.543	.106	.539	.368	.571
a_{yy}	-.0075	.019	.022	.020	.0068	.019
a_{ll}	.074	.013	.059	.010	.013	.012
a_{lk}	-.144	.022	-.108	.017	-.0049	.022
a_{lf}	-.0032	.016	-.011	.012	-.021	.014
a_l	-.839	.699	-.937	.473	-1.051	.681
a_{ll}	.079	.031	.037	.015	.048	.026
a_{ll}	.011	.0069	.0045	.0036	.012	.0075
a_{kl}	.0076	.0083	.017	.0058	.029	.0098
a_{fl}	-.019	.0076	-.022	.0065	-.041	.013
a_{yl}	-.024	.045	.056	.036	.053	.040
a_{kk}	.103	.012	.089	.010	.052	.013
a_{kf}	-.062	.016	-.070	.016	-.099	.019
a_{ff}	.033	.0089	.041	.0094	.060	.012
a_{ly}	-.0068	.0045	-.0058	.0036	-.0032	.0058
a_{ky}	.011	.0055	.0056	.0059	-.011	.0076
a_{fy}	-.0039	.0051	.0002	.0065	.014	.0096
System R^2	.906		.889		.903	
Cost R^2	.963		.960		.970	

TABLE 6-2

COEFFICIENT ESTIMATES FOR TRANSLOG VARIABLE COST MODEL: SELECTED YEARS

	1964		1972		1980	
Coefficient	Parameter	Std. Error	Parameter	Std. Error	Parameter	Std. Error
a_o	-5.534	3.19	-1.63	3.88	-2.36	6.90
a_l	.015	.13	.203	.080	.200	.131
a_k	1.093	1.32	-1.76	2.06	.852	2.80
a_f	.985	.13	.797	.080	.803	.131
a_y	.357	1.30	2.16	2.06	.3462	2.84
a_{yy}	-1.65	.148	-.128	.235	-.062	.247
a_{ll}	-.0092	.0092	.0037	.0065	.0074	.0070
a_{lk}	.012	.018	.036	.014	.047	.018
a_{lf}	.019	.019	-.0074	.013	-.015	.014
a_z	.335	.485	.110	.416	-.296	.881
a_{zz}	-.018	.025	-.011	.013	-.0032	.033
a_{lz}	.021	.008	.0070	.0040	.0088	.0078
a_{kz}	-.136	.128	.280	.160	-.086	.230
a_{fz}	-.021	.008	-.0070	.0040	-.0088	.0078
a_{yz}	.124	.123	-.229	.154	.110	.226
a_{kk}	-.012	.018	-.189	.211	-.023	.218
a_{kf}	-.011	.018	-.036	.014	-.047	.018
a_{ff}	-.0092	.0093	.0037	.0065	.0074	.0070
a_{ly}	-.015	.018	-.038	.014	-.048	.019
a_{ky}	.254	.284	.319	.442	.065	.457
a_{fy}	.015	.018	.038	.014	.048	.019
System R^2	.957		.933		.923	
Cost R^2	.984		.977		.964	

some years due mostly to a high degree of collinearity. Hence, some parameter estimates are implausible. For example, the coefficient of the squared output term is negative in some years. If this term were negative in reality, it would imply that the elasticity of cost with respect to output declines as output increases. This is equivalent to the average cost curve first increasing and then decreasing. That is, instead of possessing the usual "u" shape, the average cost curve would resemble an inverted "u" shape. Such a cost curve is most unlikely to be found in practice. That such a coefficient was estimated is a direct consequence of the collinearity between output and its square. Direct estimation of average cost curves confirms that these had the conventional shape.

Another example of collinearity is between output and the real capital stock in the variable cost models. Partly as a result of this problem, the effect of capital on variable cost was positive in all years. The expected relation is negative. The estimated coefficients indicate that additional capital increases variable cost. If true, the firms in this sample have too much capital, which tends to confirm the traditional Averch-Johnson overcapitalization hypothesis. The quality of this evidence, however, must be considered in the light of the severe collinearity problems in the cross sectional samples: large companies have more variable costs, more output, and more capital. In such circumstances, capital becomes a proxy for output, with the result that more capital appears to be associated with greater variable costs. This appearance of positive association, then, should not be interpreted as conclusive evidence of overcapitalization, although it is suggestive.

The principal concern of this report is to compare the various methods of computing productivity indices. In what follows, the cost model indices were based on the translog equation as explained previously. However, the same analysis was conducted for a simpler Cobb-Douglas cost model (having only linear terms), which does not have the collinearity difficulties of the full translog model. The overall conclusions of this analysis are unaffected by the choice of the

Cobb-Douglas or translog functional form of the cost equation. Although the collinearity seriously affects the precision of individual coefficient estimates, overall predictive power is the important ingredient in the productivity comparisons. It is in this sense that the collinearity is not an important issue in these results.

In all, this project investigated seven economic productivity measures. These were (1) the conventional TFP index, (2) multilateral TFP static index, (3) multilateral TFP dynamic index, (4) long-run cost static index, (5) long-run cost dynamic index, (6) short-run cost static index, and (7) short-run cost dynamic index. The actual values of these indexes and the resulting ranking of companies are reported in appendix F, although the identity of the companies has been suppressed in favor of an arbitrary code. The appendix reports each index for 1965 and 1981, as well as for four time periods of about 4 years each, and the overall 1964 to 1981 sample period.

The large magnitude of information in appendix F can be condensed in many ways. In this chapter, where the purpose is to compare the various productivity indexes, a convenient way to summarize the results is to find the correlations among the seven performance indexes. These correlations and some ancillary statistics are reported in tables 6-3 to 6-10 in this chapter. Each table shows the correlations among the indexes for one time period. There is a table for 1965, 1973, and 1981. In addition, the indexes were summarized for four subperiods of the sample and the correlation matrices are reported in tables 6-6 to 6-9. The subperiods were 1965 to 1968, 1969 to 1972, 1973 to 1976, and 1977 to 1981. Finally, the correlations for the 18-year summary indexes are reported in table 6-10.

These correlation tables are quite similar. They show that the seven performance indexes contain only three types of information. That is, the seven measures can be combined into three groups with very little loss of information. The tables have been arranged to illustrate these groupings. The first group consists of the first three indexes shown in the tables: the long-run static index, the multilateral TFP static index, and the long-run dynamic index. The

TABLE 6-3

CORRESPONDENCES AMONG SEVEN ECONOMIC MEASURES: 1965

Correlation Matrix

	L.R. Cost Static	Multi-Lateral TFP-Static	L.R. Cost Dynamic	Multi-Lateral TFP-Dynamic	TFP Dynamic	S.R. Cost Static	S.R. Cost Dynamic
L.R. Cost Static	1	.956	.970	.150	.096	.167	.114
M.L. TFP Static		1	.889	.054	-.013	.211	.132
L.R. Cost Dynamic			1	.185	.162	.140	.078
M.L. TFP Dynamic				1	.965	-.032	-.027
TFP Dynamic					1	-.096	-.071
S.R. Cost Static						1	.976
S.R. Cost Dynamic							1

Principal Component Anaylsis

	Factor						
	1	2	3	4	5	6	7
Variance Explained	.434	.299	.244	.015	.004	.004	0
Cumulative Variance Explained	.434	.733	.977	.992	.996	1	1

	Factor						
	1	2	3	4	5	6	7
L.R. Cost Static	-.552	.033	.194	.054	.025	.519	.620
M.L. TFP Static	-.532	-.037	.222	-.687	.229	-2.55	-.277
L.R. Cost Dynamic	-.540	.074	.178	.650	-.204	-.256	-.376
M.L. TFP Dynamic	-.156	.519	-.449	-.254	-.552	.291	-.224
TFP Dynamic	-.123	.543	-.435	.143	.576	-.314	.226
S.R. Cost Static	-.217	-.466	-.480	-.066	-.361	-.466	.392
S.R. Cost Dynamic	-.184	-.459	-.511	.113	.372	.447	-.379

TABLE 6-4

CORRESPONDENCES AMONG SEVEN ECONOMIC MEASURES: 1973

Correlation Matrix

	L.R. Cost Static	Multi-Lateral TFP-Static	L.R. Cost Dynamic	Multi-Lateral TFP-Dynamic	TFP Dynamic	S.R. Cost Static	S.R. Cost Dynamic
L.R. Cost Static	1	.973	.9870	-.161	-.165	.261	.047
M.L. TFP Static		1	.959	-.190	-.189	.260	.036
L.R. Cost Dynamic			1	-.153	-.146	.252	.040
M.L. TFP Dynamic				1	.985	.037	.097
TFP Dynamic					1	.038	.100
S.R. Cost Static						1	.955
S.R. Cost Dynamic							1

Principal Component Analysis

	Factor 1	2	3	4	5	6	7
Variance Explained	.456	.301	.230	.006	.003	.003	.001
Cumulative Variance Explained	.456	.7573	.987	.994	.996	.999	1

	Factor 1	2	3	4	5	6	7
L.R. Cost Static	.535	.024	-.218	-.216	-.421	-.153	.647
M.L. TFP Static	.533	.008	-.201	.749	.016	.286	-.180
L.R. Cost Dynamic	.530	.027	-.228	-.564	.330	.001	-.489
M.L. TFP Dynamic	-.205	.494	-.462	.060	-.493	-,328	-.382
TFP Dynamic	-.204	.494	-.462	-.026	.496	.323	.386
S.R. Cost Static	.229	.494	.438	.188	.342	-.594	.083
S.R. Cost Dynamic	.111	.517	.491	-.186	-.329	.574	-.086

TABLE 6-5

CORRESPONDENCES AMONG SEVEN ECONOMIC MEASURES: 1981

Correlation Matrix

	L.R. Cost Static	Multi-Lateral TFP-Static	L.R. Cost Dynamic	Multi-Lateral TFP-Dynamic	TFP Dynamic	S.R. Cost Static	S.R. Cost Dynamic
L.R. Cost Static	1	.967	.997	.339	.310	.350	.424
M.L. TFP Static		1	.964	.337	.316	.308	.391
L.R. Cost Dynamic			1	.345	.324	.351	.429
M.L. TFP Dynamic				1	.985	.177	.230
TFP Dynamic					1	.179	.235
S.R. Cost Static						1	.988
S.R. Cost Dynamic							1

Principal Component Analysis

	Factor						
	1	2	3	4	5	6	7
Variance Explained	.561	.227	.202	.006	.002	.001	0
Cumulative Variance Explained	.561	.789	.990	.996	.999	1	1

	Factor						
	1	2	3	4	5	6	7
L.R. Cost Static	-.454	.098	.344	-.390	-.199	-.104	.681
M.L. TFP Static	-.444	.077	.363	.806	-.075	-.072	-.062
L.R. Cost Dynamic	-.456	.092	.337	-.424	.278	.116	-6.32
M.L. TFP Dynamic	-.302	-.596	-.224	-.059	-.636	.249	-.183
TFP Dynamic	-.294	-.596	-.243	.052	.621	-.272	.183
S.R. Cost Static	-.307	.376	-.533	-.055	-.210	-.633	-.181
S.R. Cost Dynamic	-.342	.348	-.493	.092	.206	.659	.184

TABLE 6-6

CORRESPONDENCES AMONG SEVEN ECONOMIC MEASURES: 1965-1968

Correlation Matrix

	L.R. Cost Static	Multi-Lateral TFP-Static	L.R. Cost Dynamic	Multi-Lateral TFP-Dynamic	TFP Dynamic	S.R. Cost Static	S.R. Cost Dynamic
L.R. Cost Static	1	.950	.9980	.017	-.007	.194	.205
M.L. TFP Static		1	.9399	-.037	-.066	.228	.223
L.R. Cost Dynamic			1	.062	.045	.197	.209
M.L. TFP Dynamic				1	.959	.297	.310
TFP Dynamic					1	.304	.320
S.R. Cost Static						1	.992
S.R. Cost Dynamic							1

Principal Component Analysis

	Factor 1	2	3	4	5	6	7
Variance Explained	.459	3419	.184	.010	.006	.001	0
Cumulative Variance Explained	.459	.800	.984	.993	.999	1	1

	Factor 1	2	3	4	5	6	7
L.R. Cost Static	-.491	-.282	-.142	-.337	-.132	-.054	-.725
M.L. TFP Static	-.481	-.293	-.071	.792	.187	.116	.043
L.R. Cost Dynamic	-.495	-.259	-.174	-.433	-.030	-.064	.682
M.L. TFP Dynamic	-.173	.504	-.465	.195	-.6788	.022	.043
TFP Dynamic	-.164	.515	-.451	-.107	.698	-.021	-.077
S.R. Cost Static	-.334	.350	.518	.078	-.010	-.701	.006
S.R. Cost Dynamic	-.338	.355	.506	-.129	-.012	.698	.001

TABLE 6-7

CORRESPONDENCES AMONG SEVEN ECONOMIC MEASURES: 1969-1972

Correlation Matrix

	L.R. Cost Static	Multi-Lateral TFP-Static	L.R. Cost Dynamic	Multi-Lateral TFP-Dynamic	TFP Dynamic	S.R. Cost Static	S.R. Cost Dynamic
L.R. Cost Static	1	.950	.9960	.072	.109	.205	.172
M.L. TFP Static		1	.9419	.054	.074	.244	.203
L.R. Cost Dynamic			1	.065	.107	.199	.157
M.L. TFP Dynamic				1	.983	-.120	-.114
TFP Dynamic					1	-.153	-.154
S.R. Cost Static						1	.992
S.R. Cost Dynamic							1

Principal Component Analysis

	Factor 1	2	3	4	5	6	7
Variance Explained	.448	.318	.221	.010	.002	.001	0
Cumulative Variance Explained	.448	.765	.986	.996	.999	1	1

	Factor 1	2	3	4	5	6	7
L.R. Cost Static	-.537	.109	.197	.342	.255	.318	-.615
M.L. TFP Static	-.532	.079	.180	-.809	-.118	.062	.070
L.R. Cost Dynamic	-.533	.111	.206	.442	-.111	-.372	.563
M.L. TFP Dynamic	-.044	.554	-.444	-.130	.600	-.344	-.007
TFP Dynamic	-.055	.572	-.406	.118	-.611	.342	.008
S.R. Cost Static	-.274	-.407	-.504	.001	-.312	.508	-.387
S.R. Cost Dynamic	-.256	-.411	-.520	.042	.284	.513	.388

TABLE 6-8

CORRESPONDENCES AMONG SEVEN ECONOMIC MEASURES: 1973-1976

Correlation Matrix

	L.R. Cost Static	Multi-Lateral TFP-Static	L.R. Cost Dynamic	Multi-Lateral TFP-Dynamic	TFP Dynamic	S.R. Cost Static	S.R. Cost Dynamic
L.R. Cost Static	1	.963	.9990	.011	.028	.319	.269
M.L. TFP Static		1	.960	-.016	.014	.270	.222
L.R. Cost Dynamic			1	.004	.030	.306	.258
M.L. TFP Dynamic				1	.958	.084	.098
TFP Dynamic					1	.014	.040
S.R. Cost Static						1	.993
S.R. Cost Dynamic							1

Principal Component Analysis

	Factor						
	1	2	3	4	5	6	7
Variance Explained	.448	.318	.221	.010	.002	.001	0
Cumulative Variance Explained	.448	.765	.987	.996	.999	1	1

	Factor						
	1	2	3	4	5	6	7
L.R. Cost Static	-.518	-.093	-.237	-.383	.025	.036	-.720
M.L. TFP Static	-.501	-.113	-.262	.781	-.236	-.012	.038
L.R. Cost Dynamic	-.515	-.097	-.245	-.404	.187	-.068	.680
M.L. TFP Dynamic	-.043	.686	0.161	-.188	-.665	-.137	.0654
TFP Dynamic	-.041	.673	-.222	.200	.656	.151	-.061
S.R. Cost Static	-.337	.140	.600	-.020	-.111	.700	.069
S.R. Cost Dynamic	-.315	.162	.6176	.067	.153	-.680	-.063

TABLE 6-9

CORRESPONDENCES AMONG SEVEN ECONOMIC MEASURES: 1977-1981

Correlation Matrix

	L.R. Cost Static	Multi-Lateral TFP-Static	L.R. Cost Dynamic	Multi-Lateral TFP-Dynamic	TFP Dynamic	S.R. Cost Static	S.R. Cost Dynamic
L.R. Cost Static	1	.975	1	.157	.153	.346	.336
M.L. TFP Static		1	.976	.170	.170	.288	.280
L.R. Cost Dynamic			1	.160	.156	.349	.338
M.L. TFP Dynamic				1	.989	.174	.191
TFP Dynamic					1	.148	.168
S.R. Cost Static						1	.998
S.R. Cost Dynamic							1

Principal Component Analysis

	Factor 1	2	3	4	5	6	7
Variance Explained	.511	.265	.218	.004	.001	0	0
Cumulative Variance Explained	.511	.776	.994	.998	1	1	1

	Factor 1	2	3	4	5	6	7
L.R. Cost Static	-.479	.241	-.212	-.423	.020	-.037	-.699
M.L. TFP Static	-.466	.232	-.260	.811	-.056	.022	-.015
L.R. Cost Dynamic	-.479	.238	-.211	-.396	.034	.004	.715
M.L. TFP Dynamic	-.220	-.639	--.203	-.544	-.702	-.076	.009
TFP Dynamic	-.215	-.638	--.221	.034	.699	.090	-.011
S.R. Cost Static	-.339	-.080	- .614	0	-.074	.704	-.021
S.R. Cost Dynamic	-.338	-.097	- .613	.055	.089	-.699	.018

TABLE 6-10

CORRESPONDENCES AMONG SEVEN ECONOMIC MEASURES: 1965-1981

Correlation Matrix

	L.R. Cost Static	Multi-Lateral TFP-Static	L.R. Cost Dynamic	Multi-Lateral TFP-Dynamic	TFP Dynamic	S.R. Cost Static	S.R. Cost Dynamic
L.R. Cost Static	1	.957	.9990	-.042	-.004	.252	.229
M.L. TFP Static		1	.9539	-.067	-.034	.242	.214
L.R. Cost Dynamic			1	-.013	.025	.257	.234
M.L. TFP Dynamic				1	.976	.215	.240
TFP Dynamic					1	.162	.183
S.R. Cost Static						1	.997
S.R. Cost Dynamic							1

Principal Component Analysis

Factor

	1	2	3	4	5	6	7
Variance Explained	.462	.321	.206	.008	.003	0	0
Cumulative Variance	.462	.782	.988	.997	1	1	1

Factor

	1	2	3	4	5	6	7
L.R. Cost Static	-.515	-.200	-.1797	=.381	-.043	.166	-.699
M.L. TFP Static	-.503	-.214	-.166	.818	.031	.037	.035
L.R. Cost Dynamic	-.516	-.183	-.192	-.423	-.028	-.189	.669
M.L. TFP Dynamic	-.172	.580	-.389	.060	-.707	-.064	-.017
TFP Dynamic	-.077	.553	-.443	.022	.699	.054	-.005
S.R. Cost Static	-.325	.336	.539	.031	.086	-.680	-.176
S.R. Cost Dynamic	-.315	.354	.525	-.031	-.-35	.683	.177

second group contains the multilateral dynamic index and the conventional TFP dynamic index. The final set is the two variable cost indexes. Correlations between indexes within a group tend to be quite high, .9 or more, but quite low between indexes in different groups.

The lessons from these tables are intuitively straightforward. First, the cost function approach to productivity measurement yields meaningful static, or intercompany, comparisons, but is not a useful way of measuring dynamic, performance improvement of a single company over time. That is, both the static and dynamic forms of the index are actually measuring static performance. This conclusion follows from the fact that both long-run measures are highly correlated with one another (about .97) and with the static, multilateral TFP index. Also, the short-run cost indexes are highly correlated with one another (.997) and only modestly correlated (about .3) with the remaining indexes. Hence, the variable cost indexes are measuring a separate component of performance which is not measured by any of the other five. The reason that the cost function methodology produces two, virtually identical indexes (that is, the static and dynamic indexes are not distinct) is that both are based upon the difference between actual and predicted costs. In one case the prediction is a static one and in the other, the lagged cost function is used to predict next year's cost. The evolution of the production technology and hence, the cost function is sufficiently slow, however, that no meaningful distinction can be made between current and one-year lagged predictions. Hence, the cost function methodology does not in any sense generate a measure of productivity improvement, at least not for prediction lags as short as one year. A longer prediction lag could be used, with the accompanying danger that the cost function becomes increasingly misspecified as that lag lengthens.

The second lesson is that the multilateral TFP approach provides an excellent way of constructing both static and dynamic performance measures. The static or intercompany version of this index captures virtually all of the information contained in the indexes based on the econometric cost estimation while having the advantage of less computational expense. In addition, the dynamic version of the multilateral TFP index is quite similar to the conventional TFP index. Recall that the principal difference between these last two indexes is that the weights used in the multilateral approach are based on a representative firm averaged over the sample, while these are averaged over succeeding years in the conventional Divisia index. A PUC interested in TFP measurement may wish to consider using the multilateral TFP index. It gives the same dynamic index as the conventional approach and it yields a separate, static index comparable to the long-run cost estimation indexes.

The third lesson is utilities that receive a high rating for control of long-run or total costs may not receive a similar high score for management of short-run or variable costs. This follows from the low correlations that the short-run cost indexes (both static and dynamic) have with the remaining productivity measures. From the consumer's perspective, long-run cost management would seem to be somewhat more important, since long-run costs form the basis of rates. Prudent management of variable costs, however, is also desirable since much day-to-day activity is devoted to the smooth operation of large capital facilities which are fixed in the short run. Both types of management excellence are valuable, with somewhat more weight being placed, perhaps, on total cost performance. Consequently, a public utility commission interested in interfirm comparisons may wish to use both long-run and variable-cost indexes. A commission that wishes to avoid econometric cost estimation could use instead a multilateral TFP index of variable cost. Such an index was not developed for this project; however, it is straightforward to use one, particularly if such an index were already used for total cost.

These insights from the correlations reported in tables 6-3 to 6-10 are confirmed by a principal component analysis that is also contained in each table. The analysis is shown in two parts. In the first part, about in the middle of each table, the fraction of generalized variance explained by each factor is reported, where each factor is a linear combination of the seven indexes, chosen so as to explain as much of the overall or generalized variance of these seven indices as possible. With seven measures of performance, there are seven possible factors. That is, it is possible that the seven measures are all independent and contain separate information. To the extent that the seven are correlated, however, they can be summarized by fewer than seven factors. Principal component analysis helps to determine the number of such factors required to convey the information content of the sample, as well showing the weight given to each performance measure in each factor.

The tables show the percentage of the sample's overall variance explained by each of the factors. These are arranged in order of importance so that the first principal component explains the most variance, and the least explanation is provided by the final component. Tables 6-3 through 6-10 each show that the first three factors explain 98 percent of the variance or more. The cumulative explained variance is reported just below the explained variance. This confirms the previous discussion, then, that there are only three independent pieces of information in this set of seven performance indexes.

The final part of each table reports the factors arranged in the same order, that is, in descending explanatory power. The numbers in this portion of the tables are the weights or coefficients of each productivity measure in forming each factor or principal component. Taken together the first three principal components show that the indexes can be partitioned, more or less, into three groups. The first three indexes comprise the first group, the next two measures form the second group, and the final two make up the third group. These groupings correspond to those previously described: total-cost static, total-cost dynamic, and variable-cost static performance indexes.

The overall conclusion is that the constellation of economic performance measures considered in this chapter can be usefully summarized by the three indexes just mentioned. These represent essentially different aspects of performance. Together, these three are much more likely to encompass the various dimensions of performance than any of the indexes separately. A PUC interested in a performance measurement system might wish to consider using a variety of techniques that cover these three dimensions. In effect, the appropriate performance index is a portfolio having at least three dimensions. Such a portfolio is capable of identifying particularly good and particularly poor productivity. Observing a utility with poor performance in all three areas would be persuasive evidence indeed. More likely, a utility with a poor long-run static index could compensate, for example, with good short-run performance improvement. Because of this, utilities themselves might be more receptive to a PUC sponsored performance measurement program that incorporates multiple dimensions. The resulting portfolio of indexes would reduce the risk, from the utility's perspective, of being judged improperly. Such a portfolio tends to spread risk for utilities, just as a portfolio of securities does for investors.

PART III

COMPARISON AND EVALUATION OF TECHNIQUES

CHAPTER 7

DISCUSSION AND COMPARISON OF EMPIRICAL RESULTS

In this chapter, a brief discussion is presented of the differences and similarities among the various economic and decision analytic techniques for performance evaluation. In order to maintain full comparability, the methods which were illustrated in chapter 4 and 6 are applied to a common data set, consisting of 56 companies in the period 1977-1980. The resulting measures provide the basis for the discussion in the second section of this chapter. First, the two sets of techniques are briefly considered from a methodological point of view.

Methodological Comparison of Techniques

Both the economic and the decision analytic techniques for performance evaluation that have been presented and illustrated in this report have as their primary objective to provide a summary measure of the management of an electric utility. In both instances, a wealth of information (time series or cross-sectional data, performance ratios) is transformed into a summary index, which can then be used to assess the performance of the companies under consideration. The main difference between the two approaches lies in the theoretical point of departure.

The economic productivity measures, such as the total factor productivity indexes and cost function residuals discussed in the previous chapters, have as their foundation a concept of a firm or decision-making unit based on microeconomic theory. This theoretical basis determines which are the relevant variables (factors of production, prices), how they should be measured and combined mathematically (functional form of the production and cost functions, the computation of an index), and how the results of the analysis should be interpreted. As a consequence, the appropriateness of these measures in a regulatory context is crucially determined by the extent to which the special nature of the regulated firm is taken into account in the underlying theoretical framework. Unfortunately, this is often not the case in a straightforward application of total factor productivity measures and cost function estimations. This problem is well known in the economic literature, and several approaches have been suggested to take this into account. Consequently, several "adjustments" for the TFP and other measures exist to incorporate the special characteristics of the regulated firm. However, these adjustments are far from uniformly accepted and are often ignored in applied work. As a result, the theoretical basis for the economic performance measures and their "objectivity" is often less than clear, and caution is needed when interpreting the results in an unqualified manner. In addition, the current proliferation of statistical software has made it rather easy to apply the economic approaches in a fairly mechanical manner, without necessarily having a full awareness of the implied assumptions and their appropriateness in a particular regulatory situation. Also, the general lack of an "absolute" performance standard or frame of reference does not help in adversarial situations where each party in the conflict will typically have its own expert to present his or her own TFP or cost function.

The starting point for the decision analytic performance measures is totally different. In these approaches, the subjective nature of the evaluation is made explicit and the notion of efficiency and managerial performance is drawn from the regulatory context. In other words, the decision analytic measures are prescriptive, in that the notion of performance is determined in terms of specific indicators without a direct link to a theory of the "ideal" regulated firm. As a consequence, these measures are subject to challenge in an adversary situation also. However, they provide a means to organize a large set of performance ratios into summary measures and are relatively easy to implement. Providing that agreement can be reached (or enforced) and on the specific criteria and their relative importance, a subjective index could be used as part of an incentive mechanism. In that context, the index could clearly establish the importance of the objectives of the regulators and allow the company the flexibility to adjust in light of these objectives. However, it should be stressed that this would imply a considerable institutional support system, a discussion of which is beyond the scope of this report.

With these comments in mind, the several measures discussed so far in this report are compared on a common data set in the next section.

Empirical Comparison

The empirical comparison of the economic and decision analytic techniques presented in this section has two objectives. First, the degree of correspondence between the different measures and the resulting company ranks is assessed. Second, the classification of companies according to their performance is more closely analyzed, in particular in terms of the possible influence of exogenous factors (i.e., factors outside of management control).

In order to achieve full comparability of the performance measures, a common data set for 56 companies was used for a four year period (1977-1980). The size of the data set was limited by the need to have observations on all relevant variables, in particular the items that are used in the formulation of the subjective indexes. In order to maintain a sufficient number of observations for the statistical tests to be meaningful the analysis could not be applied beyond 1980. Even though the data set for the study (see the description in appendix A) contains information on more recent years, the variable range necessary to compute the subjective indexes was not fully covered for those years.

In all, ten performance measures were considered, of which seven were economic approaches discussed in chapters 5 and 6 and three were subjective indexes discussed in chapters 3 and 4. The economic measures include a traditional total factor productivity index (TFP), and indexes constructed from the residuals of a long-run cost function (both dynamic (LRD), and static (LRS), and a short-run variable cost function (dynamic (SRD), and static (SRS)), as well as a multilateral measure (dynamic (MLD), and static (MLS)). A detailed description of these measures and their derivation is presented in chapter 5 and is not repeated here. It should be noted that the measures were calculated from 81 observations on the total time period used in the empirical application discussed in chapter 6. Since in this chapter the focus is on the resulting company ranks, and not on the actual measures, a new set of rankings for the 56 companies was derived from the original TFP scores, without re-estimating the underlying cost functions. This was carried out for each of the 4 years in the period 1977-1980.

The decision analytic performance indexes were calculated with the same set of indicators used in the multicriteria workshop (see chapter 4 for a detailed discussion). The weights are the averages for the workshop participants, using the three weighting mechanisms discussed previously: direct weighting (DIR), point allocation (PO), and AHP weights (AHP). The resulting performance indexes were obtained from a weighted summation of the standardized indicator values and the corresponding weights. As discussed in chapter 3, the issue of standardization is extremely important in any multicriteria evaluation process. In order to maintain comparability of the measures over time, the grand maximum and minimum values (across companies and over the whole time period) were used to compute the standardized value. As as result, a value of 100 for the index would mean that the company under consideration (at that point in time) scored highest on all criteria in terms of their values over the four-year time period.

As pointed out earlier, in this analysis the interest is not so much in the values of the performance indexes as such but in the resulting company rankings, changes in ranks over the years, and the corresponding classification in quantiles (e.g., upper and bottom quantile). The company ranks for the ten performance measures (with a rank of 1 for the best rated company) for the 56 companies in the sample, and for each of the 4 years are presented in tables 7-1 through 7-4. As before, the actual names of the companies are not disclosed, but in order to be able to compare the different analyses, they have been consistently identified by a company number (from 1 to 56).

As can be seen quite clearly from an initial examination of the tables, there is considerable divergence among the rankings for the different performance measures, as well as across the four years in the study period. This is a direct consequence of the lack of an absolute standard for performance so that in fact the different indexes measure different aspects of an overall notion of efficient management. However, the differences observed for the economic techniques (see also chapter 6 for a similar perspective) are not reflected in the same degree for the multicriteria performance indexes, which result in fairly similar rankings.

In order to facilitate a more precise interpretation of these results, a rank correlation analysis (using a Spearman rank corelation coefficient) was carried out to test the association between the company ranks across methods at each point in time, as well as across time for each particular method. It should be noted that the truncated character of the weighted summation indexes and TFP indexes does not permit the use of the more traditional (parametric) correlation coefficients. The results of this analysis are presented in tables 7-5 through 7-18.

The first four tables of rank correlations (tables 7-5 to 7-8) provide information on the degree to which the same companies are ranked similarly according to the different methods. A high positive correlation points to agreement between the techniques, a negative correlation to conflicting results. The latter is very important for policy applications, since a negative correlation implies that

TABLE 7-1

COMPANY PERFORMANCE RANKS--1977

Company	RTFP77	RLRD77	RLRS77	RMLD77	RMLS77	RSRD77	RSRS77	RDIR77	RPO77	RAHP77
1	29	39	37	34	29	41	40	16	25	23
2	1	8	8	1	7	4	3	8	9	12
3	30	49	49	31	49	38	44	46	47	48
4	49	20	22	49	18	37	38	33	31	31
5	6	26	24	3	13	13	12	7	17	11
6	17	24	26	15	25	26	30	3	4	2
7	52	29	30	53	31	29	29	15	22	27
8	41	42	45	42	47	50	50	32	32	30
9	26	32	33	19	36	44	36	42	39	42
10	23	46	47	23	48	12	14	50	50	46
11	54	56	56	52	56	47	37	56	56	56
12	44	28	29	43	33	17	16	28	28	22
13	28	22	20	29	12	35	34	43	40	36
14	12	25	27	11	27	18	20	40	37	34
15	34	36	36	27	37	34	25	35	38	41
16	20	12	11	20	16	49	46	20	18	14
17	46	52	51	45	53	31	32	23	30	32
18	36	13	13	38	15	23	27	18	16	21
19	18	47	39	25	42	42	42	5	14	19
20	53	34	23	54	34	16	15	1	3	6
21	9	38	41	8	44	10	13	27	35	28
22	35	3	3	37	2	56	51	13	6	7
23	3	31	34	4	30	28	31	30	20	33
24	7	16	18	6	20	1	1	31	27	25
25	39	51	53	41	52	54	54	53	53	53
26	21	17	19	22	19	14	19	52	49	50
27	55	5	6	55	6	8	9	34	24	29
28	37	44	42	39	43	19	24	48	51	51
29	45	2	2	48	1	24	11	17	11	15
30	13	14	14	14	17	36	39	12	7	5
31	32	50	50	32	50	48	49	6	12	9
32	5	1	1	7	5	7	10	51	46	44
33	27	7	7	21	4	11	8	47	42	43
34	19	27	28	18	24	46	48	25	19	17
35	50	6	5	50	9	5	2	38	36	39
36	31	30	32	30	32	25	21	44	41	45
37	43	18	17	44	14	33	33	39	33	35
38	33	53	54	33	54	39	41	24	26	26
39	51	55	55	51	55	53	52	14	21	18
40	56	41	44	56	45	52	55	21	23	16
41	38	45	46	40	46	9	7	54	54	54
42	11	54	52	10	51	40	45	45	48	49
43	10	35	35	13	35	51	53	11	8	8
44	8	23	25	9	28	45	47	10	5	4
45	40	19	16	35	26	2	4	37	43	38
46	24	33	31	24	22	20	18	29	34	37
47	47	48	48	47	39	15	22	22	29	24
48	42	4	4	36	3	30	17	4	2	3
49	48	43	43	46	41	55	56	41	44	47
50	22	9	9	28	8	43	43	26	13	13
51	14	21	21	12	11	32	28	9	10	10
52	16	40	38	17	38	22	35	49	52	52
53	4	10	12	5	23	3	5	55	55	55
54	2	15	15	2	21	21	23	2	1	1
55	15	11	10	16	10	27	26	19	15	20
56	25	37	40	26	40	6	6	36	45	40

TABLE 7-2

COMPANY PERFORMANCE RANKS--1978

Company	RTFP78	RLRD78	RLRS78	RMLD78	RMLS78	RSRD78	RSRS78	RDIR78	RPO78	RAHP78
1	56	48	45	55	39	52	52	4	6	6
2	36	7	7	35	7	6	5	3	3	3
3	13	50	48	11	49	45	42	18	25	25
4	25	21	19	25	18	40	39	16	18	14
5	24	22	15	13	11	15	13	12	15	13
6	41	27	29	41	27	29	29	32	30	28
7	35	34	33	38	33	19	21	43	39	41
8	48	47	49	49	50	48	48	53	52	52
9	28	33	34	33	36	35	38	38	35	40
10	16	44	42	19	46	16	16	36	38	36
11	29	56	56	50	56	28	37	51	56	56
12	32	26	32	24	32	13	14	48	46	46
13	49	24	20	45	16	39	35	41	37	32
14	39	25	28	37	28	24	24	49	49	49
15	18	36	37	23	38	18	22	44	43	43
16	27	10	11	32	14	46	46	11	10	10
17	34	51	51	26	53	20	20	52	51	53
18	52	20	21	53	19	37	34	30	26	30
19	9	38	44	10	37	36	43	8	11	11
20	3	16	22	4	30	9	10	20	22	26
21	2	19	24	2	24	1	1	45	45	44
22	21	3	4	29	4	54	51	21	14	16
23	42	35	35	40	34	32	31	27	23	27
24	53	23	25	51	26	2	2	10	12	8
25	10	49	50	7	48	51	50	17	24	23
26	20	17	16	16	17	27	27	23	21	20
27	54	8	8	54	9	14	12	47	42	48
28	17	39	38	18	41	25	25	40	48	45
29	6	2	2	6	2	10	8	15	7	9
30	55	29	26	56	25	30	28	56	53	54
31	47	53	53	47	52	44	45	1	1	1
32	1	1	1	1	1	3	4	9	8	7
33	12	5	3	5	3	11	11	14	16	18
34	26	30	27	27	23	34	33	28	28	29
35	14	4	6	14	8	7	6	29	29	24
36	46	37	36	46	35	31	32	55	54	51
37	30	15	13	22	13	42	41	19	17	15
38	50	55	55	48	55	47	47	33	33	35
39	8	52	52	9	54	50	53	26	27	21
40	19	42	41	21	44	55	55	50	50	50
41	43	46	47	44	47	12	15	35	41	39
42	44	54	54	42	51	49	49	31	36	38
43	4	28	30	3	29	53	54	5	4	5
44	40	31	31	43	31	38	36	25	20	19
45	15	14	18	15	22	4	3	22	32	31
46	31	32	23	20	20	22	17	6	13	17
47	5	41	40	31	42	17	18	46	44	47
48	22	6	5	30	5	23	23	7	5	4
49	33	43	43	36	43	56	56	34	34	34
50	11	9	9	12	6	43	44	13	9	12
51	23	18	14	17	10	33	30	2	2	2
52	38	40	39	28	40	41	40	39	40	37
53	37	12	17	34	21	5	7	54	55	55
54	7	11	12	8	15	8	9	37	31	33
55	45	13	10	39	12	26	26	24	19	22
56	51	45	46	52	45	21	19	42	47	42

TABLE 7-3

COMPANY PERFORMANCE RANKS --1979

Company	RTFP79	RLRD79	RLRS79	RMLD79	RMLS79	RSRD79	RSRS79	RDIR79	RPO79	RAHP79
1	45	51	51	48	47	55	53	24	25	29
2	11	7	7	12	6	4	2	33	23	22
3	4	43	44	9	46	18	21	19	26	26
4	13	19	16	13	17	26	20	7	6	4
5	33	16	19	34	13	11	16	15	16	18
6	50	30	32	50	30	45	43	12	7	9
7	27	28	30	28	31	24	22	29	35	35
8	31	50	50	37	51	51	50	4	13	16
9	17	26	23	10	27	21	15	50	48	50
10	8	40	38	11	43	9	9	48	47	46
11	40	56	56	30	56	41	45	55	56	56
12	53	35	33	51	40	32	29	31	30	24
13	46	24	25	46	20	37	37	43	43	43
14	55	34	35	55	36	40	40	27	29	25
15	49	42	39	44	44	29	23	30	36	34
16	9	14	9	5	10	47	39	5	5	6
17	21	52	52	25	53	33	36	20	28	30
18	3	11	10	2	12	30	25	14	10	10
19	18	41	46	33	38	28	41	40	40	41
20	34	17	21	39	26	8	14	34	38	39
21	5	15	13	8	19	1	1	47	49	48
22	22	6	5	21	3	44	49	37	31	37
23	30	31	29	23	29	39	38	9	8	7
24	56	37	36	56	37	25	28	18	20	21
25	36	49	49	38	50	46	46	56	55	55
26	48	22	22	49	21	31	26	41	39	36
27	37	8	8	36	9	12	6	3	4	5
28	14	39	40	26	42	16	18	45	52	52
29	12	2	2	14	1	3	7	32	21	23
30	44	27	27	42	25	48	47	11	14	8
31	2	48	48	3	49	14	17	49	45	47
32	35	1	1	40	2	7	3	22	15	17
33	25	4	6	35	4	6	8	51	44	45
34	7	18	18	6	18	34	31	25	22	20
35	15	5	4	15	7	5	4	36	33	31
36	1	23	20	1	23	36	32	10	19	19
37	39	13	15	27	14	38	35	39	32	27
38	28	55	55	31	55	50	51	23	27	33
39	32	53	53	24	54	52	52	17	18	14
40	29	44	45	32	45	54	54	26	37	38
41	23	47	47	22	48	13	11	42	42	42
42	24	54	54	29	52	43	42	28	34	28
43	51	32	31	53	32	56	55	35	24	32
44	54	33	34	52	34	49	48	2	2	2
45	47	25	26	45	24	15	19	38	41	40
46	42	21	24	43	22	10	10	52	51	53
47	41	46	43	7	33	22	12	6	11	12
48	16	3	3	16	5	20	30	8	3	3
49	26	45	42	20	41	53	56	54	53	51
50	52	12	12	47	8	42	44	21	17	15
51	43	20	17	41	15	35	34	16	12	11
52	10	36	41	17	35	19	24	53	54	54
53	38	29	28	54	28	23	33	44	50	49
54	19	10	11	18	16	17	13	1	1	1
55	20	9	14	19	11	27	27	13	9	13
56	6	38	37	4	39	2	5	46	46	44

TABLE 7-4

COMPANY PERFORMANCE RANKS--1980

Company	RTFP80	RLRD80	RLRS80	RMLD80	RMLS80	RSRD80	RSRS80	RDIR80	RPO80	RAHP80
1	51	54	55	49	50	56	55	24	29	29
2	55	12	14	55	11	4	4	34	32	35
3	15	39	41	13	42	21	17	39	42	45
4	36	19	19	38	17	26	23	30	26	23
5	46	22	27	45	18	18	19	5	8	10
6	21	30	29	21	29	41	39	26	21	18
7	50	33	34	51	39	19	20	38	38	38
8	3	43	42	3	44	49	50	19	18	22
9	44	29	26	44	33	17	29	35	40	41
10	31	34	35	25	41	7	7	51	51	50
11	13	56	56	6	56	32	34	52	55	55
12	54	41	38	54	45	22	25	44	41	40
13	7	21	23	8	19	37	37	8	13	13
14	40	37	36	41	40	45	42	29	31	30
15	53	46	45	53	49	24	38	32	35	36
16	19	9	9	15	9	43	43	7	3	2
17	43	53	53	46	54	35	36	20	27	24
18	42	13	11	40	13	31	31	18	15	17
19	25	42	40	14	34	40	47	42	37	39
20	1	17	16	1	22	8	11	45	43	43
21	30	16	15	27	21	1	1	48	48	47
22	38	6	6	42	4	51	46	25	23	26
23	17	27	28	16	28	33	33	17	17	16
24	37	38	37	39	38	39	35	22	20	21
25	49	51	52	52	52	53	52	1	10	11
26	8	18	18	7	20	34	27	3	5	7
27	20	7	7	22	10	12	12	27	25	19
28	27	36	39	26	37	16	16	46	47	48
29	4	1	1	9	1	5	6	28	28	33
30	26	28	32	28	26	46	45	11	11	8
31	47	50	49	47	51	20	15	56	56	56
32	56	3	2	56	5	6	5	37	33	31
33	10	2	3	10	2	10	10	23	24	27
34	11	15	13	11	16	23	21	13	12	12
35	39	5	4	43	7	3	3	33	34	32
36	48	26	24	48	27	27	28	41	39	37
37	23	14	17	23	12	36	32	16	14	15
38	18	55	54	17	55	48	49	47	45	42
39	28	52	51	34	53	52	53	31	30	20
40	52	48	48	50	48	55	56	36	36	34
41	33	47	47	33	46	13	18	49	49	51
42	2	49	50	2	47	29	24	12	16	14
43	5	25	22	5	25	50	51	21	19	28
44	12	31	30	12	31	47	48	15	9	4
45	22	24	21	24	24	15	13	40	44	44
46	14	23	31	18	23	11	8	43	46	46
47	9	40	46	20	32	9	9	53	52	53
48	35	4	5	36	3	30	30	4	1	3
49	45	45	43	37	43	54	54	14	22	25
50	16	10	12	19	8	44	44	2	2	1
51	24	20	20	29	14	42	41	6	4	5
52	34	44	44	35	35	25	22	55	54	54
53	41	32	25	32	30	38	40	54	53	52
54	29	11	10	31	15	14	14	10	6	6
55	6	8	8	4	6	28	26	9	7	9
56	32	35	33	30	36	2	2	50	50	49

TABLE 7-5

CROSS-TECHNIQUE RANK CORRELATION--1977

	TFP	LRD	LRS	MLD	MLS	SRD	SRS	DIR	PO	AHP
TFP	1.000	0.235	0.217	0.987	0.225	0.214	0.137	0.089	0.131	0.139
LRD		1.000	0.989	0.242	0.957	0.365	0.435	0.164	0.357	0.320
LRS			1.000	0.220	0.962	0.368	0.440	0.204	0.384	0.341
MLD				1.000	0.228	0.238	0.176	0.071	0.108	0.121
MLS					1.000	0.317	0.393	0.222	0.397	0.354
SRD						1.000	0.961	-0.212	-0.231	-0.222
SRS							1.000	-0.173	-0.179	-0.182
DIR								1.000	0.949	0.949
PO									1.000	0.974
AHP										1.000

TABLE 7-6

CROSS-TECHNIQUE RANK CORRELATION--1978

	TFP	LRD	LRS	MLD	MLS	SRD	SRS	DIR	PO	AHP
TFP	1.000	0.270	0.238	0.928	0.197	0.180	0.149	0.259	0.235	0.235
LRD		1.000	0.985	0.322	0.962	0.461	0.502	0.301	0.404	0.383
LRS			1.000	0.304	0.987	0.424	0.477	0.340	0.442	0.420
MLD				1.000	0.275	0.193	0.188	0.344	0.310	0.318
MLS					1.000	0.370	0.425	0.392	0.494	0.474
SRD						1.000	0.990	-0.113	-0.124	-0.123
SRS							1.000	-0.085	-0.091	-0.091
DIR								1.000	0.972	0.972
PO									1.000	0.987
AHP										1.000

TABLE 7-7

CROSS-TECHNIQUE RANK CORRELATION--1979

	TFP	LRD	LRS	MLD	MLS	SRD	SRS	DIR	PO	AHP
TFP	1.000	0.147	0.157	0.908	0.114	0.405	0.385	-0.097	-0.094	-0.107
LRD		1.000	0.992	0.125	0.981	0.443	0.464	0.177	0.351	0.345
LRS			1.000	0.157	0.980	0.422	0.460	0.197	0.370	0.367
MLD				1.000	0.127	0.334	0.374	0.007	0.022	0.020
MLS					1.000	0.386	0.414	0.203	0.382	0.374
SRD						1.000	0.964	-0.259	-0.206	-0.200
SRS							1.000	-0.164	-0.110	-0.098
DIR								1.000	0.953	0.946
PO									1.000	0.985
AHP										1.000

TABLE 7-8

CROSS-TECHNIQUE RANK CORRELATION--1980

	TFP	LRD	LRS	MLD	MLS	SRD	SRS	DIR	PO	AHP
TFP	1.000	0.201	0.174	0.976	0.225	0.003	0.051	0.193	0.219	0.195
LRD		1.000	0.990	0.159	0.981	0.379	0.418	0.354	0.462	0.400
LRS			1.000	0.145	0.964	0.358	0.388	0.330	0.414	0.382
MLD				1.000	0.180	-0.026	0.012	0.156	0.181	0.152
MLS					1.000	0.317	0.362	0.378	0.459	0.421
SRD						1.000	0.977	-0.445	-0.431	-0.443
SRS							1.000	-0.400	-0.384	-0.394
DIR								1.000	0.980	0.960
PO									1.000	0.985
AHP										1.000

TABLE 7-9

TEMPORAL RANK CORRELATION--TFP.

	1977	1978	1979	1980
1977	1.000	-0.096	-0.079	0.046
1978		1.000	0.048	0.102
1979			1.000	-0.134
1980				1.000

TABLE 7-10

TEMPORAL RANK CORRELATION--LRD.

	1977	1978	1979	1980
1977	1.000	0.942	0.895	0.872
1978		1.000	0.937	0.919
1979			1.000	0.979
1980				1.000

TABLE 7-11

TEMPORAL RANK CORRELATION--LRS.

	1977	1978	1979	1980
1977	1.000	0.958	0.900	0.888
1978		1.000	0.949	0.929
1979			1.000	0.973
1980				1.000

TABLE 7-12

TEMPORAL RANK CORRELATION--MLD.

	1977	1978	1979	1980
1977	1.000	0.022	-0.173	0.061
1978		1.000	-0.042	0.044
1979			1.000	-0.096
1980				1.000

TABLE 7-13

TEMPORAL RANK CORRELATION--MLS.

	1977	1978	1979	1980
1977	1.000	0.967	0.926	0.902
1978		1.000	0.963	0.942
1979			1.000	0.981
1980				1.000

TABLE 7-14

TEMPORAL RANK CORRELATION--SRD.

	1977	1978	1979	1980
1977	1.000	0.883	0.755	0.702
1978		1.000	0.775	0.745
1979			1.000	0.933
1980				1.000

TABLE 7-15

TEMPORAL RANK CORRELATION--SRS.

	1977	1978	1979	1980
1977	1.000	0.931	0.767	0.705
1978		1.000	0.782	0.733
1979			1.000	0.946
1980				1.000

TABLE 7-16

TEMPORAL RANK CORRELATION--DIR.

	1977	1978	1979	1980
1977	1.000	0.348	0.478	0.233
1978		1.000	-0.022	0.286
1979			1.000	0.404
1980				1.000

TABLE 7-17

TEMPORAL RANK CORRELATION--PO.

	1977	1978	1979	1980
1977	1.000	0.496	0.662	0.473
1978		1.000	0.297	0.417
1979			1.000	0.601
1980				1.000

TABLE 7-18

TEMPORAL RANK CORRELATION--AHP.

	1977	1978	1979	1980
1977	1.000	0.421	0.597	0.443
1978		1.000	0.225	0.352
1979			1.000	0.657
1980				1.000

utilities that are rated as performing well according to one technique, would be rated as inefficient according to another. For each of the 4 years, this is the case for the indexes based on the variable cost functions (SRD and SRS) on the one hand and the multicriteria indexes (DIR, PO, and AHP) on the other hand. Also, in 1979, the traditional TFP yields an indication of performance which would contradict that of the multicriteria techniques. In 1980, the dynamic variable cost measure (SRD) is also negatively correlated with the multilateral TFP (MLD). In general terms, the multicriteria techniques can be considered as a distinct fourth category of measures, which would provide an additional dimension of information on performance. The existence of three distinct economic categories, pointed out in chapter 6, consisting of of (1) LRS, LRD, and MLS; (2) MLD and TFP; and (3) SRS and SRD is also confirmed here. It should be noted that the analysis in chapter 6 was based on a correlation between the actual measures, whereas ranks are used in this chapter.

The temporal correlation tables (7-9 to 7-18) provide an indication of the stability of each of the measures across time. A high correlation between consecutive years would point to the stability of the company rankings over the 4-year period, a negative correlation would indicate considerable variation. Alternatively, a high correlation might indicate the failure to capture short-run variations in performance and an emphasis on the long-run trend. Both the traditional TFP and the multilateral measure (MLD) show low and negative correlations, while the other economic measures are all highly positively correlated over time. The coefficients for the multicriteria indexes are considerably lower, but positive (with the exception of DIR). In general, the results confirm the previous finding that distinct categories of performance measures can be distinguished, which each measure different aspects of the notion of overall managerial efficiency. Also, there is considerable evidence that some indexes capture short-run variation markedly better than others.

It is often claimed that the performance indexes do not measure actual managerial performance, but rather the influence of exogenous factors. In order to assess the extent to which this is reflected in the techniques discussed here, a logistic discriminant analysis was carried out to explain the classification of companies into "good" or "bad" performance by variables outside of managerial control. Good explanatory power of these variables would confirm the assertion that exogenous effects (such as climate, size, geographical features of the market area) are the real underlying causes for the performance rating of the company. For two of the indexes used in the study, the traditional TFP and the multicriteria AHP, companies were classified in terms of the upper and lower median and in terms of quartiles, based on their performance ranking in each of the years of the study period. A logistic discriminant analysis attempts to explain this classification in terms of several variables. The variables chosen are often cited as determining factors of company performance that are outside of managerial control. They are: size (total sales), sales mix (ratio of residential sales to total sales), density of service area (total population/area), climate (total degree days heating), fuel prices (state average fuel cost), and general labor costs (state average wage rate). In addition to these exogenous variables, three dummy variables were used to reflect the different time periods (significant coefficients for these dummy variables would point to the need to carry out an analysis for each year separately). The results of the analysis are presented in tables 7-19 to 7-22. For each case, the estimated coefficients and their standard errors, as well as the results of a chi-square test of significance are given. Also, a general idea about the goodness-of-fit can be obtained from the overall chi-square statistic of fit (Chi-S), the likelihood ratio test (LR), and the rank correlation between true classification and predicted classification (C1).

TABLE 7-19

LOGISTIC DISCRIMINANT ANALYSIS OF DICHOTOMOUS PERFORMANCE CLASSIFICATION--AHP

	Coefficient	Std. Error	Chi-Square
Size	2.77x10-6	13.2x10-6	0.04
Mix	-3.061	2.594	1.39
Climate	-3.51x10-4	9.47x10-5	13.71
Density	-1.06x10-3	3.19x10-4	10.97
Fuel	-1.570	0.423	13.79
Wage	0.082	0.132	0.38
D1	0.251	0.439	0.33
D2	0.376	0.489	0.59
D3	0.698	0.561	1.55

Chi-S=64.7 (9) LR=245.84 C1=0.559

TABLE 7-20

LOGISTIC DISCRIMINANT ANALYSIS OF DICHOTOMOUS
PERFORMANCE CLASSIFICATION--TFP

	Coefficient	Std. Error	Chi-Square
Size	1.63x10-5	12.0x10-6	1.84
Mix	0.835	2.356	0.13
Climate	-3.03x10-5	8.06x10-5	0.14
Density	-10.1x10-5	8.52x10-5	1.41
Fuel	0.209	0.264	0.62
Wage	-0.389	0.158	6.09
D1	0.158	0.402	0.15
D2	0.383	0.449	0.73
D3	0.544	0.538	1.02

Chi-S=16.0 (9) LR=294.51 C1=0.300

TABLE 7-21

LOGISTIC DISCRIMINANT ANALYSIS OF QUARTILE
PERFORMANCE CLASSIFICATION--AHP

	Coefficient	Std. Error	Chi-Square
Size	1.16x10-5	10.8x10-6	1.16
Mix	-3.138	2.075	2.29
Climate	-2.99x10-4	7.31x10-5	16.68
Density	-8.09x10-4	2.36x10-4	11.72
Fuel	-1.583	0.320	24.44
Wage	0.029	0.116	0.06
D1	0.291	0.357	0.67
D2	0.431	0.404	1.14
D3	0.788	0.455	2.99

Chi-S=90.45 (9) LR=530.61 C1=0.483

TABLE 7-22

LOGISTIC DISCRIMINANT ANALYSIS OF QUARTILE PERFORMANCE CLASSIFICATION--TFP

	Coefficient	Std. Error	Chi-Square
Size	0.94x10-6	9.75x10-6	0.01
Mix	-0.455	2.015	0.05
Climate	-6.23x10-5	6.94x10-5	0.81
Density	-7.39x10-5	6.84x10-5	1.17
Fuel	0.494	0.239	4.29
Wage	-0.218	0.108	4.07
D1	0.096	0.346	0.08
D2	0.127	0.384	0.11
D3	0.048	0.444	0.01
Chi-S=13.57 (9) LR=607.49 C1=0.223			

In general, the fit of the discriminant equations is rather poor. For the AHP measure, in both the dichotomous and the quartile classifications, the variables associated with climate, density and fuel cost are found to be significant (at a 5 percent level) and with the proper negative sign (implying poorer performance for higher values of the variable). On the other hand, size and labor cost are found with a positive sign (although not significant), which for the latter is rather surprising. It should be noted that the AHP index used here is not necessarily the optimal one, since a rather ad hoc set of indicators were used in the context of the workshop. In all, there seems to be some (although rather weak) evidence that there may be a relation between the AHP index of performance and some of the exogeneous variables. This is not necessarily a very negative finding, since a more careful choice of the particular indicators might easily correct for this. For the TFP classification, the only significant variable (at a 5 percent level) with the proper negative sign is state labor cost. On the other hand, both size and fuel costs (and customer mix in the dichotomous classification) are found with a positive sign. Also, the goodness-of-fit for the TFP equation is clearly very poor, providing almost no explanatory power. In all, there seems to be little evidence for a strong relationship between the company performance classification and the exogenous variables considered. A careful selection of the indicators for the multicriteria index and a respecification of the wage variable in the TFP calculations would probably remove all remaining influence. A further analysis of this issue and the related concern about the comparability of utility companies is presented in appendix G.

Conclusion

The comparative analysis of the different performance measurement techniques reveals a number of interesting patterns. There is considerable evidence to support the assertion that the different indexes measure different aspects of overall performance, and result in often conflicting rankings of companies. The measures also vary in the degree to which they are sensitive to short-term variation in performance. Also, there is no strong support for the claim that these measures are influenced by factors outside of management control, although careful calibration and implementation remains necessary to avoid this. The fundamental difference between the techniques pertains to the particular point of view which is taken: the economic techniques are based on a micro-economic behavioral framework for the firm; the multicriteria techniques are prescriptive and define the notion of performance in relation to the regulatory context. As a consequence, there is no "best" way to measure performance, and considerable caution is necessary when interpreting the results of any analysis for policy purposes. The different indexes could be used as short-cut indicators for problem areas, but considerable additional detailed analysis of the operations of the utility would be necessary before any more general conclusions could be made.

CHAPTER 8

SUMMARY AND RECOMMENDATIONS

In this study, ten different approaches to assess the managerial performance of electric utilities have been discussed with respect to their underlying theoretical assumptions, and have been compared empirically. Seven of these methods are based on a more traditional microeconomic framework, and rate performance within the context of the optimal behavior of the regulated firm. These measures are based on a total factor productivity index, derived over time or across companies (multilateral), and on an analysis of the residuals of cost functions. The cost functions are based on either a long-term equilibrium reasoning (with capital included in the optimization decision) or on a short-run consideration (variables costs only). The resulting index can be static, when the actual value of costs is compared to a prediction based on the estimated cost function for the year considered. Alternatively, it can be a dynamic index that compares the actual value to a prediction based on lagged (in time) values for the company considered. The different performance measures have been derived for a set of 81 investor-owned companies, using observations over the period 1964-1981.

The three remaining categories of techniques are based on multicriteria decision analysis, and consist of a structured assessment of subjective weights for the relative importance of a set of performance indicators. The methods discussed here are the analytic hierarchy process, concordance and discordance analysis. The first is a structured approach to assess importance weights based on pairwise comparisons, and results in a weighted summation performance index. The other two techniques organize a set of criteria weights and result in a company ranking. Using the input of the participants in a workshop/seminar organized for commission staff members, several sets of criteria weights were derived using a number of common weight assessment techniques: direct weight assessment, point allocation, and a variant of the analytic hierarchy process. The empirically derived weights vary considerably according to the technique used as well as across participants. In other words, there is no clear consensus on the importance of the different indicators considered, which confirms a finding in the previous report on this subject (Anselin et al. (1981)). On the other hand, however, the notion of equal importance of the different indicators can clearly be rejected. It is therefore crucial that any performance measurment approach that may be considered for implementation be flexible enough to take the obvious differences in perceived criteria importance into account.

The seven economic measures and three subjective performance indexes (based on a weighted summation using direct weighting, point allocation weights, and AFP weights) are compared for a subset of 56 companies over the period 1977-1980. The resulting company rankings vary considerably over time as well as across techniques, indicating that different methods yield contradictory measures of the utility's performance. In general terms, four distinct categories of measures can be distinguished, which each stress a different aspect of overall performance: (1) the traditional and multilateral (across companies) dynamic TFP index; (2) a multilateral static TFP index and residual analysis based on long-run cost functions; (3) residual analysis based on variable-cost functions (short-run); (4) subjective multicriteria performance indexes.

The existence of considerable conflict between the insight gained from the different performance measures is a troubling (although not unexpected) feature from an operational point of view. It is clear that the different points of departure, either the different microeconomic conceptualizations of the regulated firm or the prescriptive and admittedly subjective approach in the multicriteria techniques, preclude the selection of a single technique as best.

Clearly, any implementation of performance measurement in a regulatory context should not be confined to one measure only, but should preferably be based on the insight gained from a variety of indexes, complemented by other information. In the context of an incentive system or penalty-reward approach to regulation, the reliance on a unique index would be problematic at best, unless considerable institutional arrangements have been put in place. Since different measures will most likely provide different company rankings, it is to be expected that in an adversary or even antagonistic situation different experts will always be able to come up with a convincing counterargument, based on an "objective" measure different from the one used originally.

This does not preclude the techniques discussed from consideration as tools in tracking the comparative performance of a number of companies under the jurisdiction of a commission. In fact, it is rather encouraging that there is little empirical evidence (for the limited set of data considered here) for the claim that the performance measures are not related to managerial efficiency, but rather to exogeneous factors beyond a utility's management control. In that respect, the techniques would provide a short-cut means to assess deviant (from the average or from a preset standard) performance and could be used as a first step in a larger, more comprehensive framework (e.g., encompassing hearings and/or focused management audits). The ease and relatively low cost of implementation of the multicriteria techniques, and the fact that they are directly related to a structured view of the objectives and priorities of performance evaluation (within a larger decision support system) would make them attractive alternatives to the more traditional, more costly economic approaches. However, the successful use of these methods by a commission staff would still be conditional on the existence of a large, uniform data base, available within a reasonable time lag.

APPENDIX A

PERFORMANCE MEASUREMENT PROJECT DATA BASE

The data base for the Performance Measurement Project contains 210 variables for 123 privately-owned electric utilities in U.S. The data base covers the period of 1964 - 1981. The data collected for each electric utility are classified into four main categories: inputs, outputs, prices, and variables useful to place electric utilities in clusters of comparable operating environments.

The current data base has been constructed using several available data sources such as Compustat, a Temple-Barker-Sloan (TBS) tape of FERC Form 1 data, as well as data available from standard statistical sources. Compustat was the source of 96 financial variables and operating statistics for the period 1962-1981. Data on 137 variables for the same companies during 1964-1978 were obtained from the TBS FERC statistics. Operating statistics, utility plant, and physical quantities of the utilities for 1979-1981 were collected from Statistics of Privately-Owned Electric Utilities in the United States. The Compustat source had 43 variables which were also available from TBS FERC statistics. Combining these two data sources, we constructed a data set of 188 variables for each electric utility for the period of 1964-1981.

Additional data on utility plant for the period of 1949-1983 were collected from "Statistics of Privately Owned Electric Utilities in the United States." The Handy-Whitman construction cost index was collected by region for the period of 1949-1981. These data are used to derive the real capital stock for each electric utility as described in chapter 4. The utilities' heat rates, average fuel prices, average hourly wage rates and weather data were collected from a variety of printed sources. What follows is a detailed description of the data base.

The electric utilities included are as follows:

ID Number	Company Number	Company Name
1	010392	ALABAMA POWER
2	037735	APPALACHIAN POWER
3	041033	ARKANSAS POWER & LIGHT
4	048303	ATLANTIC CITY ELECTRIC
5	060077	BANGOR HYDRO-ELEC CO
6	092113	BLACK HILLS POWER & LIGHT CO
7	092527	BLACKSTONE VALLEY ELECTRIC
8	100599	BOSTON EDISON
9	132194	CAMBRIDGE ELECTRIC LIGHT CO
10	137015	CANAL ELECTRIC CO
11	144141	CAROLINA POWER & LIGHT
12	155033	CENTRAL POWER & LIGHT
13	155771	CENTRAL VERMONT PUB SERV
14	186108	CLEVELAND ELECTRIC ILLUM
15	198846	COLUMBUS & SOUTHERN OHIO
16	202795	COMMONWEALTH EDISON
17	206201	CONCORD ELECTRIC CO
18	207597	CONNECTICUT LIGHT & POWER CO
19	235199	DALLAS POWER & LIGHT
20	250847	DETROIT EDISON CO
21	264399	DUKE POWER CO
22	266228	DUQUESNE LIGHT CO
23	281029	EDISON SAULT ELECTRIC
24	283677	EL PASO ELECTRIC CO
25	291461	EMPIRE DISTRICT ELECTRIC CO
26	341081	FLORIDA POWER & LIGHT
27	341099	FLORIDA POWER CORP
28	373334	GEORGIA POWER
29	387990	GRANITE STATE ELECTRIC CO
30	393154	GREEN MOUNTAIN POWER CORP
31	402479	GULF POWER
32	416506	HARTFORD ELECTRIC LIGHT CO
33	419870	HAWAIIAN ELECTRIC INDS
34	442164	HOUSTON LIGHTING & POWER CO
35	451380	IDAHO POWER CO
36	454560	INDIANA & MICHIGAN ELECTRIC
37	476556	JERSEY CENTRAL POWER & LIGHT
38	485134	KANSAS CITY POWER & LIGHT
39	485260	KANSAS GAS & ELECTRIC

ID Number	Company Number	Company Name
40	491386	KENTUCKY POWER
41	491674	KENTUCKY UTILITIES CO
42	496990	KINGSPORT POWER CO
43	546387	LOUISIANA POWER & LIGHT
44	560483	MAINE PUBLIC SERVICE
45	575634	MASSACHUSETTS ELECTRIC CO
46	591894	METROPOLITAN EDISON
47	604110	MINNESOTA POWER & LIGHT
48	605400	MISSISSIPPI POWER & LIGHT
49	605417	MISSISSIPPI POWER
50	610202	MONONGAHELA POWER
51	631005	NARRAGANSETT ELECTRIC
52	641423	NEVADA POWER CO
53	644188	NEW ENGLAND POWER
54	677347	OHIO EDISON
55	677415	OHIO POWER
56	678858	OKLAHOMA GAS & ELECTRIC
57	689648	OTTER TAIL POWER CO
58	708696	PENNSYLVANIA LIGHT CO
59	709051	PENNSYLVANIA POWER & LIGHT
60	709068	PENNSYLVANIA POWER CO
61	736508	PORTLAND GENERAL ELECTRIC CO
62	737662	POTOMAC EDISON
63	737679	POTOMAC ELECTRIC POWER
64	744465	PUBLIC SERVICE CO OF IND
65	744482	PUBLIC SERVICE CO OF NH
66	744499	PUBLIC SERVICE CO OF N MEX
67	744533	PUBLIC SERVICE CO OF OKLA
68	745332	PUGET SOUND POWER & LIGHT
69	807487	SAVANNAH ELECT & POWER
70	842400	SOUTHERN CALIF EDISON CO
71	845437	SOUTHWESTERN ELECTRIC PWR CO
72	845454	SOUTHWESTERN ELEC SERVICE
73	845743	SOUTHWESTERN PUBLIC SERV CO
74	882406	TEXAS ELECTRIC SERVICE CO
75	882661	TEXAS POWER & LIGHT CO
76	889175	TOLEDO EDISON CO
77	906548	UNION ELECTRIC CO
78	910637	UNITED ILLUMINATING CO
79	916303	UPPER PENINSULA POWER
80	917508	UTAH POWER & LIGHT
81	927804	VIRGINIA ELECTRIC & POWER CO
82	955278	WEST PENN POWER
83	956279	WEST TEXAS UTILITIES
84	958587	WESTERN MASSACHUSETTS EL CO
85	963990	WHEELING ELECTRIC CO

ID Number	Company Number	Company Name
86	040555	ARIZONA PUBLIC SERVICE CO
87	153645	CENTRAL ILLINOIS LIGHT
88	153663	CENTRAL ILL PUBLIC SERVICE
89	172070	CINCINNATI GAS & ELECTRIC
90	209111	CONSOLIDATED EDISION OF NY
91	210615	CONSUMERS POWER CO
92	240019	DAYTON POWER & LIGHT
93	452092	ILLINOIS POWER CO
94	462416	IOWA ELECTRIC LIGHT & PWR
93	452092	ILLINOIS POWER CO
94	462416	IOWA ELECTRIC LIGHT & PWR
95	462470	IOWA-ILLINOIS GAS & ELEC
96	462506	IOWA POWER & LIGHT
97	462524	IOWA PUBLIC SERVICE CO
98	462542	IOWA SOUTHERN UTILITIES CO
99	485314	KANSAS POWER & LIGHT
100	542671	LONG ISLAND LIGHTING
101	546676	LOUISVILLE GAS & ELECTRIC
102	557497	MADISON GAS & ELECTRIC CO
103	606045	MISSOURI EDISON
104	606232	MISSOURI POWER & LIGHT
105	606249	MISSOURI PUBLIC SERVICE CO
106	606385	MISSOURI UTILITIES
107	612085	MONTANA POWER CO
108	647770	NEW ORLEANS PUBLIC SERVICE
109	653522	NIAGARA MOHAWK POWER
110	684065	ORANGE & ROCKLAND UTILITIES
111	694308	PACIFIC GAS & ELECTRIC
112	694784	PACIFIC POWER & LIGHT
113	717537	PHILADELPHIA ELECTRIC CO
114	744448	PUBLIC SERVICE CO OF COLO
115	771367	ROCHESTER GAS & ELECTRIC
116	790654	ST JOSEPH LIGHT & POWER
117	797440	SAN DIEGO GAS & ELECTRIC
118	826418	SIERRA PACIFIC POWER CO
119	837004	SOUTH CAROLINA ELEC & GAS
120	906888	UNION LIGHT, HEAT & POWER CO
121	976656	WISCONSIN ELECTRIC POWER
122	976826	WISCONSIN POWER & LIGHT
123	976843	WISCONSIN PUBLIC SERVICE

The variables in the data set are measured and defined as follows. Since the data are contained in a SAS file, no file format is included here.

ID Number	Definition	Units
F1	Net All Utility Plant	MM$
F2	Total Assets and Other Debits	MM$
F3	Common Stock Issued	MM$
F4	Preferred Stock Issued	MM$
F5	Subscribed Liabilities & Premium	MM$
F6	Capital Stock Subscribed	MM$
F7	Stock Liability Conversion	MM$
F8	Premium on Capital Stock	MM$
F9	Other Paid-in Capital	MM$
F10	Installments Received on Capital Stock	MM$
F11	Discount on Capital Stock	MM$
F12	Capital Stock Exchanges	MM$
F13	Retained Earnings/Earned Surplus	MM$
F14	Unappropriated Undistributed Subsidiary Earnings	MM$
F15	Reacquired Capital Stock	MM$
F16	Total Propriety Capital	MM$
F17	Bonds (less bonds reacquired)	MM$
F18	Other Long-Term Debt	MM$
F19	Total Long-Term Debt	MM$
F20	Total Current and Accrued Liabilities	MM$
F21	Operating Revenues - Electric	MM$
F22	Operating Expense - Electric	MM$
F23	Maintenance Expense - Electric	MM$
F24	Depreciation Expense - Electric	MM$
F25	Taxes Other than Income Taxes - Electric	MM$
F26	Income Taxes-Federal - Electric	MM$
F27	Income Taxes-Other - Electric	MM$
F28	Total Operating Expenses - Electric	MM$
F29	Net Operating Revenues - Electric	MM$
F30	Electric Utility Operating Income	MM$
F31	Interest on Long-Term Debt	MM$
F32	Amortization of Debt Discount and Expense	MM$
F33	Amortization of Loss on Reacquired Debt	MM$
F34	Amortization of Premium on Debt (Credit)	MM$
F35	Amortization of Gain on Reacquired Debt (Credit)	MM$
F36	Interest on Debt to Associated Companies	MM$
F37	Other Interest Expenses	MM$
F38	Interest Charged to Construction	MM$
F39	Total Interest Charges	MM$
F40	Income Before Extraordinary Items	MM$
F41	Dividends Declared - Preferred Stock	MM$
F42	Dividends Declared - Common Stock	MM$
F43	Number of Customers - Residential	M
F44	Number of Customers - Commercial	M
F45	Number of Customers - Industrial	M

ID Number	Definition	Units
F46	Total Ultimate Consumers	M
F47	KW-Hour Sales - Residential	MMKWH
F48	KW-Hour Sales - Commercial	MMKWH
F49	KW-Hour Sales - Industrial	MMKWH
F50	Total Sales to Ultimate Consumers	MMKWH
F51	Sales for Resale	MMKWH
F52	Total KW-Hour Sales	MMKWH
F53	Revenues - Residential	MM$
F54	Revenues - Commercial	MM$
F55	Revenues - Industrial	MM$
F56	Revenues from Sale for Resale	MM$
F57	Total Revenues from Sales of Electricity	MM$
F58	Total Electric Operating Revenues	MM$
F59	Fuel Expense for Steam Power Production	MM$
F60	Steam Power Production Expenses	MM$
F61	Fuel Expense for Nuclear Power Production	MM$
F62	Nuclear Power Production Expenses	MM$
F63	Water for Power Expenses	MM$
F64	Hydraulic Power Production Expenses	MM$
F65	Fuel Expenses - Other Production	MM$
F66	Purchased Power Expense	MM$
F67	Total Production Expenses	MM$
F68	Underground Line Expenses - Operation - Transmission	MM$
F69	Total Operation Expenses - Transmission	MM$
F70	Underground Line Expenses - Maintenance - Transmission	MM$
F71	Total Transmission Expenses	MM$
F72	Underground Line Expenses - Operation - Distribution	MM$
F73	Underground Line Expenses - Maintenance - Distribution	MM$
F74	Total Distribution Expenses	MM$
F75	Total Customer Accounts Expenses	MM$
F76	Total Sales Expenses	MM$
F77	Total Administrative & General Expenses	MM$
F78	Total Electric Operation and Maintenance Expenses	MM$
F79	Salaries and Wages - Production	MM$
F80	Salaries and Wages - Transmission	MM$
F81	Salaries and Wages - Distribution	MM$
F82	Salaries and Wages - Customer Accounts	MM$
F83	Salaries and Wages - Administrative & General	MM$
F84	Total Salaries and Wages	MM$
F85	Regular Full-time Employees	
F86	Part-time and Temporary Employees	
F87	Total Electric Department Employees	
F88	Total Customer Service and Informational Expenses	MM$
F89	Construction Work in Progress	MM$
F90	Total Electric Utility Plant	MM$
F91	Accumulated Provisions for Depreciation and Amortization	MM$ MM$

ID Number	Definition	Units
F92	Net Electric Utility Plant	MM$
F93	Total Steam Production Plant	MM$
F94	Total Nuclear Production Plant	MM$
F95	Total Hydraulic Production Plant	MM$
F96	Total Production Plant	MM$
F97	Total Transmission Plant	MM$
F98	Total Distribution Plant	MM$
F99	Total General Plant	MM$
F100	Total Electric Plant in Service	MM$
F101	Additions - Steam Production Plant	MM$
F102	Additions - Hydraulic Production Plant	MM$
F103	Additions - Total Production Plant	MM$
F104	Additions - Transmission Plant	MM$
F105	Additions - Distribution Plant	MM$
F106	Additions - General Plant	MM$
F107	Total Electric Plant Additions	MM$
F108	Total Production Plant Capacity	MM$
F109	Generation - Steam	MKW
F110	Generation - Nuclear	MMKWH
F111	Generation - Hydraulic	MMKWH
F112	Total Net Generation	MMKWH
F113	Purchases	MMKWH
F114	Interchanges - Net	MMKWH
F115	Total Net Energy Generated and Received	MMKWH
F116	Losses of Electric Energy	MMKWH
F117	Total Tower Lines (Structure Miles) - Transmission	Miles
F118	Total Tower Lines (Circuit Miles) - Transmission	Miles
F119	Total Pole Lines (Circuit Miles) - Transmission	Miles
F120	Total Structure Miles (Total Overhead Lines) - Transmission	Miles
F121	Total Circuit Miles (132 Volts and Above) - Transmission	Miles
F122	Underground and Submarine Lines (Circuit Miles) - Transmission	Miles
F123	Substations, Transformer Capacity, Kva - Transmission	KVA
F124	Substations, Transformer Capacity, Kva - Distribution	KVA
F125	Line Transformers - Number - Distribution	
F126	Line Transformers - Capacity - Kva - Distribution	
F127	Meters - Number	KVA
F128	Dividends on Preferred Stock - Application of Funds	MM$
F129	Dividends on Common Stock - Application of Funds	MM$
F130	Long-Term Debt - Application of Funds	MM$
F131	Redemption of Capital Stock - Application of Funds	MM$
F132	Purchase of Other Non-current Assets - Application of Funds	MM$
F133	Investments in and Advances to Associated Companies - Application of Funds	MM$
F134	Other (Net) - Application of Funds	MM$

ID Number	Description	Units
F135	Total Application of Funds for Retirement of Securities and Short-Term Debt	MM$ MM$
F136	Nonoperating Income	MM$
F137	Gross Income	MM$
F138	Interest from Short-Term Debt	MM$
F139	Subsidiary Preferred Dividends	MM$
F140	Minority Interest	MM$
F141	Extraordinary Items and Discontinued Operations	MM$
F142	Preference Dividend Requirements	MM$
F143	Income Availability for Common after Adjustments for Common Stock Equivalents	MM$
F144	Earnings per Share Excluding Extraordinary Items and Discontinued Operations	$
F145	Pension and Retirement Expenses	MM$
F146	Labor and Related Expenses	MM$
F147	Common Equity - Total	MM$
F148	Operation Expense - Production	MM$
F149	Operation Expense - Fuel	MM$
F150	Operation Expense - Purchased Power - Net	MM$
F151	Operation Expense - Distribution	MM$
F152	Operation Expense - Customer Accounts	MM$
F153	Operation Expense - Administrative and General	MM$
F154	Operation Expense - Customer Service and Information	MM$
F155	Operation Expense - Sales	MM$
F156	Maintenance Expense - Production	MM$
F157	Maintenance Expense - Transmission	MM$
F158	Maintenance Expense - Distribution	MM$
F159	Maintenance Expense - Administrative and General	MM$
F160	Electric Sales - Other	MMKWH
F161	Electric Operating Revenues - Ultimate Customers (Other)	MM$
F162	Electric Operating Revenues - Ultimate Customers (Total)	MM$
F163	Electric Operating Revenues - Other	MM$
F164	Electric Customers - Other	M
F165	Electric Customers - Sale for Resale	M
F166	Electric Generation (Net) from Pumped Storage	MMKWH
F167	Electric Generation (Net) from Gas Turbines	MMKWH
F168	Summer Peak	MKW
F169	Winter Peak	MKW
F170	System Capability	MKW
F171	Load Factor - Annual	%
F172	Net Generation - Total	MMKWH
F173	Fuel Cost - Solid	MM$
F174	Fuel Cost - Liquid	MM$
F175	Fuel Cost - Gas	MM$
F176	Fuel Cost - Total	MM$
F177	Average Cost per Million Btu	$
F178	Electric Population Served	M

ID Number	Definition	Unit
F179	Electric Square Miles of Territory Served	M
F180	Utility Plant - Net Additions	MM$
F181	Market Adjustments Factor (Cumulative) by Ex-Date	Ratio
F182	Price - High	$
F183	Price - Low	$
F184	Price - Close	$
F185	S&P Corporate Bond Rating by Class of Debt	Code
F186	Common Shares Outstanding	MM
F187	Pension and Retirement Expense	MM$
F188	Operating Income Taxes	MMS
F189	Heat Rate	BTU/KWH
F190	State Index	CODE
F191	State Average Fuel Price	$
F192	State Average Hourly Wage Rate	$
F193	Heating Degree Days	^{o}F-d
F194	Cooling Degree Days	^{o}F-d
F195	Interest Rate at S&P Bond Rating Class	%
F196	Adjusted Average Price of Common Stock	$
F197	Adjusted Dividends per Share	$
F198	Real - Steam Production Plant Capital	MM$
F199	Real - Hydro Production Plant Capital	MM$
F200	Real - Nuclear Production Plant Capital	MM$
F201	Real - Transmission Plant Capital	MM$
F202	Real - Distribution Plant Capital	MM$
F203	Real - General Plant Capital	MM$
F204	Real - Total Plant Capital	MM$

The Handy-Whitman index by region is used to calculate the real capital of the electric utilities. The data base lists the Handy-Whitman index in the following manner.

ID Number	Definition
Region	Region defined for Handy-Whitman index
SPI	Handy-Whitman cost index for Steam Production Plant
HPI	Handy-Whitman cost index for Hydro Production Plant
NPI	Handy-Whitman cost index for Nuclear Producton Plant
TI	Handy-Whitman cost index for Transmission Plant
DI	Handy-Whitman cost index for Distribution Plant

APPENDIX B

PROGRAM OF THE SEMINAR/WORKSHOP ON "A DECISION SUPPORT SYSTEM FOR ELECTRIC UTILITY PERFORMANCE EVALUATION"

THE NATIONAL REGULATORY RESEARCH INSTITUTE

Seminar/Workshop

A Decision Support System for Electric Utility Performance

May 21-22, 1984
Holiday Inn On the Lane
Columbus, Ohio 43201

Program

Monday, May 21, 1984

a.m. 8:00 - Registration
8:15 - Coffee and Donuts
8:30 - Welcome: Dr. Douglas N. Jones, NRRI
8:45 - Introduction: Dr. Luc Anselin, Ohio State University/NRRI
9:00 - Presentations:

- Dr. J. Stephen Henderson, NRRI
"Electric Utility Performance Measurement, an Overview"
- Mr. Michael Foley, NARUC
"Financial and Operating Performance Indicators"

10:00 - Coffee Break
10:15 - Presentations:

- Mr. Kenneth W. Costello, Illinois Commerce Commission
"The Role of Performance Measurement of Public Utility Regulation"
- Mr. Enver Masud, Iowa State Commerce Commission
"Simulated Competition as an Incentive for Utility Efficiency"
- Dr. Orman Panaanen, New Mexico State University
"An Approach to Electric Utility Performance Evaluation in New Mexico"

12:00 - Lunch

p.m. 1:30 - Presentations:

- Dr. Luc Anselin, Ohio State University/NRRI
"The Use of Multicriteria Decision Techniques to Evaluate Electric Utility Performance"

2:30 - Coffee Break
2:45 - Demonstration of Multicriteria Techniques - Workshop
4:45 - Summary and Evaluation
5:00 - Cocktail Hour (Cash Bar)
Columbus Room - 11th Floor
7:00 - End

Program (Continued)

Tuesday, May 22, 1984

a.m. 8:30 - Coffee and Donuts
9:00 - Presentation and Discussion of Workshop Results
9:30 - Panel Discussion: "The Regulatory Use of Performance Measures" (incentive mechanisms, performance and regulation, comparability of utilities, a role for NRRI)
- Panel Members: Dr. Luc Anselin, Mr. Kenneth W. Costello, Mr. Michael Foley, Dr. J. Stephen Henderson, Dr. Kevin A. Kelly, Mr. Enver Masud

10:30 - Coffee Break
10:45 - Panel Discussion (Continued)
11:45 - Closing Remarks - Evaluation of the Seminar/Workshop
12:00 - End

APPENDIX C

LIST OF ATTENDEES AT THE SEMINAR/WORKSHOP ON "A DECISION SUPPORT SYSTEM FOR ELECTRIC UTILITY PERFORMANCE EVALUATION"

A Decision Support System for Electric Utility Performance

Attendees

Martin Ahrens
Assistant General Counsel
Kansas Corporation Commission
Legal Division
4th Floor, State Office Bldg.
Topeka, Kansas 66612-1571
(913) 296-2864

Paul Ballonoff
Operations Research Analyst
Kansas Corporation Commission
4th Floor, State Office Bldg.
Topeka, Kansas 66612-1571
(913) 296-3391

Gary Bangert
Management Services Specialist
Missouri Public Service Commission
P.O. Box 360
Jefferson City, Missouri 65102
(314) 751-7438

Richard Collins
Utah Public Service Commission
160 E. 300 South
P.O. Box 5802
Salt Lake City, Utah 84110
(801)

Marcy Kotting
Analyst
Public Utilities Commission of Ohio
180 E. Broad Street
Columbus, Ohio 43215
(614) 466-3963

Daniel M. Dasho
Electric Engineer
Wisconsin Public Service Commission
Hill Farms State Office Bldg.
P.O. Box 7854
Madison, Wisconsin 53707
(608) 266-0910

Tom Driscoll
Accountant
Wyoming Public Service Commission
320 West 25th Street
Cheyenne, Wyoming 82002
(307) 777-7427

Larry Dobesh
North Dakota Public Service Comm.
State Capitol Building
Bismarck, North Dakota 58505
(701) 224-2400

Michael Fielek
Environmental Specialist
Michigan Public Service Commission
P.O. Box 30221
Lansing, Michigan 48909
(517) 373-8171

Mike Foley*
National Association of
Regulatory Utility Commissioners
1102 Interstate Commerce Comm. Bldg.
P.O. Box 684
Washington, D.C. 20044
(202) 628-7325

*This person was a speaker at the workshop

Mahesh Ganmukhi
Senior Electrical & Tele-
communications Engineer
Kansas Corporation Commission
4th Floor, State Office Bldg.
Topeka, Kansas 66612-1571
(913) 296-3391

Stephen Hogg
Manager, Management Services
Missouri Public Service Commission
P.O. Box 360
Jefferson City, Missouri 65102
(314) 751-7436

Stan Hvostik
Utility Systems Engineer
Florida Public Service Commission
101 E. Gaines Street
Tallahassee, Florida 32308
(904) 488-8501

Bob Kennedy
Arkansas Public Service Commission
400 Union Station
Markham and Victory Streets
Little Rock, Arkansas 72201
(501)

James E. Komer
Utilities Engineering Specialist II
Alabama Public Service Commission
P.O. Box 991
Montgomery, Alabama 36130
(205) 261-5868

Mark R. Laux
Economic Analyst
Florida Public Service Commission
101 E. Gaines Street
Tallahassee, Florida 32301
(904) 487-1325

Henry Leak, III
Associate Util. Management Analyst
New York Public Service Commission
Three Empire State Plaza
Albany, New York 12223
(518) 474-4368

Phil Lehr
Engineer
Wyoming Public Service Commission
320 West 25th Street
Cheyenne, Wyoming 82002
(307) 777-7427

Evelyn Lievman
New Jersey Board of Public Utilities
1100 Raymond Blvd.
Newark, New Jersey 07102
(201) 648-2026

Doug Maag
Chief, Rates & Tariffs
Public Utilities Commission of Ohio
180 E. Broad Street
Columbus, Ohio 43215
(614) 466-3016

Don Marker
Rate Design Administrator
Kansas Corporation Commission
4th Floor, State Office Building
Topeka, Kansas 66612-1571
(913) 296-3391

Enver Masud*
Iowa State Commerce Commission
Lucas Building
Des Moines, Iowa 50319
(515) 281-5979

Roger Montgomery
Chief Accounting Officer of Accounts
Public Utilities Commission of Ohio
180 E. Broad Street
Columbus, Ohio 43215
(614) 466-4687

*This person was a speaker at the workshop

Hossein Novin
Construction Inspector
Kansas Corporation Commission - REA
4th Floor, State Office Bldg.
Topeka, Kansas 66612-1571
(913) 296-5460

Mark Oligschlaeger
Regulatory Auditor
Missouri Public Service Commission
P.O. Box 360
Jefferson State Office Building
Jefferson City, Missouri 65101
(314)

Orman Paananen*
New Mexico State Corporation Commission
P.O. Drawer 1269
Santa Fe, New Mexico 87501
(505)

Arlene S. Pfleeger
Regulatory Auditor
Missouri Public Service Commission
P.O. Box 360
Jefferson State Office Building
Jefferson City, Missouri 65101
(314)

Ken Powell
Utah Public Service Commission
160 E. 300 South
P.O. Box 5802
Salt Lake City, Utah 84110
(801)

Mike Proctor
Manager, Research & Planning Dept.
Missouri Public Service Commission
P.O. Box 360
Jefferson City, Missouri 65102
(314) 751-7518

John J. Reilly
Associate Director for Utilities
The Governor's Energy Council
P.O. Box 8010
Harrisburg, Pennslyvania 17105
(717) 787-8999

Thomas M. Renaghan
Public Utility Regulatory Analyst
California Public Utilities Commission
Revenue Requirements Room 5212
455 Golden Gate Avenue
San Francisco, California 94102
(415) 557-2226

Robert Rosenthal
Supervisor Val. & Rate Structure,
Electric Division
Pennsylvania Public Utility Comm.
P.O. Box 3265
Harrisburg, Pennsylvania 17120
(717) 783-5392

Wilson Symansic
Chief, Electric Fuel Cost Recovery
Public Utilities Commission of Ohio
180 E. Broad Street
Columbus, Ohio 43215
(614) 466-6609

Kim Sarap
Electric Rate Analyst
Public Utilities Commission of Ohio
180 E. Broad Street
Columbus, Ohio 43215
(614) 466-3016

Sam Skinner
Electric Engineer
Public Utility Commission of Texas
7800 Shoal Creek Blvd., Suite 400N
Austin, Texas 78757
(512) 458-0107

*This person was a speaker at the workshop

Charles A. Smetak
Chief, Electric Division
Pennsylvania Public Utility Comm.
P.O. Box 3265
Harrisburg, Pennsylvania 17120
(717) 787-5553

Marc A. Smith
Associate Economist
New York Public Service Commission
3 Empire State Plaza
Albany, New York 12223
(518) 474-1721

Charles B. Stults
Alabama Public Service Commission
RSE Division
P.O. Box 991
Montgomery, AL 36130
(205) 261-5868

James Watkins
Operations Research Specialist
Missouri Public Service Commission
P.O. Box 360
Jefferson City, Missouri 65102
(314) 751-7528

Charles Weekly
Pennsylvania Public Utilities Comm.
P.O. Box 3265
Harrisburg, Pennsylvania 17120
(717) 783-5392

Warren L. Wendling
Asst. Supervising Engin. Analyst
Colorado Public Utilities Commission
Room 520, State Services Building
1525 Sherman Street
Denver, Colorado 80203
(303) 866-3182

Rudolph Yanuck
Electric Engineering Supervisor
Pennslyvania Public Utility Commission
P.O. Box 3265
Harrisburg, Pennsylvania 17120
(717) 783-1559

Fred Young
Electrical Engineer
Arizona Corporation Commission
Utilities Division
1200 West Washington
Phoenix, Arizona 85006
(602) 255-4251

The National Regulatory Research
Institute
2130 Neil Avenue
Columbus, Ohio 43210
(614) 422-9404

Luc Anselin*
Project Leader

J. Stephen Henderson*
Senior Institute Economist

Kevin Kelly*
Associate Director for Gas and Electric

*This person was a speaker at the workshop

APPENDIX D

PERFORMANCE EVALUATION WORKSHOP SURVEY FORM

THE NATIONAL REGULATORY RESEARCH INSTITUTE

WORKSHOP

DEMONSTRATION OF MULTICRITERIA DECISION TECHNIQUES TO EVALUATE ELECTRIC UTILITY PERFORMANCE

INTRODUCTION

The following demonstration of multicriteria evaluation techniques consists of a series of questionnaires, designed to assess ranks and weights of the different performance indicators considered. Each of the sets of questions pertains to a specific method, and it would be appreciated if you could attempt to answer each set independently of your response to previous questions, in order to obtain results with the highest degree of meaningfulness. Since the techniques are "subjective", there is no correct answer.

You have the option of remaining anonymous (in which case your answers will only be identified by a code number), or to enter your name on each response sheet. In the latter case, an individualized set of results on your evaluation of the companies in the sample (using the different methods) will be provided to you shortly.

The data used in the exercise are from actual performance indicators for 10 Midwestern all-electric utilities in 1982. In order to focus the attention on the techniques, and not on the specific companies, the names of the utilities have been omitted.

The precise definition of the performance measures considered is given in Table 1. The observations for the 10 companies are listed in Table 2 (in raw form) and the standardized scores are presented in Table 3. Now, please move on to Section 1, to start the evaluation exercise. If at any time you have questions, do not hesitate to ask. Someone will assist you.

Name ________________

SECTION 1

Carefully consider the information contained in Tables 2 and 3. Taking this as a whole, enter your subjective overall performance score as a value between 0 and 100 next to the company in the space provided below. Also, enter the resulting rank from 1 to 10, with 1 being the best. Revise your answer as many times as necessary until you are completely satisfied with it.

COMPANY	RANK	SCORE
A	____	_____
B	____	_____
C	____	_____
D	____	_____
E	____	_____
F	____	_____
G	____	_____
H	____	_____
I	____	_____
J	____	_____

Name _______________

SECTION 2

Below, you are given the list of indicators used. For each of these indicators, using a scale from 0 - 100 (with 100 as most important), assign an importance rating in the space provided. Again, do not hesitate to revise your rating until you are satisfied with it (refer to Table 1 for a precise definition of the indicators used).

average residential rates _____

change in average residential rates _____

average revenue/kwh _____

change in average revenue/kwh _____

return/kwh _____

change in return/kwh _____

residential sales growth _____

commercial sales growth _____

industrial sales growth _____

after-tax interest coverage ratio _____

change in after-tax interest coverage ratio _____

operating expenses / gross revenue _____

change in operating expenses / gross revenue _____

long term debt / assets _____

change in long term debt / assets _____

operating income / net plant _____

change in operating income / net plant _____

net income / assets _____

change in net income / assets _____

return on equity _____

change in return on equity	_____
growth in earnings per share	_____
average capacity use : average kwh / system capacity	_____
change in average capacity use	_____
reserve margin : peak load / system capacity	_____
change in reserve margin	_____
steam station heat rate	_____
change in steam station heat rate	_____
average fuel cost	_____
change in average fuel cost	_____
operating & maintenance expenses / net plant	_____
change in O & M expenses / net plant	_____
transmission & distribution expenses, per customer	_____
change in T & D expenses per customer	_____
administrative & general expenses, per customer	_____
change in administrative & general expenses per customer	_____

Name _______________

SECTION 3

Now, consider the different categories of weights in somewhat more detail. They have been grouped below into SERVICE, FINANCE and PRODUCTION. First, go over the list again, and consider the grouping presented below. Given this categorization, divide 100 importance points over the three group headings in the space provided immediately below:

SERVICE _____

FINANCE _____

PRODUCTION _____

Now, consider each group in turn, and divide 100 importance points over the indicators contained in the group (100 points for the "Service" indicators, 100 points for the "Finance" indicators and 100 points for the "Production" indicators), and enter your values in the space provided below. Revise as necessary, until you are satisfied with the values you entered.

SERVICE (100 points to be allocated)

average residential rates _____

change in average residential rates _____

average revenue / kwh _____

change in average revenue / kwh _____

return / kwh _____

change in return / kwh _____

residential sales growth _____

commercial sales growth _____

industrial sales growth _____

FINANCE (100 points to be allocated)

after-tax interest coverage ratio	_____
change in after-tax interest coverage ratio	_____
operating expenses / gross revenue	_____
change in operating expenses / gross revenue	_____
long term debt / assets	_____
change in long term debt / assets	_____
operating income / net plant	_____
change in operating income / net plant	_____
net income / assets	_____
change in net income / assets	_____
return on equity	_____
change in return on equity	_____
growth in earnings per share	_____

PRODUCTION (100 points to be allocated)

average capacity use: average kwh / system capacity	_____
change in average capacity use	_____
reserve margin: peak load / system capacity	_____
change in reserve margin	_____
steam station heat rate	_____
change in steam station heat rate	_____
average fuel cost	_____
change in average fuel cost	_____
operating & maintenance expenses / net plant	_____
change in O & M expenses / net plant	_____
transmission and distribution expenses, per customer	_____
change in transmission and distribution expenses per customer	_____
administrative and general expenses, per customer	_____
change in administrative and general expenses, per customer	_____

Name ________________

SECTION 4

Consider the hierarchical classification of the different indicators presented in Table 4. Using the scale from 1-9 which is described in Table 5, proceed through the pairwise comparisons outlined below. Enter your values in the upper triangular part where the space is provided. Proceed in two steps: first rank the elements considered in order of decreasing importance (most important first), then use this rank to guide you in entering the values for the pairwise comparisons. Again, revise as many times as necessary, until you are satisfied that your answer accurately reflects your judgment.

Example:

You are rating three kinds of soft drinks (A, B, C) with respect to sweetness. First rank the three in order of decreasing importance, e.g.,

1. A 2. C 3. B

Next, consider the 3x3 pairwise comparison matrix below:

	A	B	C
A	1	___	___
B		1	___
C			1

First, compare A to B: you prefer A to B, thus the value you will enter will be larger than 1. Say you prefer A strongly, but not absolutely, and use a value of 5 from the scale in Table 5. Fill in this value as shown:

	A	B	C
A	1	5	___
B		1	___
C			1

Now compare A to C. A is also preferred to C, but less so than to B. Consequently, to be consistent, the number entered should be less than 5, e.g., 3. However, it may be that your initial ranking does not really correspond to what you think. In that case, you would change the ranking and re-assess the pairwise comparisons, until you are satisfied with it. Using the value of

3, the new matrix would be:

	A	B	C
A	1	5	3
B		1	___
C			1

Finally, the last comparison pertains to B and C. Since B is less preferred than C, the value entered should be less than 1. Reverse the comparison and consider how much more preferred C is to B, e.g. slightly, a 2. Enter the inverse of this, 1/2, and the final matrix becomes:

	A	B	C
A	1	5	3
B		1	1/2
C			1

Before you proceed with the evaluation, make sure to become familiar with the process and the particular scale used. If you have any questions, do not hesitate to ask, someone will assist you.

1. Criteria importance.

Consider the three criteria Service (S), Finance (F) and Production (P) with respect to their relative importance for performance evaluation. Refer back to the Tables 1 and 4 for the precise meaning of the criteria. First, rank them in order of decreasing importance below:

1. _____ 2. _____ 3. _____

Next, fill out the elements in the upper triangular part of the 3x3 pairwise comparison matrix given below. Make sure you are satisfied with the values entered before you proceed to the next part.

	S	F	P
S	1	___	___
F		1	___
P			1

2. Time dimension.

For each of the three criteria used, consider the relative importance of the static indicators with respect to the dynamic indicators for that criterion (if the meaning of these concepts is not clear, refer back to Tables 1 and 4). Again, use a two-step approach in which you first give the ranks and then fill out the 2x2 matrix.

- For Service: Static (S) and Dynamic (D)

  Rank 1. ____ 2. ____

  Pairwise Comparison Matrix

	S	D
S	1	___
D		1

- For Finance: Static (S) and Dynamic (D)

  Rank 1. ____ 2. ____

  Pairwise Comparison Matrix

	S	D
S	1	___
D		1

- For Production: Static (S) and Dynamic (D)

  Rank 1. ____ 2. ____

  Pairwise Comparison Matrix

	S	D
S	1	___
D		1

3. Indicator importance.

For each of the criteria, now consider the relative importance of the indicators. Again, proceed in two steps for each evaluation.

- For static service : - average residential rates (ARR)
  - revenue (RE)

Rank 1. ____ 2. ____

Pairwise Comparison Matrix

	ARR	RE
ARR	1	____
RE		1

- For dynamic service : - sales growth (SG)
  - change in average residential rates (CARR)
  - change in revenue (CRE)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	SG	CARR	CRE
SG	1	___	___
CARR		1	___
CRE			1

- For static finance : - coverage ratios (CR)
  - return (R)

Rank 1. _____ 2. _____

Pairwise Comparison Matrix

	CR	R
CR	1	___
R		1

- For dynamic finance :
  - change in coverage ratios (CCR)
  - change in return (CR)
  - growth in earnings per share (GES)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	CCR	CR	GES
CCR	1	___	___
CR		1	___
GES			1

- For static production :
  - capacity use (CU)
  - fuel use (FU)
  - expenses (E)

Rank 1. _____ 2. _____

Pairwise Comparison Matrix

	CU	FU	E
CU	1	___	___
FU		1	___
E			1

- For dynamic production :
  - change in capacity use (CCU)
  - change in fuel use (CFU)
  - change in expenses (CE)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	CCU	CFU	CE
CCU	1	___	___
CFU		1	___
CE			1

4. Subindicator Importance.

Finally, for each of the indicators, consider the relative importance of the subindicators.

- For revenue : - average revenue / kwh (AR)
  - return / kwh (R)

Rank 1. _____ 2. _____

Pairwise Comparison Matrix

	AR	R
AR	1	___
R		1

- For change in revenue : - change in average revenue / kwh (CAR)
  - change in return / kwh (CR)

Rank 1. _____ 2. _____

Pairwise Comparison Matrix

	CAR	CR
CAR	1	___
CR		1

- For sales growth : - residential (RES)
  - commercial (COM)
  - industrial (IND)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	RES	COM	IND
RES	1	___	___
COM		1	___
IND			1

- For coverage ratios :
  - after tax interest coverage (ATI)
  - operating expenses / gross revenue (OPR)
  - long term debt / assets (LDA)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	ATI	OPR	LDA
ATI	1	___	___
OPR		1	___
LDA			1

- For change in coverage ratios :
  - change in after tax interest coverage (CATI)
  - change in operating expenses / gross revenue (COPR)
  - change in long term debt / assets (CLDA)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	CATI	COPR	CLDA
CATI	1	___	___
COPR		1	___
CLDA			1

- For return : - operating income / net plant (OIP)
  - net income / assets (NIA)
  - return on equity (ROE)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	OIP	NIA	ROE
OIP	1	___	___
NIA		1	___
ROE			___

- For change in return : - change in operating income / net plant (COIP)
  - change in net income / assets (CNIA)
  - change in return on equity (CROE)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	COIP	CNIA	CROE
COIP	1	___	___
CNIA		1	___
CROE			1

- For capacity use : - average capacity utilization (ACU)
  - peak, reserve margin (RM)

Rank 1. _____ 2. _____

Pairwise Comparison Matrix

	ACU	RM
ACU	1	___
RM		1

- For change in capacity use :
  - change in average capacity utilization (CACU)
  - change in reserve margin (CRM)

Rank 1. _____ 2. _____

Pairwise Comparison Matrix

	CACU	CRM
CACU	1	___
CRM		1

- For fuel use : - heat rate (HR)
  - average fuel cost (AFC)

Rank 1. _____ 2. _____

Pairwise Comparison Matrix

	HR	AFC
HR	1	___
AFC		1

- For change in fuel use : - change in heat rate (CHR)
  - change in average fuel cost (CAFC)

Rank 1. _____ 2. _____

Pairwise Comparison Matrix

	CHR	CAFC
CHR	1	___
CAFC		1

- For expenses :
  - O & M / net plant (OM)
  - transmission and distribution / customer (TD)
  - administrative and general / customer (AG)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	OM	TD	AG
OM	1	___	___
TD		1	___
AG			1

- For change in expenses :
  - change in O & M / net plant (COM)
  - change in transmission and distribution / customer (CTD)
  - change in administrative and general / customer (CAG)

Rank 1. _____ 2. _____ 3. _____

Pairwise Comparison Matrix

	COM	CTD	CAG
COM	1	___	___
CTD		1	___
CAG			1

Name _______________

SECTION 5

Thank you for going through the evaluation exercise. Your judgments will be most helpful. As mentioned earlier, if you wish to list your name on the forms, an individualized printout of the result of your evaluation will be provided to you. At this point, you have the opportunity to evaluate some of the techniques discussed during this afternoon. There are a small number of short questions, and space is provided for any open-ended comments you may have. Please take as much time as needed.

1. Your main background is in:

   engineering _____ economics _____ law _____ accounting _____

   other _____________________

2. The list of indicators used in this exercise is:

   a. realistic _____ unrealistic _____

   b. long enough _____ too long _____

      too short _____

   c. detailed enough _____ too detailed _____

      not detailed enough _____

If appropriate, please list in the space below any indicators which you think should be considered in addition to or instead of the ones used here.

3. How do you judge the use of performance indicators as such (i.e., with no further information, weights or groupings) in the regulatory process:

useful _____ not useful _____ no opinion _____

4. In line with what you responded to question 3, list the three main reasons why the use of performance indicators would be useful or not:

____

____

____

5. How do you find the use of the Analytic Hierarchy Process technique to assess relative weights for the indicators:

a. useful _____ not useful _____ no opinion _____

b. right complexity _____ too complex _____

not complex enough _____

c. provides insight _____ is confusing _____

6. How would you judge the use of a multicriteria decision analytic technique in combination with a set of performance indicators in the regulatory process:

useful _____ not useful _____ no opinion _____

7. In line with your answer in 6, list the three main reasons why such an approach would be useful or not:

____

____

____

8. Of the different techniques discussed today, such as total factor productivity, econometric models, decision analysis, etc., list below the ones you would consider useful in the regulatory process and rank them in order of importance (1 for the most important):

____

____

____

____

____

9. What do you see as the main role for performance evaluation of electric utilities within a regulatory context:

10. List any other comments, remarks or suggestions you may have:

APPENDIX E

WORKSHOP RESULTS: COMPANY SCORES FOR PARTICIPANTS

This appendix reports the performance indexes assigned to each company by each participant in the NRRI, May 21-22, 1984 workshop on "A Decision Support System for Electric Utility Performance Evaluation." Each participant was asked to evaluate the companies using four subjective methods. These scores are reported in four tables, one for each evaluation method.

TABLE E-1

COMPANY PERFORMANCE INDEXES--WORKSHOP RESULTS
METHOD ONE: HOLISTIC EVALUATION

Respondent	Company									
	A	B	C	D	E	F	G	H	I	J
2	84	84	94	74	81	85	88	81	83	83
3	70	80	95	75	90	65	80	50	30	45
4	65	30	80	75	25	50	40	55	95	90
5	80	30	100	60	50	20	40	10	90	70
6	80	38	94	36	60	40	39	75	95	37
7	75	60	85	63	62	68	70	65	78	80
8	50	45	85	5	70	30	5	80	90	5
9	63	43	90	10	42	22	21	61	77	11
10	85	60	100	50	75	70	73	83	95	65
11	85	70	95	45	50	65	63	75	80	60
12	19	16	22	19	12	17	17	17	30	21
13	67	35	55	58	25	43	58	66	71	71
14	67	20	66	10	38	36	46	42	68	60
15	76	65	100	0	60	35	40	70	90	15
16	70	0	80	100	40	20	10	30	90	60
17	75	50	80	45	30	65	40	60	95	80
18	85	60	80	80	70	60	62	65	90	65
19	85	40	75	45	80	60	83	50	95	74
20	75	60	86	74	63	71	79	67	81	83
21	52	0	60	20	12	8	44	4	100	36
22	93	75	95	85	80	89	85	85	100	93
23	80	70	85	85	50	70	80	75	100	80
24	70	55	80	60	0	90	75	79	40	100
25	55	40	70	40	45	45	40	50	65	48
26	70	0	80	55	50	30	40	20	100	65
27	81	40	100	54	57	61	72	25	78	40
28	58	38	63	19	59	40	34	64	48	39
29	73	14	150	5	39	36	19	57	81	5
31	80	50	50	30	30	30	50	10	100	60
33	82	65	87	73	60	78	70	75	95	80
34	80	50	100	10	60	30	40	70	90	20
35	95	70	55	50	65	75	80	90	60	85
36	60	46	90	20	48	27	30	50	80	22
37	85	60	85	75	65	55	70	50	90	80
38	100	26	89	33	0	73	59	42	11	76
39	55	50	70	45	60	40	40	65	50	50
40	75	65	85	25	45	35	40	70	90	20
41	75	0	75	40	0	65	30	35	95	70
42	20	48	45	69	30	30	58	15	64	82

TABLE E-2

COMPANY PERFORMANCE INDEXES--WORKSHOP RESULTS
METHOD TWO: WEIGHTED SUMMATION, DIRECT WEIGHTS

Respondent	Company A	B	C	D	E	F	G	H	I	J
2	61.07	44.26	65.84	44.85	46.32	50.38	48.85	47.82	67.17	55.41
3	62.56	45.98	62.71	40.27	48.55	51.90	41.06	47.29	65.33	53.76
4	58.65	48.55	60.69	47.86	44.51	48.85	43.80	49.31	66.52	49.91
5	55.91	44.87	61.66	52.77	38.42	50.31	44.24	46.98	66.31	57.45
6	65.65	38.23	79.01	37.41	57.76	42.30	37.61	49.85	73.71	51.36
7	62.64	45.47	66.03	45.98	37.68	53.33	46.55	49.50	63.30	60.81
8	56.24	42.23	69.22	46.68	47.03	46.14	33.61	52.95	75.11	59.94
9										
10	57.28	40.52	64.95	47.56	40.45	46.50	43.28	48.43	70.36	55.32
11	51.04	49.67	61.62	50.66	36.17	51.31	38.09	48.57	62.77	52.80
12	56.41	43.36	61.72	48.26	39.19	47.66	43.22	47.42	67.18	54.65
13	53.94	43.98	60.81	48.57	41.32	47.21	39.89	50.12	67.63	55.21
14	53.24	43.75	66.38	52.36	37.14	46.82	42.40	50.30	72.33	53.73
15	53.37	43.85	60.26	49.88	40.53	49.03	42.15	48.78	68.68	52.18
16	61.79	42.44	76.59	40.90	46.90	47.50	41.06	49.90	78.65	56.47
17	57.41	45.10	59.65	47.58	45.07	48.67	42.53	47.48	67.08	50.51
18	56.20	44.66	63.77	48.88	45.25	49.98	44.34	48.25	70.02	54.24
19	61.08	37.53	69.70	45.46	47.41	45.95	42.17	49.56	78.95	59.69
20	60.62	40.92	66.12	45.78	47.37	46.86	42.39	47.67	72.35	57.04
21	63.71	39.90	67.92	38.95	42.86	47.72	46.65	48.36	70.91	54.35
22	57.83	45.21	58.60	44.87	39.42	49.66	45.13	47.35	62.75	49.35
23	56.49	41.39	61.55	48.85	40.55	47.16	42.70	47.88	69.85	55.02
24	58.95	44.62	65.31	48.60	41.52	47.87	44.72	48.63	68.43	56.03
25										
26	54.12	50.16	57.45	45.97	42.17	52.61	38.95	53.01	62.43	51.99
27	61.04	33.34	68.26	43.95	42.17	39.30	42.01	45.81	75.25	53.07
28	51.83	45.74	59.82	51.44	40.02	47.56	37.68	48.95	67.03	55.46
29	57.44	40.89	67.47	50.92	44.87	48.77	39.91	42.98	76.38	55.69
31	62.75	39.27	61.32	23.65	65.67	43.37	12.34	61.45	65.63	34.48
33	60.33	51.78	61.68	43.05	45.90	54.97	43.80	46.74	59.07	50.07
34										
35	68.67	37.29	77.94	41.39	48.61	45.34	53.32	46.90	80.89	61.61
36	51.32	42.22	57.61	52.33	33.62	42.81	37.19	45.59	66.91	50.31
37	51.37	47.54	58.77	50.33	33.81	50.58	39.32	48.38	64.46	54.63
38	55.96	56.52	54.35	50.45	36.53	54.45	38.72	52.38	56.24	57.29
39	52.95	47.57	64.63	49.58	39.26	47.55	35.55	51.14	63.50	51.76
40	56.45	40.95	66.50	52.09	44.58	46.15	41.54	45.26	73.26	50.89
41	61.51	40.45	60.87	40.76	44.08	45.86	44.90	48.81	69.18	56.46
42	54.98	42.74	59.95	48.55	38.43	48.59	42.55	47.17	66.99	53.37
43	56.07	38.28	64.15	47.52	38.87	41.51	40.43	48.89	75.37	56.46

TABLE E-3

COMPANY PERFORMANCE INDEXES--WORKSHOP RESULTS
METHOD THREE: WEIGHTED SUMMATION, POINT ALLOCATION WEIGHTS

Respondent	Company									
	A	B	C	D	E	F	G	H	I	J
2	71.04	48.12	80.95	25.86	59.01	46.53	47.86	48.44	75.11	45.32
3	63.09	39.21	78.87	39.99	41.91	48.03	38.19	50.35	74.86	45.20
4	60.55	48.32	69.98	49.23	44.18	41.91	44.26	49.73	70.71	47.25
5	59.93	35.88	82.71	35.16	46.67	44.96	23.42	58.97	91.10	39.67
6	70.32	39.79	82.07	36.87	59.75	46.65	38.12	51.60	84.45	46.10
7	66.35	44.83	60.77	36.78	49.68	58.10	40.13	57.73	65.37	62.23
8	58.59	33.89	72.73	42.33	45.13	44.13	27.35	51.21	82.18	60.28
9										
10	69.41	37.15	87.49	25.97	49.59	40.34	37.04	51.52	82.03	31.70
11	52.21	53.89	59.18	47.36	43.13	51.66	37.45	48.56	57.94	49.17
12	61.30	45.16	70.29	38.82	46.31	41.90	37.66	44.44	68.93	47.80
13	54.79	45.71	60.94	46.21	49.71	46.27	31.92	53.51	70.05	52.83
14	53.06	38.15	71.28	49.44	34.00	47.75	47.86	42.15	69.51	50.60
15	54.09	43.18	57.10	46.85	46.10	49.50	39.32	49.57	68.45	52.78
16	58.38	41.82	68.74	40.66	43.02	44.40	36.45	48.61	71.60	50.09
17	36.86	26.78	33.89	26.25	35.27	29.82	21.48	29.98	42.56	33.59
18	58.02	44.87	64.19	43.92	49.29	50.54	43.49	50.03	71.76	54.42
19	61.55	42.08	72.26	48.86	45.25	49.25	42.29	52.60	78.98	61.80
20	65.50	44.09	69.36	37.23	56.07	47.94	44.95	47.50	71.98	56.60
21	61.47	35.79	68.55	39.43	44.04	44.50	44.41	48.29	74.18	53.18
22	60.99	46.69	71.22	49.56	45.58	52.53	46.36	45.55	69.57	60.45
23	62.57	41.68	70.03	45.91	42.30	49.27	46.13	49.28	76.95	60.42
24	70.76	44.07	77.85	40.64	45.74	51.83	44.82	54.00	77.92	61.21
25										
26	57.29	44.83	62.08	43.03	42.21	49.13	42.06	47.53	65.89	53.67
27	65.88	23.67	89.04	37.83	47.15	40.69	34.65	47.22	88.22	42.41
28	51.32	43.54	57.55	49.58	42.00	41.00	36.92	48.56	69.10	51.34
29	55.21	38.58	63.44	53.73	42.44	55.51	45.64	34.29	69.97	63.68
31	62.82	34.60	66.83	21.29	60.04	43.47	11.00	60.89	72.00	32.14
33	65.81	46.17	75.46	34.80	44.55	48.42	45.77	47.04	66.47	47.57
34										
35	68.09	39.16	77.99	41.67	47.93	45.60	53.16	47.38	80.15	61.36
36	46.90	44.66	53.76	49.24	30.89	46.11	36.69	49.05	63.97	50.30
37	55.81	40.66	62.11	46.79	42.16	47.23	42.36	48.43	73.76	56.16
38	61.82	54.21	52.10	44.51	41.21	52.76	35.18	57.51	56.97	59.42
39	55.35	50.28	64.97	41.40	43.07	49.52	36.89	53.13	64.50	43.15
40	59.26	42.17	70.36	49.50	49.82	52.31	39.27	44.22	76.41	56.55
41	64.00	44.86	69.57	33.92	47.38	46.53	48.41	45.41	64.67	53.18
42	57.49	43.74	61.42	46.57	43.21	47.65	40.99	48.24	72.15	54.76
43	62.74	38.68	80.35	42.98	44.74	40.88	45.44	47.97	77.48	51.95

TABLE E-4

COMPANY PERFORMANCE INDEXES--WORKSHOP RESULTS
METHOD FOUR: WEIGHTED SUMMATION, AHP WEIGHTS

Respondent	Company									
	A	B	C	D	E	F	G	H	I	J
2	63.48	50.04	76.50	27.72	57.58	41.74	36.42	51.87	74.21	37.34
3	63.34	50.23	75.29	38.59	50.14	47.79	40.92	49.36	73.60	39.27
4	65.02	45.27	70.49	51.26	44.71	33.96	51.48	53.45	75.21	39.31
5	66.39	45.18	86.77	21.77	55.38	36.06	31.83	60.66	85.05	29.16
6	66.00	37.49	78.87	29.10	53.33	39.67	29.48	46.88	75.98	34.37
7	67.56	32.73	51.82	29.76	46.76	58.70	56.25	41.28	65.93	67.15
8	56.73	43.94	69.62	54.17	44.56	42.39	32.92	49.42	82.32	64.68
9	63.28	46.58	77.57	26.57	49.94	45.57	33.37	54.66	77.02	38.16
10	63.13	48.94	77.76	23.27	56.31	38.35	28.45	65.02	82.43	35.91
11	36.61	67.50	44.75	68.24	43.28	51.63	23.12	53.83	57.16	46.76
12	62.90	48.84	77.22	26.54	49.85	44.78	36.69	56.00	75.70	38.56
13	60.42	37.18	74.34	34.49	52.14	44.81	28.20	55.54	80.55	40.06
14	56.69	29.37	56.20	32.99	23.16	38.81	44.90	45.79	79.92	54.37
15	54.47	42.46	47.15	43.44	54.97	49.44	39.15	35.21	62.45	57.63
16	61.99	49.34	76.00	29.30	49.14	37.29	27.93	58.54	77.21	39.47
17	50.71	56.03	36.87	48.72	67.92	46.36	23.23	32.77	54.73	52.95
18	50.90	59.95	51.38	47.31	66.23	51.30	34.14	41.02	57.94	52.25
19	62.58	31.03	73.65	57.10	44.22	56.96	37.67	44.05	76.67	67.87
20	68.58	46.65	79.38	19.48	45.09	46.18	42.66	61.09	78.42	40.26
21	53.69	45.18	60.83	49.21	44.78	53.38	54.24	56.71	57.02	58.15
22	64.49	35.02	76.46	47.04	42.42	47.28	47.87	48.09	78.97	55.91
23	59.45	47.74	65.53	40.33	44.31	49.95	43.32	52.83	67.11	50.45
24	65.86	50.84	82.49	23.28	52.08	39.83	31.52	66.04	83.70	36.71
25	77.99	36.79	53.73	28.08	50.79	51.24	63.22	42.80	62.37	67.30
26	65.38	33.18	67.51	48.75	46.80	46.84	42.97	45.45	73.88	59.42
27	61.59	32.59	75.92	32.87	46.25	41.66	25.79	55.24	82.55	53.80
28	48.42	51.62	43.97	47.86	61.63	46.29	18.59	46.08	60.56	52.81
29	55.16	39.48	67.66	56.88	39.11	40.23	36.11	48.70	81.46	71.40
31	60.26	49.75	71.08	37.93	45.28	55.28	56.93	47.44	63.53	51.86
33	37.57	54.84	50.16	63.11	40.56	46.95	23.83	39.74	58.32	50.48
34	58.60	41.03	43.71	36.63	36.04	49.40	45.83	49.50	65.38	58.89
35	55.03	35.45	59.10	43.51	26.02	34.85	41.99	39.96	57.51	45.78
36	64.07	52.92	44.76	34.84	44.94	60.95	47.52	55.52	58.06	61.85
37	66.05	52.22	71.00	38.92	43.30	62.03	52.56	52.59	65.02	61.18
38	62.53	33.06	79.60	58.40	42.32	38.87	45.99	45.10	79.93	64.83
39	70.35	44.77	71.99	26.81	48.49	45.14	55.37	41.96	63.90	59.47
40	62.64	51.44	77.65	45.18	37.33	46.79	40.36	61.55	70.17	62.66
41	57.84	40.15	74.87	35.30	48.65	41.12	26.96	59.90	82.52	46.87
42	51.54	35.77	63.39	47.96	54.12	47.06	21.04	54.97	86.73	59.57
43	47.76	53.83	47.95	52.31	68.81	44.39	23.74	37.60	61.26	46.34

APPENDIX F

COMPANY TOTAL FACTOR PRODUCTIVITY INDEXES

This appendix reports the values of the 7 total factor productivity indexes described in chapters 5 and 6. These are arranged in 7 tables, each of which lists the value of the index for 3 years (1965, 1973, and 1981), for the most recent 5 years (1977 to 1981), and for the entire sample period (1964 to 1981). In addition, the ranking of the utility in each of these periods is listed. The name of the electric utilities is not included. Instead, an arbitrary code has been assigned to each company to facilitate comparisons between tables for those readers interested in doing so.

The values of the indexes may be interpreted as the percentage difference in cost when compared to some benchmark. The benchmark itself is different for each index. Those indexes based on econometric cost estimation have benchmarks of predicted costs. The dynamic TFP indexes have last year's performance as the benchmark. The static multilateral TFP index uses the 1980 performance of a particular company as the benchmark.

TABLE F-1

LONG-RUN COST STATIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
101086	0.303	0.483	0.566	2.819	8.560	7	1	1	1	1
844120	0.519	0.385	0.176	1.259	7.363	1	3	15	8	2
494885	0.475	0.418	0.507	1.670	6.660	2	2	2	4	3
809055	0.471	0.369	0.254	1.313	6.545	3	5	9	6	4
812159	0.309	0.332	0.193	0.856	5.451	6	7	13	15	5
115281	0.360	0.344	0.178	1.205	5.204	4	6	14	9	6
018974	0.132	0.293	0.423	1.874	5.194	19	8	3	3	7
861226	0.051	0.260	0.332	2.153	4.715	32	11	7	2	8
773240	0.327	0.281	-0.072	0.203	4.570	5	9	49	30	9
710194	0.117	0.379	0.326	1.375	4.205	21	4	8	5	10
004134	0.215	0.278	0.137	0.618	3.945	10	10	19	19	11
860166	0.261	0.108	0.194	1.280	3.842	9	19	12	7	12
581933	0.293	0.190	0.100	0.604	3.780	8	13	25	20	13
411099	0.020	0.234	0.204	1.134	2.952	37	12	11	10	14
12699	0.078	0.151	0.136	0.843	2.542	29	14	21	16	15
211212	0.181	0.150	0.023	0.226	2.351	14	15	35	29	16
94490	0.092	0.006	0.166	0.989	2.292	26	35	17	12	17
532812	-0.035	0.094	0.078	0.467	2.196	48	21	29	24	18
132841	-0.015	0.104	0.123	0.886	1.931	43	20	22	14	19
860124	0.158	0.013	0.097	0.200	1.860	16	33	27	32	20
018848	0.200	0.073	-0.070	-0.080	1.598	12	25	48	44	21
170586	0.145	-0.023	-0.020	0.186	1.576	18	45	43	34	22
348719	0.084	-0.008	0.175	0.737	1.532	28	38	16	18	23
463687	0.209	0.140	-0.169	-0.903	1.464	11	17	63	70	24
328969	0.198	-0.016	-0.005	0.091	1.401	13	41	41	39	25
300547	0.154	-0.032	0.360	0.803	1.164	17	47	4	17	26
775168	0.005	0.086	0.069	0.578	1.078	39	22	32	22	27
949991	0.107	0.112	-0.091	-0.264	0.757	24	18	51	51	28
847707	-0.044	0.148	0.115	0.458	0.725	49	16	23	25	29
794661	0.169	0.019	0.022	0.040	0.545	15	32	36	40	30
579844	0.060	0.075	0.073	-0.053	0.521	31	24	30	43	31
348758	-0.046	0.024	0.137	0.439	0.474	50	31	20	26	32
278267	0.109	0.033	-0.190	-0.429	0.363	23	29	67	57	33
826565	0.088	-0.064	0.339	0.495	0.225	27	50	6	23	34
165143	0.027	-0.095	-0.135	-0.239	0.125	35	56	58	49	35
308543	-0.109	0.001	0.099	0.590	-0.048	56	36	26	21	36
26935	0.110	-0.015	-0.143	-0.414	-0.055	22	40	59	54	37
844914	0.032	-0.023	0.061	-0.040	-0.080	34	44	33	41	38
912633	-0.097	0.079	0.070	0.255	-0.085	55	23	31	27	39
565430	-0.019	0.038	-0.066	-0.208	-0.093	45	26	47	48	40
245646	-0.014	-0.039	-0.078	-0.181	-0.224	42	48	50	45	41
590233	0.001	0.025	-0.002	0.092	-0.272	40	30	38	38	42

TABLE F-1--Continued

LONG-RUN COST STATIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
132978	0.104	-0.230	0.358	1.037	-0.306	25	75	5	11	43
411180	-0.019	-0.022	-0.047	-0.184	-0.386	44	43	46	46	44
710419	-0.032	0.008	0.056	0.138	-0.401	47	34	34	35	45
775882	-0.123	0.034	0.020	0.230	-0.461	57	28	37	28	46
516623	-0.005	-0.016	-0.134	-0.350	-0.476	41	42	57	53	47
411175	-0.185	0.035	-0.003	0.119	-0.487	67	27	39	36	48
307074	0.025	-0.008	-0.161	-0.712	-0.501	36	37	61	64	49
411133	0.062	-0.133	-0.123	-0.426	-0.616	30	61	55	56	50
368017	0.035	-0.096	-0.092	-0.460	-0.907	33	57	52	58	51
761474	-0.161	-0.009	-0.003	-0.049	-0.986	66	39	40	42	52
200699	-0.151	-0.030	-0.011	0.112	-1.002	64	46	42	37	53
326894	0.132	-0.073	-0.183	-0.784	-1.173	20	51	66	67	54
526820	-0.052	-0.086	-0.165	-0.424	-1.179	51	54	62	55	55
506714	-0.028	-0.057	-0.202	-0.691	-1.568	46	49	70	62	56
892660	-0.368	-0.082	0.208	0.927	-1.587	79	53	10	13	57
912672	0.011	-0.135	-0.131	-0.780	-1.595	38	62	56	66	58
185068	-0.142	-0.090	-0.177	-0.337	-1.627	62	55	65	52	59
105635	-0.129	-0.164	-0.033	-0.256	-1.739	59	67	44	50	60
148008	-0.133	-0.115	0.084	0.200	-1.788	60	60	28	31	61
128068	-0.144	-0.192	0.111	0.192	-1.826	63	71	24	33	62
354761	-0.135	-0.108	-0.120	-0.567	-2.080	61	59	54	59	63
411117	-0.154	-0.218	-0.040	-0.208	-2.366	65	73	45	47	64
237718	-0.124	-0.139	0.146	-0.666	-2.401	58	64	18	61	65
424094	-0.086	-0.107	-0.204	-0.982	-2.682	53	58	71	71	66
564034	-0.260	-0.190	-0.097	-0.694	-2.775	75	70	53	63	67
015842	-0.188	-0.148	-0.201	-0.755	-3.028	68	65	69	65	68
032731	-0.088	-0.081	-0.240	-1.276	-3.075	54	52	74	74	69
831967	-0.287	-0.186	-0.143	-0.606	-3.237	77	69	60	60	70
588557	-0.081	-0.199	-0.299	-1.451	-3.597	52	72	77	77	71
436801	-0.203	-0.151	-0.199	-0.879	-3.665	69	66	68	68	72
715166	-0.226	-0.273	-0.174	-0.903	-3.975	71	77	64	69	73
16000	-0.224	-0.185	-0.345	-1.267	-4.331	70	68	80	73	74
463602	-0.257	-0.240	-0.254	-1.452	-4.735	74	76	75	78	75
170291	-0.243	-0.135	-0.329	-1.381	-4.808	72	63	78	75	76
266033	-0.256	-0.304	-0.339	-1.610	-4.966	73	79	79	80	77
494843	-0.261	-0.297	-0.236	-1.396	-5.228	76	78	73	76	78
17969	-0.441	-0.221	-0.207	-1.000	-5.250	80	74	72	72	79
467838	-0.343	-0.360	-0.291	-1.575	-6.393	78	80	76	79	80
563222	-0.637	-0.550	-0.652	-3.342	-11.02	81	81	81	81	81

TABLE F-2

MULTILATERAL TFP STATIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
018974	0.795	1.191	1.317	6.276	20.423	10	4	1	2	1
101086	0.769	1.227	1.277	6.461	20.411	13	3	3	1	2
494885	1.021	1.232	1.301	5.620	19.986	1	2	2	3	3
812159	0.953	1.164	1.021	4.962	19.769	5	6	9	9	4
115281	1.002	1.176	1.062	5.454	19.549	3	5	8	6	5
844120	1.016	1.111	0.866	4.808	18.905	2	7	23	12	6
710194	0.733	1.238	1.158	5.512	18.490	17	1	4	4	7
860166	0.885	0.955	1.018	5.449	18.110	6	15	10	7	8
809055	0.978	1.083	0.930	4.742	17.854	4	8	14	14	9
581933	0.872	0.976	0.888	4.466	16.686	7	12	19	18	10
12699	0.683	0.976	0.950	4.850	16.346	19	13	13	11	11
860124	0.808	0.868	0.926	4.309	16.344	9	27	15	23	12
411099	0.573	1.037	0.988	5.148	16.291	34	10	11	8	13
773240	0.794	1.029	0.618	3.766	16.280	11	11	56	38	14
211212	0.773	0.966	0.815	4.167	15.822	12	14	33	29	15
004134	0.644	1.059	0.817	4.226	15.615	24	9	32	27	16
775168	0.610	0.928	0.894	4.703	15.319	27	19	18	15	17
94490	0.639	0.791	0.926	4.792	15.174	25	33	16	13	18
861226	0.411	0.943	0.957	5.487	15.122	58	17	12	5	19
532812	0.467	0.883	0.805	4.239	15.023	49	23	36	26	20
132841	0.538	0.902	0.869	4.669	14.830	37	21	22	16	21
794661	0.810	0.878	0.837	4.089	14.699	8	24	28	31	22
949991	0.736	0.943	0.724	3.718	14.520	16	16	41	40	23
018848	0.739	0.877	0.677	3.714	14.427	15	25	44	41	24
579844	0.654	0.901	0.884	3.990	14.403	23	22	20	33	25
170586	0.668	0.750	0.721	3.962	14.230	20	39	42	34	26
165143	0.667	0.712	0.646	3.674	14.161	21	50	52	42	27
847707	0.519	0.934	0.894	4.395	14.038	39	18	17	20	28
26935	0.745	0.815	0.671	3.534	13.833	14	31	47	46	29
590233	0.602	0.863	0.812	4.150	13.799	29	28	35	30	30
463687	0.701	0.927	0.535	2.758	13.775	18	20	64	71	31
775882	0.485	0.874	0.846	4.335	13.749	46	26	27	21	32
200699	0.503	0.846	0.850	4.323	13.669	43	29	26	22	33
300547	0.663	0.729	1.082	4.446	13.291	22	45	7	19	34
308543	0.417	0.799	0.876	4.521	12.942	56	32	21	17	35
761474	0.444	0.823	0.784	3.908	12.935	51	30	38	37	36
826565	0.603	0.718	1.098	4.296	12.836	28	49	6	24	37
328969	0.594	0.752	0.674	3.569	12.700	32	37	45	45	38
132978	0.599	0.554	1.118	4.888	12.673	31	75	5	10	39
348719	0.512	0.721	0.832	4.185	12.578	41	48	29	28	40
710419	0.507	0.775	0.830	4.046	12.562	42	35	30	32	41
411133	0.587	0.649	0.637	3.380	12.199	33	61	53	51	42

TABLE F-2--Continued

MULTILATERAL TFP STATIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
245646	0.516	0.746	0.633	3.467	12.147	40	41	55	48	43
278267	0.599	0.779	0.508	3.117	12.064	30	34	71	59	44
844914	0.555	0.738	0.763	3.529	12.021	36	43	39	47	45
411180	0.481	0.734	0.657	3.413	11.691	47	44	50	50	46
348758	0.388	0.759	0.799	3.911	11.680	61	36	37	36	47
516623	0.493	0.749	0.571	3.280	11.582	44	40	62	54	48
368017	0.570	0.671	0.633	3.218	11.577	35	57	54	56	49
565430	0.472	0.741	0.604	3.207	11.360	48	42	58	57	50
307074	0.522	0.729	0.533	2.902	11.074	38	46	65	66	51
326894	0.618	0.703	0.593	3.054	11.067	26	51	59	61	52
354761	0.430	0.693	0.648	3.248	10.913	54	52	51	55	53
912633	0.349	0.728	0.729	3.628	10.866	65	47	40	44	54
912672	0.493	0.617	0.605	3.075	10.746	45	67	57	60	55
715166	0.441	0.635	0.669	3.196	10.741	52	63	48	58	56
411175	0.236	0.752	0.698	3.655	10.710	74	38	43	43	57
148008	0.379	0.661	0.824	3.922	10.660	62	58	31	35	58
105635	0.365	0.606	0.672	3.377	10.304	64	69	46	52	59
16000	0.400	0.680	0.507	2.879	10.139	60	55	72	68	60
185068	0.294	0.676	0.526	3.316	10.138	69	56	66	53	61
506714	0.464	0.661	0.477	2.770	9.972	50	59	75	70	62
128068	0.326	0.566	0.813	3.762	9.964	67	71	34	39	63
526820	0.405	0.634	0.497	2.994	9.944	59	64	73	62	64
892660	0.090	0.683	0.861	4.271	9.916	79	54	24	25	65
237718	0.365	0.625	0.860	2.955	9.616	63	66	25	63	66
424094	0.440	0.656	0.508	2.613	9.505	53	60	70	73	67
411117	0.326	0.522	0.667	3.438	9.447	66	76	49	49	68
015842	0.322	0.630	0.552	2.946	9.350	68	65	63	64	69
831967	0.267	0.595	0.577	2.929	9.263	72	70	61	65	70
032731	0.411	0.684	0.488	2.407	9.147	57	53	74	74	71
564034	0.204	0.555	0.589	2.830	8.924	77	74	60	69	72
436801	0.277	0.639	0.516	2.892	8.627	70	62	69	67	73
588557	0.427	0.565	0.405	2.110	8.418	55	72	78	77	74
494843	0.275	0.499	0.522	2.398	7.661	71	77	67	75	75
170291	0.256	0.612	0.377	2.288	7.571	73	68	80	76	76
17969	0.035	0.560	0.519	2.661	6.912	80	73	68	72	77
266033	0.213	0.442	0.381	1.992	6.877	76	79	79	80	78
463602	0.219	0.475	0.444	2.103	6.859	75	78	76	78	79
467838	0.150	0.403	0.412	2.007	5.645	78	80	77	79	80
563222	-0.134	0.195	0.000	-0.037	0.644	81	81	81	81	81

TABLE F-3

LONG-RUN COST DYNAMIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
101086	0.372	0.517	0.564	2.826	8.571	6	1	1	1	1
844120	0.588	0.429	0.192	1.261	7.073	1	3	12	8	2
494885	0.499	0.439	0.497	1.685	6.438	4	2	2	4	3
809055	0.547	0.413	0.277	1.320	6.292	2	4	9	6	4
018974	0.134	0.307	0.420	1.902	5.348	26	10	3	3	5
115281	0.507	0.386	0.204	1.252	5.267	3	6	10	9	6
812159	0.290	0.344	0.168	0.848	5.107	11	7	16	16	7
861226	0.178	0.299	0.317	2.150	5.026	18	11	7	2	8
773240	0.393	0.312	-0.083	0.211	4.537	5	9	50	30	9
710194	0.102	0.394	0.314	1.400	4.368	32	5	8	5	10
004134	0.304	0.324	0.111	0.609	4.004	10	8	24	20	11
860166	0.257	0.109	0.181	1.300	3.909	12	21	14	7	12
581933	0.350	0.235	0.122	0.615	3.624	7	13	19	19	13
411099	0.038	0.260	0.182	1.157	3.174	40	12	13	10	14
12699	0.102	0.170	0.121	0.851	2.694	33	16	21	15	15
532812	-0.008	0.126	0.053	0.449	2.572	51	20	31	25	16
94490	0.137	0.039	0.177	1.010	2.434	25	32	15	12	17
211212	0.215	0.180	0.031	0.253	2.396	15	14	34	28	18
132841	0.020	0.127	0.114	0.899	2.274	47	19	23	14	19
860124	0.127	-0.000	0.069	0.198	1.909	28	43	29	32	20
348719	0.172	0.026	0.160	0.741	1.761	22	35	17	18	21
170586	0.176	0.005	-0.036	0.193	1.743	19	42	43	34	22
018848	0.230	0.095	-0.086	-0.081	1.683	14	23	51	43	23
328969	0.311	0.069	-0.015	0.081	1.595	9	27	40	39	24
463687	0.247	0.169	-0.190	-0.909	1.517	13	17	66	70	25
775168	0.020	0.108	0.067	0.598	1.360	46	22	30	22	26
300547	0.207	-0.001	0.362	0.815	1.348	16	44	4	17	27
847707	-0.017	0.177	0.118	0.477	1.081	52	15	22	24	28
348758	0.037	0.056	0.122	0.442	0.850	41	29	20	26	29
949991	0.153	0.151	-0.072	-0.227	0.807	23	18	48	49	30
579844	0.034	0.085	0.045	-0.059	0.724	43	25	33	42	31
912633	0.134	-0.086	0.018	0.195	0.622	27	58	36	33	32
794661	0.173	0.026	0.010	0.054	0.611	21	37	37	40	33
278267	0.176	0.066	-0.188	-0.427	0.552	20	28	65	57	34
826565	0.118	-0.040	0.330	0.506	0.447	30	49	6	23	35
165143	-0.006	-0.163	-0.177	-0.282	0.364	50	69	63	51	36
308543	-0.091	0.026	0.077	0.601	0.299	61	36	27	21	37
565430	0.054	0.094	-0.033	-0.206	0.161	37	24	42	48	38
844914	0.087	0.011	0.069	-0.031	0.159	35	39	28	41	39
245646	0.027	-0.013	-0.082	-0.170	0.063	44	46	49	45	40
26935	0.149	0.015	-0.133	-0.390	0.030	24	38	56	54	41
590233	0.005	0.040	-0.013	0.107	0.026	48	31	39	38	42

TABLE F-3--Continued

LONG-RUN COST DYNAMIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
411175	-0.105	0.072	-0.009	0.146	-0.021	64	26	38	36	43
411180	0.035	0.011	-0.047	-0.173	-0.055	42	41	47	46	44
775882	-0.113	0.054	0.025	0.260	-0.098	65	30	35	27	45
710419	-0.002	0.036	0.051	0.157	-0.109	49	33	32	35	46
132978	0.126	-0.206	0.339	1.042	-0.164	29	75	5	11	47
516623	0.043	0.011	-0.141	-0.338	-0.192	38	40	57	53	48
307074	0.117	0.030	-0.175	-0.705	-0.229	31	34	62	64	49
411133	0.078	-0.106	-0.144	-0.420	-0.424	36	61	58	56	50
368017	0.088	-0.059	-0.086	-0.439	-0.632	34	55	52	58	51
200699	-0.159	-0.020	-0.025	0.139	-0.648	68	47	41	37	52
761474	-0.225	-0.030	-0.039	-0.082	-0.758	75	48	45	44	53
526820	0.020	-0.045	-0.154	-0.416	-0.806	45	51	60	55	54
912672	0.349	-0.239	-0.147	-0.793	-0.862	8	76	59	67	55
892660	-0.316	-0.051	0.194	0.947	-0.921	79	52	11	13	56
326894	0.192	-0.042	-0.192	-0.747	-1.023	17	50	68	66	57
185068	-0.070	-0.057	-0.198	-0.336	-1.167	56	54	69	52	58
506714	0.041	-0.012	-0.184	-0.692	-1.303	39	45	64	62	59
105635	-0.081	-0.135	-0.037	-0.252	-1.320	58	65	44	50	60
148008	-0.096	-0.091	0.078	0.215	-1.440	62	59	26	29	61
128068	-0.085	-0.162	0.092	0.210	-1.477	59	68	25	31	62
354761	-0.089	-0.073	-0.101	-0.536	-1.747	60	56	53	59	63
411117	-0.097	-0.187	-0.044	-0.199	-1.961	63	71	46	47	64
237718	-0.074	-0.111	0.139	-0.654	-1.967	57	63	18	61	65
564034	-0.202	-0.161	-0.116	-0.694	-2.262	72	67	55	63	66
424094	-0.030	-0.074	-0.190	-0.963	-2.379	53	57	67	71	67
015842	-0.143	-0.123	-0.199	-0.728	-2.602	67	64	70	65	68
032731	-0.042	-0.055	-0.253	-1.269	-2.746	55	53	75	73	69
831967	-0.228	-0.137	-0.111	-0.584	-2.800	76	66	54	60	70
436801	-0.179	-0.103	-0.224	-0.909	-3.235	69	60	72	69	71
588557	-0.031	-0.170	-0.305	-1.446	-3.281	54	70	77	78	72
715166	-0.136	-0.258	-0.157	-0.850	-3.552	66	77	61	68	73
16000	-0.238	-0.195	-0.366	-1.294	-4.096	77	72	80	74	74
463602	-0.193	-0.204	-0.243	-1.434	-4.162	70	74	74	77	75
170291	-0.202	-0.108	-0.343	-1.377	-4.284	73	62	79	76	76
266033	-0.195	-0.274	-0.342	-1.600	-4.402	71	78	78	80	77
17969	-0.400	-0.199	-0.219	-0.989	-4.613	80	73	71	72	78
494843	-0.224	-0.275	-0.238	-1.369	-4.763	74	79	73	75	79
467838	-0.297	-0.333	-0.300	-1.572	-5.755	78	80	76	79	80
563222	-0.579	-0.515	-0.635	-3.319	-10.27	81	81	81	81	81

TABLE F-4

MULTILATERAL TFP DYNAMIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
892660	0.071	0.078	0.007	0.004	0.843	16	7	18	37	1
101086	0.073	-0.062	-0.038	-0.047	0.581	14	75	52	57	2
826565	0.080	0.046	0.236	0.374	0.575	10	27	2	3	3
861226	0.027	0.045	-0.042	-0.003	0.573	56	30	57	40	4
237718	0.064	0.020	0.295	0.310	0.558	26	45	1	4	5
018974	0.032	0.019	0.014	0.113	0.554	52	46	15	7	6
132978	0.033	0.204	0.021	0.376	0.553	50	1	10	2	7
300547	0.101	0.045	0.220	0.384	0.520	5	28	3	1	8
710194	0.069	0.074	0.064	0.076	0.494	19	8	5	16	9
308543	0.033	0.069	-0.094	0.018	0.491	51	9	77	34	10
348758	0.066	0.059	-0.012	0.075	0.477	23	14	32	17	11
411175	0.009	0.052	-0.034	-0.042	0.472	64	22	49	52	12
148008	0.017	-0.023	-0.025	0.105	0.462	58	67	42	9	13
17969	-0.023	0.050	-0.076	0.049	0.461	77	25	72	23	14
128068	-0.026	-0.034	-0.004	0.300	0.461	78	71	27	5	15
912633	0.068	0.063	-0.066	-0.016	0.448	21	12	68	44	16
847707	0.066	0.097	0.004	0.010	0.442	22	5	20	36	17
532812	0.099	-0.331	-0.071	-0.060	0.437	6	81	70	60	18
132841	0.103	0.092	-0.076	-0.226	0.434	3	6	73	78	19
411099	-0.004	-0.001	-0.024	-0.105	0.410	72	51	40	68	20
348719	0.062	0.032	-0.036	0.055	0.382	28	36	51	21	21
775882	0.013	0.027	-0.023	0.024	0.373	60	39	37	29	22
564034	-0.017	-0.005	-0.011	0.090	0.367	76	57	31	11	23
105635	0.058	-0.021	-0.025	0.088	0.365	31	66	41	12	24
411117	0.013	-0.013	-0.058	0.052	0.354	62	62	64	22	25
200699	-0.010	0.022	0.004	0.086	0.337	74	44	21	13	26
467838	0.071	0.036	0.008	-0.008	0.334	15	35	17	41	27
710419	0.010	-0.003	0.000	0.073	0.333	63	53	24	18	28
94490	0.045	-0.006	-0.042	-0.066	0.333	42	58	55	63	29
12699	0.051	-0.001	0.025	0.080	0.318	38	52	9	15	30
494885	0.036	-0.088	0.202	0.152	0.316	48	78	4	6	31
775168	0.028	0.023	-0.058	-0.045	0.312	54	43	63	54	32
831967	0.002	0.002	-0.008	-0.053	0.312	68	50	30	59	33
761474	-0.030	0.057	0.002	0.018	0.310	79	15	23	35	34
436801	0.052	0.141	-0.074	-0.106	0.291	34	3	71	69	35
185068	0.053	0.053	-0.085	-0.199	0.285	33	21	76	76	36
590233	0.074	0.041	-0.029	-0.046	0.284	13	32	44	56	37
579844	0.051	-0.008	0.036	0.044	0.281	37	59	8	24	38
860166	0.146	-0.034	-0.130	-0.015	0.279	1	70	80	43	39
463602	0.052	0.017	0.017	0.019	0.277	35	47	14	33	40
015842	0.045	0.051	-0.062	-0.032	0.275	43	23	66	48	41
494843	0.027	0.057	0.003	0.105	0.274	55	16	22	8	42

TABLE F-4--Continued

MULTILATERAL TFP DYNAMIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
266033	0.099	0.045	0.011	0.001	0.266	7	29	16	38	43
844914	0.058	0.025	0.060	0.099	0.266	30	42	6	10	44
354761	0.031	-0.003	-0.049	0.021	0.248	53	54	59	32	45
411180	0.068	0.039	-0.020	-0.015	0.244	20	34	36	42	46
715166	-0.006	-0.055	-0.007	0.040	0.222	73	73	29	25	47
526820	0.102	0.065	-0.042	-0.192	0.194	4	11	56	75	48
245646	0.064	0.026	-0.056	-0.074	0.181	25	40	62	66	49
004134	0.007	-0.009	-0.084	0.066	0.180	65	60	75	19	50
565430	0.036	-0.018	-0.049	-0.001	0.169	47	64	60	39	51
328969	0.084	-0.041	-0.006	-0.020	0.164	9	72	28	45	52
516623	0.071	0.057	-0.036	-0.122	0.149	17	17	50	72	53
115281	0.079	-0.004	-0.025	-0.037	0.139	11	56	43	51	54
170291	0.018	0.160	-0.064	-0.095	0.138	57	2	67	67	55
860124	0.016	-0.016	0.046	-0.043	0.135	59	63	7	53	56
032731	0.056	0.051	0.000	0.024	0.133	32	24	25	30	57
368017	0.069	-0.009	-0.033	0.033	0.133	18	61	48	28	58
563222	-0.016	0.025	-0.024	-0.062	0.118	75	41	38	62	59
424094	0.048	0.060	-0.016	-0.035	0.116	40	13	33	49	60
411133	0.066	-0.146	0.020	-0.074	0.115	24	79	12	65	61
912672	-0.004	0.016	-0.041	0.036	0.108	71	48	53	27	62
307074	0.093	0.027	-0.083	-0.049	0.103	8	38	74	58	63
170586	0.040	-0.083	-0.102	-0.073	0.093	46	77	79	64	64
211212	0.048	-0.070	-0.031	-0.036	0.091	39	76	47	50	65
794661	0.059	-0.027	-0.020	0.039	0.086	29	68	35	26	66
506714	0.052	-0.004	-0.031	-0.114	0.065	36	55	46	70	67
326894	0.041	0.067	-0.030	0.023	0.016	45	10	45	31	68
018848	0.075	0.040	-0.041	-0.135	0.013	12	33	54	73	69
278267	0.104	0.101	-0.101	-0.234	0.013	2	4	78	79	70
581933	-0.003	-0.058	-0.060	0.061	0.013	70	74	65	20	71
588557	0.034	0.053	-0.001	-0.046	0.013	49	19	26	55	72
809055	0.044	0.043	-0.024	-0.030	-0.003	44	31	39	46	73
16000	-0.116	0.028	0.005	-0.199	-0.009	80	37	19	77	74
949991	0.000	0.053	-0.019	-0.030	-0.011	69	20	34	47	75
165143	0.003	-0.150	-0.149	-0.061	-0.019	67	80	81	61	76
26935	0.013	0.003	-0.071	-0.120	-0.061	61	49	69	71	77
844120	0.062	0.049	-0.045	-0.267	-0.087	27	26	58	80	78
773240	0.046	-0.019	-0.052	-0.368	-0.130	41	65	61	81	79
812159	-0.217	-0.030	0.019	0.082	-0.149	81	69	13	14	80
463687	0.007	0.055	0.021	-0.166	-0.159	66	18	11	74	81

TABLE F-5

CONVENTIONAL TFP INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
892660	0.073	0.078	0.009	-0.029	0.790	12	10	23	50	1
861226	0.035	0.063	-0.035	0.025	0.651	50	13	58	33	2
018974	0.019	0.026	0.025	0.150	0.615	60	44	12	6	3
101086	0.078	-0.055	-0.033	-0.051	0.592	10	75	55	56	4
826565	0.073	0.050	0.237	0.364	0.589	13	28	2	3	5
237718	0.068	0.020	0.297	0.314	0.583	20	47	1	4	6
300547	0.103	0.050	0.228	0.390	0.566	3	29	3	1	7
308543	0.029	0.078	-0.086	0.006	0.526	53	9	75	38	8
348758	0.069	0.059	-0.019	0.076	0.508	19	18	44	17	9
847707	0.067	0.103	0.005	-0.017	0.487	21	5	25	45	10
411175	0.011	0.053	-0.032	-0.055	0.484	65	26	54	58	11
17969	-0.020	0.046	-0.080	0.050	0.481	75	32	73	26	12
148008	0.012	-0.022	-0.012	0.105	0.473	64	69	37	9	13
710194	0.052	0.052	0.051	0.053	0.472	35	27	6	25	14
411099	-0.011	-0.019	-0.046	-0.123	0.468	73	68	62	71	15
128068	-0.026	-0.036	-0.000	0.253	0.468	77	73	32	5	16
132841	0.090	0.095	-0.076	-0.223	0.460	7	6	72	79	17
710419	0.007	0.004	-0.003	0.094	0.443	69	55	33	12	18
532812	0.090	-0.335	-0.075	-0.077	0.427	8	81	70	62	19
348719	0.066	0.030	-0.042	0.055	0.403	22	41	61	22	20
775882	0.010	0.043	-0.013	0.011	0.399	66	34	38	36	21
105635	0.063	-0.013	-0.020	0.077	0.394	26	64	45	16	22
132978	0.025	0.205	0.016	0.379	0.393	56	1	18	2	23
912633	0.056	0.054	-0.075	-0.014	0.382	31	25	71	43	24
411117	0.013	-0.011	-0.055	0.054	0.378	63	63	66	23	25
564034	-0.012	-0.011	-0.009	0.081	0.377	74	62	35	14	26
94490	0.048	0.003	-0.031	-0.066	0.362	38	57	53	60	27
775168	0.028	0.033	-0.020	-0.002	0.353	55	39	46	39	28
200699	-0.023	0.023	0.000	0.049	0.339	76	45	31	27	29
467838	0.072	0.037	0.014	-0.005	0.331	14	38	20	40	30
12699	0.047	-0.004	0.042	0.100	0.329	42	61	9	11	31
494843	0.030	0.060	0.015	0.120	0.318	52	17	19	8	32
185068	0.058	0.047	-0.081	-0.184	0.309	28	31	74	76	33
590233	0.069	0.057	-0.022	-0.053	0.303	18	19	48	57	34
463602	0.056	0.021	0.030	0.018	0.300	32	46	10	35	35
579844	0.033	0.011	0.045	0.061	0.298	51	52	8	20	36
494885	0.028	-0.081	0.197	0.138	0.298	54	77	4	7	37
844914	0.063	0.032	0.070	0.101	0.295	25	40	5	10	38
015842	0.054	0.054	-0.074	-0.027	0.293	34	23	69	49	39
354761	0.039	0.008	-0.025	0.046	0.287	46	53	52	28	40
761474	-0.052	0.081	0.004	0.019	0.284	79	8	26	34	41
411180	0.072	0.043	-0.013	-0.013	0.278	16	35	39	42	42

TABLE F-5--Continued

CONVENTIONAL TFP INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
266033	0.102	0.054	0.018	-0.008	0.268	4	24	15	41	43
115281	0.079	0.002	0.020	0.010	0.261	9	58	13	37	44
715166	0.042	-0.017	0.026	0.060	0.251	45	67	11	21	45
860166	0.133	-0.028	-0.110	-0.025	0.251	1	71	80	47	46
436801	0.048	0.159	-0.067	-0.132	0.244	41	2	68	73	47
328969	0.097	0.011	0.009	0.053	0.217	6	50	22	24	48
004134	0.014	0.001	-0.093	0.064	0.192	62	59	77	19	49
831967	0.022	0.018	0.018	-0.044	0.192	59	48	16	54	50
245646	0.064	0.029	-0.053	-0.070	0.188	24	42	65	61	51
526820	0.108	0.071	-0.025	-0.182	0.185	2	12	51	75	52
170291	0.018	0.131	-0.058	-0.080	0.173	61	3	67	65	53
368017	0.072	-0.002	-0.023	0.034	0.166	15	60	49	32	54
565430	0.048	0.003	-0.018	-0.016	0.154	40	56	43	44	55
912672	0.025	-0.016	-0.010	0.088	0.152	58	65	36	13	56
860124	-0.008	0.011	0.049	-0.044	0.142	72	51	7	55	57
211212	0.050	-0.068	-0.018	-0.038	0.137	36	76	42	53	58
307074	0.035	0.043	-0.093	-0.078	0.134	49	36	78	63	59
516623	0.071	0.056	-0.034	-0.119	0.133	17	20	57	70	60
032731	0.055	0.048	0.003	0.034	0.128	33	30	28	31	61
424094	0.058	0.074	0.004	-0.026	0.126	29	11	27	48	62
411133	0.059	-0.135	0.018	-0.057	0.120	27	79	17	59	63
170586	0.035	-0.085	-0.104	-0.078	0.105	47	78	79	64	64
326894	0.044	0.082	-0.024	0.042	0.100	43	7	50	29	65
506714	0.057	0.012	-0.007	-0.110	0.080	30	49	34	69	66
794661	0.049	-0.030	-0.022	0.038	0.080	37	72	47	30	67
581933	0.003	-0.041	-0.037	0.067	0.067	70	74	59	18	68
278267	0.102	0.108	-0.087	-0.216	0.061	5	4	76	78	69
563222	0.003	0.045	-0.015	-0.082	0.051	71	33	40	66	70
018848	0.075	0.042	-0.042	-0.128	0.030	11	37	60	72	71
588557	0.035	0.055	0.013	-0.034	0.018	48	21	21	51	72
949991	0.009	0.063	0.002	-0.019	0.017	68	14	30	46	73
26935	0.025	0.008	-0.049	-0.108	-0.029	57	54	64	68	74
809055	0.048	0.054	-0.017	-0.038	-0.050	39	22	41	52	75
16000	-0.122	0.028	0.002	-0.205	-0.054	80	43	29	77	76
844120	0.065	0.062	-0.034	-0.293	-0.059	23	16	56	80	77
773240	0.043	-0.017	-0.048	-0.344	-0.094	44	66	63	81	78
165143	-0.039	-0.151	-0.167	-0.086	-0.130	78	80	81	67	79
463687	0.010	0.062	0.020	-0.167	-0.140	67	15	14	74	80
812159	-0.227	-0.023	0.005	0.079	-0.219	81	70	24	15	81

TABLE F-6

SHORT-RUN COST STATIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
892660	0.022	0.343	0.994	4.643	8.134	36	4	1	1	1
831967	0.326	0.251	0.266	1.617	6.013	3	7	9	3	2
307074	0.591	0.417	0.306	1.241	5.755	1	1	7	7	3
12699	0.192	0.381	0.324	1.425	5.517	13	2	6	5	4
860166	0.229	0.362	0.197	0.790	4.483	9	3	13	14	5
101086	0.079	0.333	0.160	1.071	4.233	25	5	16	8	6
809055	0.138	0.158	0.372	1.485	4.085	17	14	5	4	7
132841	0.274	0.231	0.146	0.712	3.604	4	8	17	15	8
26935	0.271	0.134	0.110	0.801	3.449	5	18	26	13	9
148008	0.224	-0.048	0.466	1.260	3.383	10	43	3	6	10
411175	0.215	0.116	0.143	0.830	2.973	11	22	18	12	11
564034	0.083	0.120	0.390	0.918	2.798	22	21	4	11	12
861226	0.143	0.186	0.111	1.054	2.752	16	10	24	9	13
018974	0.082	0.140	0.262	0.952	2.644	23	17	10	10	14
794661	0.330	0.175	-0.090	-0.082	2.416	2	13	49	37	15
128068	-0.100	0.089	0.648	2.457	2.319	58	25	2	2	16
761474	0.147	0.157	0.247	0.646	2.307	15	16	11	18	17
94490	0.074	0.006	0.079	0.690	2.109	26	35	28	16	18
949991	0.248	0.187	-0.157	-0.301	2.057	7	9	65	51	19
354761	0.207	0.127	0.118	0.449	2.030	12	19	21	23	20
812159	0.245	-0.038	0.011	0.597	1.833	8	41	33	19	21
860124	0.148	0.086	0.132	0.380	1.769	14	26	20	24	22
211212	0.259	0.058	-0.091	-0.237	1.744	6	28	50	49	23
516623	0.109	0.178	-0.160	-0.440	1.408	19	11	66	58	24
912633	0.033	0.111	0.117	0.575	1.327	33	23	22	20	25
424094	-0.026	0.158	0.111	0.575	1.209	44	15	25	21	26
715166	0.105	-0.019	0.138	0.461	0.983	20	39	19	22	27
328969	0.071	0.026	-0.116	0.104	0.916	27	30	55	30	28
579844	0.040	-0.017	0.167	0.033	0.860	32	38	15	32	29
494885	-0.115	0.091	0.115	0.278	0.802	61	24	23	27	30
185068	-0.058	0.007	-0.139	0.371	0.797	51	34	63	25	31
032731	-0.007	0.125	0.213	0.060	0.328	40	20	12	31	32
132978	-0.026	-0.184	0.089	0.120	0.291	45	74	27	29	33
165143	0.043	-0.032	-0.117	-0.198	0.251	31	40	56	46	34
105635	0.069	-0.045	-0.081	-0.358	-0.084	28	42	45	53	35
300547	-0.128	0.009	0.305	0.690	-0.219	66	32	8	17	36
266033	-0.002	-0.084	-0.124	-0.352	-0.254	39	56	58	52	37
004134	0.005	0.176	-0.170	-0.682	-0.365	37	12	69	64	38
775882	0.060	0.007	-0.128	-0.437	-0.454	30	33	60	57	39
17969	-0.033	0.061	0.019	-0.088	-0.542	46	27	32	38	40
348758	0.137	-0.053	-0.170	-0.835	-0.561	18	45	68	70	41
200699	-0.117	-0.082	0.001	0.332	-0.590	63	55	34	26	42

TABLE F-6--Continued

SHORT-RUN COST STATIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
278267	-0.015	-0.087	-0.056	0.014	-0.697	41	57	40	33	43
348719	0.098	-0.103	-0.078	-0.756	-0.755	21	59	44	67	44
015842	-0.090	-0.078	0.044	0.204	-0.765	54	52	31	28	45
532812	-0.047	-0.135	-0.087	-0.272	-0.821	48	65	48	50	46
170586	0.062	-0.119	-0.049	-0.126	-0.823	29	62	39	40	47
245646	-0.117	-0.013	-0.160	-0.513	-0.882	62	36	67	60	48
308543	-0.051	-0.145	-0.061	-0.168	-0.900	49	67	42	42	49
588557	-0.160	0.023	-0.059	-0.229	-0.998	72	31	41	48	50
494843	0.031	-0.126	0.077	-0.422	-1.061	35	63	29	55	51
411133	0.080	-0.249	-0.379	-1.101	-1.117	24	77	79	75	52
565430	-0.099	-0.050	-0.049	-0.165	-1.157	57	44	38	41	53
411099	0.002	-0.072	-0.064	-0.202	-1.324	38	51	43	47	54
018848	-0.020	-0.069	-0.195	-0.690	-1.413	42	50	71	65	55
368017	-0.062	-0.061	-0.119	-0.561	-1.418	52	47	57	62	56
581933	-0.096	-0.014	-0.202	-0.764	-1.452	55	37	73	68	57
411180	0.031	-0.138	-0.196	-0.848	-1.516	34	66	72	71	58
844120	-0.024	-0.101	-0.249	-0.816	-1.686	43	58	75	69	59
844914	-0.098	-0.173	-0.002	-0.169	-1.708	56	72	35	43	60
847707	-0.072	-0.131	-0.105	-0.406	-1.739	53	64	53	54	61
710194	-0.196	0.039	-0.140	-0.187	-1.797	75	29	64	45	62
326894	-0.056	-0.066	0.061	-0.052	-1.828	50	49	30	36	63
590233	-0.117	-0.104	-0.099	-0.430	-1.907	64	60	51	56	64
773240	-0.175	-0.116	-0.028	0.013	-1.936	73	61	37	34	65
710419	-0.038	-0.215	-0.082	-0.557	-2.179	47	76	46	61	66
467838	-0.158	-0.182	-0.138	-0.885	-2.319	71	73	62	73	67
506714	-0.193	-0.055	-0.103	-0.182	-2.501	74	46	52	44	68
775168	-0.127	-0.080	-0.137	-0.697	-2.669	65	54	61	66	69
170291	-0.109	0.296	-0.335	-1.332	-2.674	59	6	77	77	70
563222	-0.264	-0.080	-0.110	-0.500	-2.683	79	53	54	59	71
912672	-0.230	-0.189	-0.126	-0.675	-3.036	77	75	59	63	72
526820	-0.264	-0.277	-0.084	0.011	-3.095	78	81	47	35	73
826565	-0.317	-0.153	0.169	-0.103	-3.157	80	69	14	39	74
463687	-0.130	-0.062	-0.443	-1.824	-3.192	67	48	81	80	75
237718	-0.151	-0.165	-0.003	-0.874	-3.295	69	70	36	72	76
16000	-0.219	-0.150	-0.347	-1.343	-3.634	76	68	78	78	77
463602	-0.135	-0.172	-0.230	-1.322	-3.679	68	71	74	76	78
115281	-0.111	-0.258	-0.175	-1.076	-3.915	60	78	70	74	79
411117	-0.155	-0.258	-0.261	-1.440	-4.125	70	79	76	79	80
436801	-0.454	-0.267	-0.406	-1.853	-7.006	81	80	80	81	81

TABLE F-7

SHORT-RUN COST DYNAMIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
892660	0.028	0.473	0.944	4.617	8.449	35	2	1	1	1
831967	0.379	0.265	0.300	1.684	6.040	2	7	9	3	2
307074	0.525	0.536	0.230	1.193	5.890	1	1	10	7	3
12699	0.182	0.387	0.342	1.414	5.572	13	4	6	4	4
860166	0.204	0.372	0.230	0.835	4.508	12	5	11	13	5
101086	0.088	0.328	0.224	0.878	4.118	25	6	12	11	6
809055	0.125	0.157	0.369	1.406	4.098	20	23	4	5	7
132841	0.287	0.252	0.160	0.696	3.671	4	8	20	16	8
148008	0.234	-0.009	0.465	1.245	3.539	8	41	3	6	9
26935	0.257	0.149	0.135	0.802	3.273	5	25	23	14	10
564034	0.095	0.197	0.352	0.902	3.004	24	12	5	10	11
411175	0.223	0.170	0.118	0.847	2.995	10	22	26	12	12
861226	0.172	0.218	0.137	0.995	2.770	14	11	22	9	13
018974	0.031	0.082	0.311	1.085	2.712	34	29	8	8	14
128068	-0.083	0.196	0.612	2.433	2.686	56	13	2	2	15
794661	0.299	0.187	-0.067	-0.054	2.299	3	16	47	36	16
761474	0.144	0.232	0.186	0.507	2.296	17	9	16	22	17
94490	0.076	0.017	0.098	0.646	2.229	28	35	27	18	18
354761	0.217	0.151	0.137	0.472	2.015	11	24	21	23	19
949991	0.226	0.187	-0.135	-0.322	1.792	9	17	59	51	20
812159	0.238	-0.144	0.051	0.705	1.761	7	75	29	15	21
860124	0.105	0.083	0.132	0.422	1.745	23	28	24	24	22
516623	0.122	0.228	-0.173	-0.435	1.609	21	10	68	56	23
211212	0.245	0.051	-0.071	-0.262	1.588	6	31	48	50	24
424094	-0.011	0.183	0.122	0.619	1.506	42	19	25	20	25
328969	0.169	0.185	-0.163	0.212	1.462	15	18	67	28	26
494885	-0.091	0.037	0.218	0.339	1.223	57	33	14	27	27
185068	-0.037	0.111	-0.184	0.363	1.215	48	26	71	26	28
715166	0.136	0.066	0.188	0.513	1.139	18	30	15	21	29
912633	-0.043	0.190	0.049	0.643	1.104	51	14	30	19	30
132978	-0.002	-0.055	0.164	0.197	0.940	39	49	18	30	31
579844	0.043	-0.033	0.163	0.057	0.893	31	46	19	31	32
032731	0.004	0.176	0.181	0.003	0.628	37	21	17	35	33
165143	-0.041	0.017	-0.173	-0.227	0.306	50	36	69	47	34
300547	-0.126	0.047	0.335	0.693	0.267	63	32	7	17	35
105635	0.081	0.021	-0.083	-0.357	0.191	27	34	52	52	36
266033	0.013	0.008	-0.146	-0.372	0.077	36	38	61	53	37
004134	0.086	0.181	-0.151	-0.613	-0.035	26	20	63	64	38
17969	-0.027	0.187	-0.020	-0.132	-0.118	44	15	37	43	39
200699	-0.147	-0.080	0.014	0.410	-0.272	71	59	33	25	40
775882	0.057	0.008	-0.102	-0.442	-0.311	30	39	56	57	41
278267	-0.007	-0.078	-0.066	0.029	-0.330	40	58	46	33	42

TABLE F-7--Continued

SHORT-RUN COST DYNAMIC INDEXES AND RANKINGS
IN ORDER OF 18-YEAR OVERALL PERFORMANCE

CODE	YEAR 1965	YEAR 1973	YEAR 1981	YEARS 77-81	YEARS 65-81	RANK 1965	RANK 1973	RANK 1981	RANK 77-81	RANK 65-81
348758	0.155	-0.010	-0.151	-0.830	-0.399	16	42	64	68	43
532812	-0.011	-0.104	-0.090	-0.245	-0.431	41	67	53	48	44
015842	-0.081	-0.041	0.027	0.200	-0.472	55	47	31	29	45
245646	-0.110	0.016	-0.161	-0.518	-0.478	61	37	66	61	46
588557	-0.150	0.084	-0.076	-0.221	-0.481	72	27	50	46	47
308543	-0.034	-0.104	-0.027	-0.101	-0.537	47	65	38	40	48
170586	0.076	-0.066	-0.049	-0.120	-0.542	29	55	41	42	49
348719	0.126	-0.061	-0.058	-0.766	-0.566	19	53	44	67	50
565430	-0.079	-0.073	-0.047	-0.143	-0.853	54	57	40	44	51
411133	0.107	-0.165	-0.380	-1.105	-0.887	22	77	79	74	52
494843	0.042	-0.058	0.078	-0.444	-0.919	33	50	28	58	53
368017	-0.056	-0.029	-0.114	-0.561	-1.006	52	45	58	62	54
411099	0.003	-0.092	-0.017	-0.248	-1.159	38	61	36	49	55
018848	-0.014	-0.064	-0.197	-0.717	-1.178	43	54	73	66	56
411180	0.043	-0.111	-0.193	-0.852	-1.262	32	69	72	70	57
844914	-0.092	-0.159	0.002	-0.179	-1.355	58	76	35	45	58
326894	-0.028	-0.024	0.014	-0.058	-1.414	45	44	34	37	59
581933	-0.131	-0.016	-0.183	-0.871	-1.418	64	43	70	71	60
710194	-0.222	-0.046	-0.060	-0.085	-1.440	75	48	45	39	61
847707	-0.069	-0.136	-0.075	-0.435	-1.443	53	72	49	55	62
773240	-0.144	-0.138	-0.050	0.007	-1.483	68	73	42	34	63
590233	-0.132	-0.104	-0.079	-0.426	-1.598	65	66	51	54	64
844120	-0.037	-0.093	-0.231	-1.009	-1.622	49	62	74	73	65
467838	-0.145	-0.072	-0.160	-0.884	-1.722	70	56	65	72	66
710419	-0.033	-0.190	-0.057	-0.562	-1.888	46	78	43	63	67
506714	-0.183	-0.061	-0.100	-0.116	-2.068	73	52	55	41	68
563222	-0.197	0.007	-0.035	-0.461	-2.117	74	40	39	60	69
170291	-0.099	0.408	-0.361	-1.351	-2.176	60	3	78	77	70
775168	-0.144	-0.085	-0.105	-0.703	-2.327	69	60	57	65	71
826565	-0.306	-0.111	0.222	-0.063	-2.454	79	70	13	38	72
526820	-0.250	-0.267	-0.095	0.051	-2.539	77	81	54	32	73
237718	-0.137	-0.109	0.015	-0.841	-2.812	66	68	32	69	74
463687	-0.095	-0.059	-0.466	-1.825	-2.878	59	51	80	80	75
463602	-0.118	-0.144	-0.239	-1.296	-3.244	62	74	75	76	76
912672	-0.336	-0.103	-0.150	-0.454	-3.329	80	64	62	59	77
16000	-0.237	-0.093	-0.348	-1.506	-3.411	76	63	77	79	78
411117	-0.142	-0.191	-0.256	-1.459	-3.629	67	79	76	78	79
115281	-0.276	-0.262	-0.137	-1.237	-3.864	78	80	60	75	80
436801	-0.395	-0.121	-0.486	-1.894	-6.255	81	71	81	81	81

APPENDIX G

CLUSTERING ANALYSIS OF UTILITY COMPANIES

In this appendix, a brief illustration is provided of a cluster analysis of utility companies, in order to obtain an arrangement in similar categories with respect to exogenous factors. As mentioned in the discussion in chapter 7, it is often argued that electric utilities cannot be compared with respect to managerial performance since the individual circumstances facing each company are too diverse. Also, it has been suggested that actual measures of performance reflect more the particular context in which the utility operates (i.e., exogenous factors, beyond managerial control) than they assess its efficiency.

Cluster analysis is often suggested as a statistical means of grouping observations (companies) into similar categories with respect to a prespecified set of variables. A large number of cluster analysis algorithms have been developed, and several are available in most popular statistical analysis computer packages. Most procedures are based on classifying observations into groups of which the elements are more similar to each other than to the elements of other groups. The notion of similarity is measured in a variety of possible ways, based on some type of correlation or notion of distance. A detailed technical discussion of clustering techniques is clearly beyond the scope of this appendix. The interested reader is referred to the treatment and references in, among others, Anderberg (1973), Everitt (1980), Hartigan (1975), and most popular statistical packages, such as SAS (SAS Institute (1982)). While it is an extremely powerful technique, it should be noted that each particular method is based on an extensive set of assumptions, which are not necessarily reflected in the data set at hand. It should also be kept in mind that the results of a cluster analysis are not unique in any way, and involve to a considerable degree the judgment of the analyst, for example, with respect to the choice of the proper technique, the number and type of exogeneous variables, the number of clusters, the interpretation of the results, and so on. As a result, the same data set can lead to a number of different classifications, each valid in its own right, and with no clear-cut distinction of a "correct" (or false) solution. Hence, cluster analysis should not be mistaken for an "objective" means of classifying companies, but should be considered as one of many techniques for reducing information to a more manageable size. In an antagonistic situation, it would be of limited use as a decisive argument or proof.

With these caveats in mind, the results of a simple clustering exercise of the 56 companies considered in chapter 7 can now be discussed (for ease of comparison the company numbers used in the tables below are consistent with the ones in chapter 7). The particular clustering technique used is one due to Ward (for a nontechnical discussion, see SAS Institute (1982)), which measures the distance between two clusters in terms of a sum of squares criterion. Four exogeneous variables were selected to form the basis for the clustering: climate (number of degree-days heating), density of market area (population/area), labor cost (state average wage level), and fuel cost (state average fuel cost). Consistent with the approach taken in chapter 7, the clustering was carried out for each of the years in the period 1977-1980. The results for four clustering levels are presented in table G-1. This level was chosen in part for ease of exposition, and is not necessarily optimal (although clearly satisfactory from a statistical point of view) in each of the four years. Higher levels tend to consist mainly of one company cluster, which is an unavoidable side result for any cluster analysis. In fact, any procedures will provide a range of clusters from one (with all companies included) to one that consists of as many clusters as there are observations. The ultimate selection is left to the analyst, and the many statistical (and heuristic) tests that can be used as a guide in this selection do not necessarily agree.

TABLE G-1

CLUSTERING OF UTILITY COMPANIES, 1977-1980

Company	1977	1978	1979	1980
1	A	A	A	A
2	A	A	A	A
3	C	C	C	C
4	A	A	A	A
5	A	A	A	A
6	B	B	B	B
7	B	B	B	B
8	B	B	B	B
9	B	B	B	B
10	C	C	C	C
11	D	D	D	D
12	B	B	B	B
13	A	A	A	A
14	B	B	B	B
15	B	B	B	B
16	A	A	A	A
17	B	B	B	B
18	B	B	B	B
19	A	A	A	A
20	A	A	A	A
21	C	C	C	C
22	A	A	A	A
23	B	B	B	B
24	B	B	B	B
25	A	A	B	B
26	A	A	B	B
27	B	B	B	B
28	C	C	C	C
29	A	A	A	A
30	B	B	B	B
31	B	B	B	B
32	B	B	B	B
33	A	A	A	A
34	B	B	B	B
35	C	C	C	C
36	B	B	B	B
37	A	A	B	B
38	B	B	B	B
39	B	B	B	B
40	B	B	B	B
41	B	B	B	B
42	A	C	C	A
43	B	B	B	B
44	B	B	B	B
45	C	C	C	C
46	A	A	A	A

TABLE G-1--Continued

Company	1977	1978	1979	1980
47	A	C	C	A
48	A	A	A	A
49	B	B	B	B
50	A	A	A	A
51	A	A	A	A
52	C	C	C	C
53	B	B	B	B
54	B	B	B	B
55	A	A	B	B
56	C	C	C	C
Number of companies in each cluster				
A	21	19	15	17
B	26	26	30	30
C	8	10	10	8
D	1	1	1	1

The four clusters have been labeled A through D, for ease of exposition (these labels, although consistent across years, do not have any meaning in themselves). The clusters are fairly stable over the period under consideration, with only two types of shifts occurring. The first type consists of a change in membership from cluster A in 1977-1978 to cluster B in 1979-1980, and occurs for 4 companies (25, 26, 37, 55). The second type of shift is made up of two changes over time, first from cluster A in 1977 to cluster C in 1978-1979, and back to cluster A in 1980. It occurs for two companies, 42 and 47. The stability of the results for the other companies could be due to a failure of the clustering variables to pick up short-term changes in the "general" exogeneous factors. However, it is more likely caused by a great similarity in the temporal pattern for the clustering variables for the companies encompassed in each category. Note also that company 11 consistently forms a unitary cluster (this is the case for cluster sizes of 3 up to 7), pointing to a clearly different magnitude for the exogeneous variables. This is particularly interesting in light of the fact that this company also ranks as one of the poorest in performance according to most indexes listed in tables 7-1 to 7-4 in the report.

In order to further assess the existence and extent of a relationship between the grouping of utilities in similar categories according to exogeneous factors, and the classification in terms of performance, several simple chi-square tests of dependence were carried out. The companies were classified in terms of performance using the same types of categories as in chapter 7 (dichotomous and quartiles), for the traditional TFP measure and the subjective multicriteria AFP index. Because it would cause cell frequencies that are too small to be properly considered in the statistical analysis, company 11 was eliminated from the following tests. The results are presented in table G-2.

TABLE G-2

TESTS ON THE INDEPENDENCE BETWEEN COMPANY CLUSTERS AND PERFORMANCE CLASSIFICATION

1977:		
- Dichotomous classification:	AHP:	$\chi^2 =$ 5.84
(2 d.f.)	TFP:	$\chi^2 =$ 0.58
- Quartile classification:	AHP:	$\chi^2 =$ 7.80
(6 d.f.)	TFP:	$\chi^2 =$ 6.95
1978:		
- Dichotomous classification:	AHP:	$\chi^2 =$ 22.66
(2 d.f.)	TFP:	$\chi^2 =$ 8.03
- Quartile classification:	AHP:	$\chi^2 =$ 24.93
(6 d.f.)	TFP:	$\chi^2 =$ 8.50
1979:		
- Dichotomous classification:	AHP:	$\chi^2 =$ 2.20
(2 d.f.)	TFP:	$\chi^2 =$ 4.87
- Quartile classification:	AHP:	$\chi^2 =$ 5.00
(6 d.f.)	TFP:	$\chi^2 =$ 9.27
1980:		
- Dichotomous classification:	AHP:	$\chi^2 =$ 9.73
(2 d.f.)	TFP:	$\chi^2 =$ 2.50
- Quartile classification:	AHP:	$\chi^2 =$ 24.17
(6 d.f.)	TFP:	$\chi^2 =$ 13.77

A value of the test statistic larger than 5.99 (for the dichotomous classification) or 12.59 (for the quartile classification) is an indication of a lack of independence between the two categories (at a 5 percent significance level). For exactly half of the tests this is not the case. The TFP index does not show a relationship at all with the exogeneous clusters for the dichotomous performance classification. For AHP there is an indication of dependence in 1978 and 1980. When the quartile classification is used the results are more mixed, pointing to a greater tendency for dependence when AHP is used (except in 1979), than when TFP is used (only dependence in 1980).

These results largely confirm the findings in chapter 7, that there does not seem to be strong evidence for a clear relationship between performance and factors beyond management control. A more careful calibration of the performance index used should be able to eliminate most bias in this respect. However, it should be kept in mind that both the clustering and the econometric techniques imply an averaging out of individual factors, so that care should be taken in keeping the interpretation of the importance of these short-cut measures in perspective, particularly within a policy context.

APPENDIX H

ABSTRACTS OF PAPERS PRESENTED AT THE NRRI PERFORMANCE EVALUATION WORKSHOP

In this appendix, a brief abstract is provided for each of the five papers presented at the NRRI Workshop/Seminar on "A Decision Support System for Electric Utility Performance Evaluation," held on May 21-22, 1984 in Columbus, Ohio (for a program of this workshop/seminar, see appendix B). The abstracts were compiled by the NRRI staff and do not necessarily represent the full views and opinions of the individual authors. They are provided for the general information of the reader. Queries on the content and availability of the complete papers should be addressed to each author separately.

J. Stephen Henderson, NRRI: "Electric Utility Performance Measurement, An Overview."

This paper presents a general overview of the methodological problems associated with utility performance evaluation. Particular attention is paid to the issues involved in the application of total factor productivity indexes and econometric cost functions. The regulatory interest in and use for performance measures is discussed against this background.

Michael Foley, Director of Financial Analysis, National Association of Regulatory Utility Commissioners: "Electric Utility Financial and Operating Performance Study."

This paper discusses a methodological approach and presents extensive results on the financial performance, electricity price trends and operating performance of 130 major electric utility companies during the period 1972-1981. Ten financial performance indicators are suggested as well as the use of total factor productivity to measure utility operating performance.

Enver Masud, Director, Operations Review Division, Iowa State Commerce Commission: "Simulated Competition as an Incentive for Utility Efficiency."

This paper presents an approach, developed by the Operations Review Division of the Iowa State Commerce Commi0sion (the "ORD" approach), to measure utility performance by ranking utilities against one another and thereby simulating competition. The method is based on average measures (over time) of a number of performance indicators that are summarized in a general rating (excellent, good, fair, poor) and linked to a penalty/reward scheme.

Orman Panaanen, Department of Economics, New Mexico State University: "Measuring Efficiency, Penalties and Rewards."

This paper presents a potential penalty and reward structure for electric utilities under an incentive system, based on a measure of efficiency. The efficiency measure consists of four cost modules: production-transmission, distribution, customer accounts, general and administrative. The methodological background behind these measures is outlined and linked to a cost penalty mechanism.

Luc Anselin, Department of City and Regional Planning, Ohio State University and NRRI: "The Use of Multicriteria Decision Techniques to Evaluate Electric Utility Performance."

This paper presents an overview of a conceptual approach towards performance evaluation, encompassed in a decision support system. The usefulness and application of several multicriteria decision techniques is discussed using a simple illustrative example.

APPENDIX I

SYNOPSIS OF THE PANEL DISCUSSION ON "THE REGULATORY USE OF PERFORMANCE MEASURES"

In this appendix, a brief synopsis is presented of the main remarks made during the panel discussion on "The Regulatory Use of Performance Measures," which was held at the NRRI Seminar/Workshop on "A Decision Support System for Electric Performance Evaluation", May 21-22, 1984 in Columbus, Ohio. The panel was moderated by Luc Anselin (Ohio State University/NRRI), NRRI Project Director, and consisted of J. Stephen Henderson and Kevin A. Kelly of NRRI, Michael Foley of the NARUC, Enver Masud of the Iowa Commerce Commission, and Orman Panaanen of the New Mexico State University.

The synopsis given here is by design brief and should not be considered to be a verbatim transcript of the panel discussion. It may therefore not include all comments and remarks made by the participants. It has been compiled by NRRI staff and does not necessarily accurately reflect the opinions of the participants. It is provided for the general information of the reader, and does not constitute a position taken by NRRI, the NARUC, or any other commissions represented at the panel.

The panel discussion focused on the issue of using performance measurements for the purpose of eventually improving electric utility performance. In this discussion two primary concerns were addressed: the availability and use of adequate data and the regulatory actions to be taken after performance measurements are completed.

Orman Panaanen, of the New Mexico State University, stressed the point that the overall cost of production and service delivery should be of primary concern when evaluating electric utility efficiency. Due to the inadequacy of recent, comparable data, current utility evaluation is less than precise. Henry Leak III of the New York Public Service Commission added that in order for the available data, primarily from FERC, to be used for comparison purposes it must first be cleaned and then manipulated, both of which are time consuming and costly processes. In agreement with Leak, Ken Powell of the Utah Public Service Commission also noted that by the time the data becomes available to the commissions it is already 2 years old.

Various suggestions were made in response to the obvious need for more accurate and timely data. Michael Foley, referring to the data collection process used by the Edison Electric Institute proposed that the commissions themselves collect and clean the data. This would ensure pertinent up-to-date data but may eliminate the feasibility of cross-sectional comparisons. Taking Foley's proposal one step further, Bob Kennedy of the Arkansas Public Service Commission suggested that data collection and cleaning be performed by the individual commissions and then submitted to a central system, such as NRRI's new online information service, for nationwide access to the data base. Kevin Kelly of NRRI agreed that the online information service would be a good vehicle for data gathering and storage, but noted that its success would depend primarily on the commissions' employment of uniform cleaning methods, which had been inadequate in a previous attempt at this procedure.

Also of importance in the panel discussion was the regulatory course of action to be taken upon receipt of electric utility performance data. Kelly posed the question of whether to focus on a specific performance target for measurement and comparison purposes or to evaluate the overall performance of one utility. Enver Masud responded by saying that both aspects of the utility should be considered: performance investigation of the disaggregate should be initiated without losing sight of the aggregate.

Stephen Henderson noted that regardless of which focus is taken, either aggregate or disaggregate, the regulatory commissions should maintain a level of unpredictability. Thus, the individual utilities would be less likely to mask their performance in attempting to satisfy the open requirements of the commissions. Also the maintenance of a certain level of unpredictability would ensure the exercise of a certain amount of judgment reserved for the decision maker.

Ken Powell of the Utah Public Service Commission was in strong disagreement with Henderson and stated that a commission should be consistent and therefore predictable. In his opinion, a commission must tell the utility what the required direction is and encourage it to head in that direction. This, Powell added, is most effectively accomplished through incentives, a notion previously discussed by Orman Panaanen under the heading of "rewards and penalties."

At this point Kelly drew the distinction between what he calls the "soft use" and "hard use" of utility performance evaluations. The soft use approach involves an investigation as to the utility's poor performance in a particular area. It calls for an explanation on the part of management possibly followed by an audit and an intercompany comparison. As the name implies, the hard approach uses more severe measures as an incentive for utility performance improvement. This approach begins with a comparison of company performance but ends with a penalization or reward depending on performance levels.

The predominant opinion of the hard use-soft use issue was stated by Masud when he suggested that companies with a rating of "poor" should be given a chance to explain to the commissions how they plan to improve before more severe measures are taken. Foley added that performance penalties in specific areas should only be used where there is either a desparate need to control or where a utility has been given numerous chances but refuses to improve.

During the course of this panel discussion various unanswered questions were raised. Powell, for instance, raised the issue of one utility serving more than one jurisdiction and therefore being responsible to both jurisdictions. Charles Stults of the Alabama Public Service Commission questioned the feasibility of setting improvement targets for companies which are already in the "good" rank.

In sum, there seemed to be a general consensus on the need for improvement of data gathering and consistent data cleaning methods. Although the issue of regulatory actions and incentives was left somewhat unresolved it became apparent that the use of various multicriteria decision techniques to evaluate electric utility performance was welcomed as a viable approach in aiding in the formation of regulatory judgment decisions.

References

- Anderberg. M.R., 1980. Cluster Analysis for Applications (New York: Academic Press).

- Anselin, Luc, 1982. "A Note on a Multi-Criteria Approach to Relative Performance Evaluation of Electric Utilities," Ohio State University, Department of City and Regional Planning Working Paper WP 82-2, March.

- Anselin, Luc, 1983. "Guidelines for the Use of Program "TREE," the Analytic Hierarchy Process for Project Evaluation," Ohio State University, Department of City and Regional Planning Working Paper WP 83-5, May.

- Anselin, Luc, 1984. "The Use of Multicriteria Decision Techniques to Evaluate Electric Utility Performance, The Conceptual Framework," Work Note DSS84-3, The National Regulatory Research Institute, Columbus, Ohio, May.

- Anselin, Luc, 1984. "The Empirical Evaluation of Electric Utility Performance, Soft Techniques," Work Note DSS84-3, The National Regulatory Research Institute, Columbus, Ohio, August.

- Anselin, Luc, 1984. "A Decision Support Framework for Regulatory Evaluation of Electric Utility Performance," in R. W. Lawton (Ed.) Proceedings of the Fourth NARUC Biennial Regulatory Information Conference, The National Regulatory Research Institute, Columbus, Ohio, September: pp. 997-1008.

- Anselin, Luc, Ernest G. Arias, 1983. "A Multi-Criteria Framework as a Decision Support System for Urban Growth Management Applications: Central City Redevelopment." European Journal of Operational Research 13 (3): 300-309.

- Anselin, Luc, J. Stephen Henderson, with others, 1984. "A Decision Support System for Electric Utility Performance Evaluation: Data Base Description," Work Note DSS84-1, The National Regulatory Research Institute, Columbus, Ohio, May.

- Anselin, Luc, Lynne M. Pike, George L. Smith, J., 1981. The Measurement of Electric Utility Performance: Preliminary Analysis. (Columbus, Ohio: The National Regulatory Research Institute).

- Armstrong, Ronald D., Wade D. Cook and Lawrence M. Seiford, 1982. "Priority Ranking and Consensus Formation: The Case of Ties," Management Science 28 (6): 638-645.

- Banker, Rajiv D., 1980. "A Game Theoretic Approach to Measuring Efficiency," European Journal of Operational Research 5 (3): 262-266.

- Banker, R.D., A. Charnes, W. W. Cooper, and A. P. Schinnar, 1981. "A Bi-Extremal Principle for Frontier Estimation and Efficiency Evaluations," Management Science 27 (12): 1370-1382.

- Batty, M. and R. Spooner, 1982. "Models of Attitudes towards Urban Modelling," Environment and Planning B, 9 (1): 33-61.

- Bell, David E., Ralph L. Keeney, Howard Raiffa (Eds.), 1977. Conflicting Objectives in Decisions. New York: Wiley.

- Berndt, E. R., C. J. Morrison, and G. L. Watkins, 1981. "Dynamic Models of Energy Demand: An Assessment and Comparison" in Modeling and Measuring Natural Resource Substitution, E. R. Berndt and B. C. Field (eds.)(Cambridge, Mass.: The MIT Press).

- Bessent. A., W. Bessent, J. Kennington and B. Reagan, 1982. "An Application of Mathematical Programming to Assess Productivity in the Houston Independent School District," Management Science 28 (12): 1355-1367.

- Blair, Peter D., 1979. Multi-Objective Regional Energy Planning. (Boston: Martinus Nijhoff).

- Caves, D. W., and L. R. Christensen, 1980. "Multilateral Comparisons of Output, Input and Productivity Using Superlative Index Numbers," Social Systems Research Institute Paper No. 8008 (Madison, WI: University of Wisconsin).

- Caves, D. W., L. R. Christensen, and M. W. Tretheway, 1981. "U.S. Trunk Air Carriers, 1972 -1977: A Multilateral Comparison of Total Factor Productivity," in Productivity Measurement in Regulated Industries, T. G. Cowing and R. E. Stevenson (eds) (New York, NY: Academic Press).

- Changkong, Vira and Yacov Haimes, 1983. Multiobjective Decision Making: Theory and Methodology, (New York: North-Holland).

- Charnes, A., W. W. Cooper, E. Rhodes, 1978. "Measuring the Efficiency of Decision Making Units," European Journal of Operational Research 2 (6): 429-444.

- Charnes, A., W. W. Cooper, E. Rhodes, 1981. "Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through," Management Science 27 (6): 668-697.

- Charnes, A., W. W. Cooper, L. Seiford, J. Stutz, 1982. "A Multiplicative Model for Efficiency Analysis," Socio-Economic Planning Sciences 16 (5): 223-224.

- Cohon, Jared, 1978. Multiobjective Programming and Planning, (New York: Academic Press).

- Cook, Richard L. and Thomas R. Stewart, 1975. "A Comparison of Seven Methods for Obtaining Subjective Descriptions of Judgmental Policy," Organizational Behavior and Human Performance 13: 31-45.

- Cook, Wade D. and Lawrence M. Seiford, 1982. "On the Borda-Kendall Method for Priority Ranking Problems," Management Science 28 (6): 621-637.

- Costello, Kenneth W., and Rodney E. Stevenson, 1981. "The Application of Performance Measures in Public Utility Regulation," Paper Presented at the ASSA Annual Meetings, Washington, D.C., December 29.

- Costello, K. W., Incentive Regulation: What Direction Should It Take? Mimeo, Illinois Commerce Commission, May 1984.

- Cowing, Thomas G., and Rodney E. Stevenson (eds.), 1981. Productivity Measurement in Regulated Utilities. (New York: Academic Press).

- Cowing, T. G., and A. G. Holtmann, 1983. "Multiproduct Short-Run Hospital Cost Functions: Empirical Evidence and Policy Implications from Cross-Section Data," Southern Economic Journal, 49 (1).

- T. G. Cowing, J. Small, and R. E. Stevenson, 1981. "Comparative Measures of Total Factor Productivity in the Regulated Sector: The Electric Utility Industry" in Productivity Measurement in Regulated Industries, T. G. Cowing and R. E. Stevenson (eds)(New York, NY: Academic Press).

- Daniel, Wayne W., 1978. Applied Nonparametric Statistics (Boston: Houghton Mifflin).

- Dawes, Robyn M. and Bernard Corrigan, 1974. "Linear Models in Decision Making," Psychological Bulletin 81 (2): 95-106.

- Denison, E. F., 1962. "The Sources of Economic Growth in the U.S. and the Alternatives Before Us," Supplementary Paper No. 13 (New York, NY: Committee for Economic Development).

- Diewert, W. Erwin, 1981. "The Theory of Total Factor Productivity Measurement in Regulated Industries," in Productivity Measurement in Regulated Industries, T. G. Cowing and R. E. Stevenson (eds) (New York, NY: Academic Press).

- Edwards, Ward, 1977. "How to Use Multiattribute Utility Measurement for Social Decisionmaking," IEEE Transactions on Systems, Man and Cybernetics 7 (5): 326-340.

- Einhorn, Hillel J., 1975. "Unit Weighting Schemes for Decision Making," Organizational Behavior and Human Performance 13:L 171-192.

- Everitt, B.S., 1980. Cluster Analysis (London: Heinemand Educational Books).

- Ferguson, C. E., 1972. Microeconomic Theory, (Homewood, IL: Richard D. Irwin, Inc.)

- Fishburn, Peter C., 1978. "A Survey of Multiattribute/Multicriteria Evaluation Theories," in S. Zionts (Ed.) Multiple Criteria Problem Solving (New York: Springer), pp. 181-224.

- Foley, Michael, 1984 "Electric Utility Financial and Operating Performance Review," (National Association of Regulatory Utility Commissioners; Washington, D.C.).

- Goddard, Stephen T., 1983. "Ranking in Tournaments and Group Decision-making," Management Science 29 (2): 1384-1392.

- Hartigan, J.A., 1975. Clustering Algorithms (New York: John Wiley).

- Hauser, John R. and Glen L. Urban, 1979. "Assessment of Attribute Importance and Consumer Utility Functions: Von Neuman-Morganstern Theory Applied to Consumer Behavior," Journal of Consumer Research, 5 (March): 251-262.

- Henderson, J. Stephen, 1984. "Estimating Short Term Cost Functions for Electric Utilities," in R. W. Lawton (Ed.) Proceedings of the Fourth NARUC Biennial Regulatory Information Conference, The National Regulatory Research Institute, Columbus, Ohio, September: pp. 143-156.

- Hershey, John C., Howard Kunreuther and Paul J. Schoemaker, 1982. "Sources of Bias in Assessment Procedures for Utility Functions," Management Science (8) 936-954.

- Hinloopen, Edwin, Peter Nijkamp and Piet Rietveld, 1983. "Qualitative Discrete Multiple Criteria Choice Models in Regional Planning," Regional Science and Urban Economics, 13 (1): 77-102.

- Hobbs, Benjamin F., 1980. "A Comparison of Weighting Methods in Power Plant Siting," Decision Sciences 11: 725-737.

- Intercompany Performance Comparison Group, 1980. "1979 Annual Report." Detoit, Michigan.

- Johnson, Charles R., 1980. "Constructive Critique of a Hierarchical Prioritization Scheme Employing Paired Comparisons," Proceedings of the International Conference on Cybernetics and Society, pp. 373-378.

- Keeney, Ralph and Howard Raiffa, 1976. Decisions with Multiple Objective: Preferences and Value Tradeoffs, (New York: Wiley).

- Kendrick, J. W., 1961. Productivity Trends in the United States, (Princeton, NJ: Princeton University Press).

- MacCrimmon, Kenneth R. and Donald A. Wehrung, 1977. "Trade-Off Analysis: The Indifference and Preferred Proportions Approaches," in D. Bell, R. Keeney, J. Raiffa (Eds.), Conflicting Objectives in Decisions, (New York: Wiley), pp. 123-147.

- Miller, G. A., 1956. "The Magical Number Seven Plus or Minus Two: Some Limits on Our Capacity for Processing Information." The Psychological Review 63 (March): L 81-97.

- Nadiri, M. Isaq, 1970. "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey." Journal of Economic Literature 8: 1137-1177.

- Newman, Robert J., 1977. "Differential Weighting in Multiattribute Utility Measurement: When It Should Not and When It Does Make a Difference," Organizational Behavior and Human Performance 20: 312-325.

- Nijkamp, Peter, 1982. "Soft Multicriteria Analysis as a Tool in Urban Land Use Planning, "Environment and Planning B, 9 (2): 197-208.

- Nijkamp, Peter and Henk Voogd, 1979. "The Use of Psychometric Techniques in Evaluation Procedures: Methodology and Application," Papers, Regional Science Association, 42: 119-138.

- Paelinck, J., 1976. "Qualitative Multiple Criteria Analysis, Environmental Protection and Multiregional Development," Papers, Regional Science Association, 36: 59-74.

- Raiffa, H., 1970. Decision Analysis, Introductory Lectures on Choices Under Uncertainty (Reading: Addison-Wesley).

- Rietveld, Piet, 1980. Multiple Objective Decision Methods and Regional Planning, (Amsterdam: North-Holland).

- Rowe, Michael D. and Barbara L. Pierce, 1982a. "Sensitivity of the Weighting Summation Decison Method to Incorrect Application." Socio-Economic Planning Sciences, 16 (4): 173-177.

- Rowe, Michael D. And Barbara L. Pierce, 1982b. "Some Tests of Analytical Multiobjective Decision-Making Methods," Socio-Economic Planning Sciences, 16 (3): 133-140.

- Roy, B., 1977. "Partial Preference Analysis and Decision-Aid: The Fuzzy Outranking Relation Concept," in D. Bell, R. Keeney, HJ. Raiffa (Eds.), Conflicting Objectives in Decisions, (New York: Wiley), pp. 40-75.

- Saaty, T. L., 1977. "A Scaling Method for Priorities in Hierarchical Structures," Journal of Mathematical Psychology 15: 234-281.

- Saaty, Thomas L., 1980. The Analytic Hierarchy Process. New York: McGraw-Hill.

- Saaty, Thomas L., 1982. Decision Making for Leaders, (Belmont: Lifetime Learning Publications).

- Saaty, Thomas L. and H. Gholamnezhad, 1982. "High Level Nuclear Waste Management: Analysis of Options," Environment and Planning B, 9 (2): 181-196.

- Saaty, Thomas L., R. S. Mariano, 1979. "Rationing Energy to Industries: Priorities and Input-Output Dependence." Energy Systems and Policy 3 (1): 85-11.

- Saaty, Thomas L. and Luis Vargas, 1982. The Logic of Priorities, (Boston: Martinus Nijhoff).

- SAS Institute Inc., 1982. SAS User's Guide: Statistics, 1982 Edition (Cary, NC: SAS Institute Inc.).

- Schoemaker, Paul J. H. and C. Carter Waid, 1982. "An Experimental Comparison of Different Approaches to Determining Weights in Additive Utility Models." Management Science, 28 (2): 182-196.

- Voogd, Henk, 1982. "Multicriteria Evaluation with Mixed Qualitative and Quantitative Data," Environment and Planning B, 9 (2): 221-236.

- Voogd, H., 1983. Multicriteria Evaluation for Urban and Regional Planning, (London: Pion).

- Waid, C. Carter and Paul J. Schoemaker, 1981. "On the Fidelity of Multi-Attribute Preference Representation: Some Analytical Considerations." In J. Morse (Ed.), Organizations: Multiple Agents with Multiple Criteria (New York: Springer Verlag), pp. 447-464.

- Wierzbicki, Andrezej P., 1983. "Critical Essay on the Methodology of Multiobjective Analysis, "Regional Science and Urban Economics, 13 (1): 5-29.

- Wind, Y. and T. L. Saaty, 1980. "Marketing Applications of the Analytic Hierarchy Process." Management Science 26 (7): 641-658.

- Zionts, Stanley (Ed.), 1978. Multiple Criteria Problem Solving, New York: Springer Verlag.