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EFFICIENCY MEASUREMENT IN THE REGULATED SECTOR: AN EMPIRICAL STUDY OF THE MASSACHUSETTS ELECTRIC UTILITY INDUSTRY EMPLOYING THE WILLIAMSON EXPENSE PREFERENCE THEORY IN A POOLED REGRESSION MODEL

A Dissertation Presented

By

WILLIAM C. LAWLER

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

February 1981

School of Business Administration

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ABSTRACT

Efficiency Measurement in the Regulated Sector: An Empirical Study of the Massachusetts Electric Utility Industry Employing the Williamson Expense Preference Theory In a Pooled Regression Model

(February, 1981)

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In the accounting literature the measurement of top management performance is traditionally based upon profitability. Since both efficiency and effectiveness impact upon profitability, composite measures usually suffice and these separate dimensions of performance are seldom investigated.

However, when focusing on top management performance in the regulated sector, profitability measures are of limited use due to the constraints placed upon profit. In addition, since management is insulated from competitive pressures, the necessity to be efficient is no longer present, and, thus, performance measurement now becomes two dimensional--both efficiency and effectiveness must be investigated. Of increasing importance to regulatory commissions is the question of top management efficiency.

The purpose of this thesis is to develop a prototype model for estimating the efficiency of management in the regulated sector. The analysis proceeds in two stages. The first stage deals with the lack of an operational definition for top management efficiency in the regulated sector. Although this subject has been extensively developed in the economic literature, it is shown that this generally accepted definition of efficiency is not applicable to the problem at hand due to the lack of concern for control. To be a valid measure of efficiency, top management control must be demonstrated and, thus, a somewhat radical definition of efficiency espoused by Oliver Williamson [1964, 1970] is operationalized. This definition emphasizes control and focuses on expense preference items--those incurred not for their contribution to production but rather for the manner in which they enhance personal goals. The relationship of these items--size of staff, emoluments and discretionary profits--to the cost per kilowatt output is then used to measure efficiency.

The final stage involves the construction of a methodology for comparative analysis among utilities which controls for the diverse characteristics of these utilities. Since the nature of the industry dictates a small sample size when attempting any comparative analysis, such diverse factors as vertical integration, generation mix, market type, size and variability of demand have historically invalidated research findings. By employing a pooled regression model developed and extended by Zellner [1966] and Swamy [1970], this problem is overcome.

Using the electric utility industry of Massachusetts as a data base, the results of the analysis suggest that at least one expense preference item, size of staff, has a statistically significant direct relationship to the costs per kilowatt of the utilities in the sample and, therefore, may be used as a barometer of top management efficiency. In addition, it was found that the pooled regression methodology which, as stated, was used to control for the diverse characteristics of the utilities, performed well. However, no generalizations were made.

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CHAPTER I

INTRODUCTION

Background

Within the Classical Theory of the Firm, the "invisible hand" as described by Adam Smith [1937], plays an important role. Those firms which are inefficient are eliminated through the natural selection process; efficiency becomes a necessary condition for continuity of life. As a result, management performance measures need only focus on effectiveness; efficiency is prerequisite.

However, the foundation of the Classical Theory is pure competition, where firms are price-takers, not price-makers. Inefficiency leads to higher costs which cannot simply be passed on to the consumer since prices are set by the market and not the firm. This does not hold true for other sectors of the economy which may be combined and loosely termed the regulated sectors. Although economic theory states that monopolies and oligopolies are price-makers, this, in reality, is not true in all cases. The Government, as originally hypothesized by Keynes [1931], becomes a regulatory body which sets prices to yield "fair" returns. In much the same manner, prices are set to yield zero returns in the nonprofit sector.

The resulting price allows the regulated firm to recover its operating costs plus a "fair" return on invested capital, usually defined as that which would assure financial soundness to the investment community. Herein lies the problem. The "invisible hand" is no longer operative. The pricing mechanism of the competitive market is short-circuited by the regulatory process where firms are now allowed to recover all costs plus a fair return on invested capital. It is alleged that inefficiencies are simply passed on to consumers in the form of higher prices. There is no longer any incentive to be efficient.

Two factors in the recent past have accentuated this alleged problem. First, through the 1960's and into the 1970's, there has been more reliance put on government intervention, rather than laissez-faire, as the correct method to regulate the economy. In an increasing number of sectors, the price-setter has become the government rather than the supply and demand conditions of the market. And secondly, the advent of double digit inflation has produced a cry for better regulatory processes. Consumers correctly argue that inefficiencies should not be passed on to them, but rather should be absorbed by the firms. Efficiency as a measure of performance has moved to the forefront of the regulatory process.

However, for a number of reasons, the success of the regulatory bodies in measuring efficiency has been limited. First, definitions and objectives have been poorly delineated, if delineated at all. Secondly, due to the varied nature of the industries which fall into the regulated sectors, widely differing characteristics do not facilitate comparisons that may yield evidence of inefficiencies. And thirdly, compounding the second problem, the number of firms under the regulatory agency is usually small, resulting in questionable validity of any statistical methodologies.

Current literature abounds with examples of measurement problems encountered by regulatory agencies. In the automobile industry, for example, it has been alleged that the problems besetting Chrysler may be due in part to inefficiencies, as evidence by their high costs relative to other car manufacturers. Chrysler rebuts these allegations by denying that the "Big Three" are comparable--the size of General Motors allows it huge economies of scale not available to Chrysler. Thus the high costs are not solely due to inefficient management but may be explained, in part, by unavailable economies of scale.[1]

Likewise, in the not-for-profit sector, numerous studies[2] have used various measures of cost-effectiveness as substantiation for the need to consolidate many of New York City's hospitals. A close reading reveals that efficiency rather than cost-effective measures are being used as evidence, since cost per inputs (cost per patient and/or cost per bed, as well as cost per average length of stay), not cost per output, are discussed. Regardless, the hospitals very simply rebut these studies by arguing that they are not comparable--some specialize in one area, others in another, while still others can be termed "general" hospitals. To compare cost per inputs without some recognition of these diverse factors yields little useful information

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[1]For an excellent discussion of this see the Wall Street Journal, "Deepening Mire," December 19, 1979.

[2]Two studies that the author is familiar with are: Brooklyn's Hospital System, New York State Health Planning Commission [1978] and The Effectiveness of the Total New York City Hospital System: Costs and Service, Program Planners, Inc. [1979].

and may very well obscure the true facts.

Much the same problems are present in the public utility sector. Costs per kilowatt have been used as measures of efficiency without recognition given to the diverse characteristics of the individual utilities. To control specifically for these factors in a statistical sense is difficult for, due to the nature of the industry, there is only a small number of utilities. However, to yield any useful information, this must be attempted. The focus of this thesis will be the public utility sector, specifically the electric utility industry in Massachusetts, which will be used in the sections to follow to illustrate a systems approach to the development of an efficiency measurement model for regulated sectors. The model's applicability to other sectors should be apparent.

The Problem

The Department of Public Utilities (DPU) in Massachusetts finds itself faced with a task that is seemingly impossible to accomplish. Its responsibility is to act as an arbiter between the utility companies and the consumers in order to insure that the revenues earned by the utilities

> . . . should be reasonably sufficient to assure confidence in the financial soundness of the utility, and should be adequate, under efficient and economical management, to maintain and support its credit and enable it to raise the money necessary for proper discharge of its public duties [262 US679, 1923, p. 692]. [emphasis added]

Theoretically, the regulatory process is well defined. Very simply, total revenue is constrained such that a utility is allowed to recover its operating costs plus a fair return on invested capital. To calculate fair return, the rate base, defined as all assets used and useful is multiplied by a composite cost of capital. The traditional finance model is employed whereby the component costs are multiplied by their respective weights to arrive at the composite cost. In Massachusetts, the cost of equity capital is fixed at 13% after tax. By summing the operating costs and the fair return on invested capital, the allowable revenue is derived and rates are set accordingly. Excess profits are returned to the consumer and deficiencies are remedied by rate hikes.

With the advent of inflationary times in the early 1970's came an increase in the number of rate hike requests. Those justified by soaring fuel prices and capital costs should properly be granted, with the costs then being passed on to the consumer. But those resulting from inefficient management should be denied, with the costs then being absorbed by the shareholders in the form of lower earnings. The demonstration of "efficient and economical management" thus has become the focal point of rate hike hearings and has to this date proved insurmountable for the DPU. A brief history of one electric utility, Boston Edison,[3] can best illustrate the scope of the problem faced by the DPU and the frustration it has encountered.

In July 1974, during a rate hike hearing which eventually re-

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[3]Choice of Boston Edison in the example was based upon availability of information. Other utilities have gone through much the same process, but their histories were not as well documented. There is no bias implied in the use of Boston Edison.

sulted in a $40 million rate hike, the DPU placed the burden of proof on Boston Edison by ordering them to undertake an independent study of the "efficiency of Boston Edison's operations" [DPU, 1974]. No definition of efficiency was mandated, nor was operations defined, and methodology was not even mentioned. A second rate hike request was filed and subsequently granted in September 1975 for $29.5 million. Three weeks later, in October 1975, a third rate hike request was filed for $49.5 million. During hearings on the third request, a study by Price Waterhouse [1974] entitled "Manpower Utilization Study" was entered as evidence that Boston Edison had undertaken the ordered study of efficiency of operations. The report was accepted as an initial step and further studies narrowing the focus to top management efficiency were suggested. In August 1976, the DPU allowed $11 million of the requested $49.5 million and concluded with the warning that

> . . . the company [Boston Edison] affirmatively demonstrate in any future rate case that it has moved to improve the efficiency of its operations and the productivity of its employees, both management and non-management [DPU, 1976].

A fourth request for $69.5 million was filed in August 1977. In response to the above warning, a report by Theodore Barry and Associates [1976] was submitted as evidence that Boston Edison was improving and/or investigating the efficiency of their operations. Focusing only on three areas--individual productivity, work force management, and level of productive work--the report was described as "woefully inadequate" and the DPU concluded: "Clearly this was not the intent of the Commission's directive. Totally disregarded was our insistence that productivity of management be examined" [DPU, 1977].

In the summary of the fourth rate hearing, the frustration of the DPU is apparent. For five years Boston Edison had refused to comply with the directive for an independent audit of management efficiency. During this period $120 million in rate relief was granted, some portion of it allegedly due to inefficiency of management. To order more studies was clearly futile. To penalize management by lowering the allowed rate of return on equity would probably only penalize the consumer in the long run. The only viable option, the DPU concluded, was to attempt another approach. As an incentive to increase efficiency, Boston Edison was allowed an additional one-half percent return on equity, effective 1978.

Objectives of Study

The problem of measuring management efficiency has to be attacked in a much more direct manner. Simply to give the utilities a rather nebulous directive to study their own efficiency is not sufficient, as can be witnessed by the actions of the utility industry.

A more systematic approach is dictated, involving at least three steps. First, the scope has to be defined. Efficient management pertains to all levels of management, but of greatest concern is top management efficiency. This seems to be the focus of the DPU directives.

Secondly, a definition of efficiency must be explicitly stated. Efficiency, to an economist, is a highly theoretical construct while efficiency to an accountant may have a much more pragmatic meaning. A key step is agreement on an operational definition.

And lastly, a methodology for measuring efficiency must be developed that will accomplish the task in an objective and verifiable manner. Various studies cited in the DPU hearings used some rather arbitrary and seemingly biased methods and procedures. A much more rigorous and independent model must be developed.

The purpose of this study is to develop such a model. A brief summary of each step follows.

Scope. The DPU has unequivocally stated that its prime concern is top management efficiency. The aforementioned Price Waterhouse and Theodore Barry Associates studies were accepted as steps in the right direction, but were criticized for the narrowness of their focus. Work force management and individual employee productivity are important, but of critical concern is top management performance.

What is needed first is a definition of top management. As will be discussed in the following section, since efficiency has to do with capital investment as well as routine operating decisions, a definition that suggests itself is "that level of management that has responsibility for future investment decisions as well as operations."

In addition, the distinction between management efficiency and segment efficiency must be made clear. The former involves only those items that are controllable by management, whereas segment efficiency does not make this differentiation. Given that the focus of this thesis is on the former, then any factors that are to be examined as to their impact on efficiency must be dichotomized into those controllable by management and those not. Those factors which management has no influence over, even though their impact on segment efficiency is evident, must be segregated and clearly labeled as extraneous with regard to management efficiency.[4] To do otherwise would result in a measure of efficiency which would be of little use; if control is not established, responsibility cannot be affixed.

Although the distinction that must be made is clear and well documented in the accounting literature on control systems, an operational definition of control has never been agreed upon. The common rule of thumb is that if a manager can influence the incurrence or avoidance of the cost, then he has control over that cost. This definition will be used here and in the chapters to follow; where factors are classified as controllable or uncontrollable, the rationale used will be discussed.

If one is to classify as to long-run or short-run, the concern of this efficiency measurement system will be short-run, due to the irreversible nature of the investment decision in the public utility sector. Optimal capital asset mixes will not be investigated, but rather the existing capital asset mixes will be treated as given.[5]

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[4]Although extraneous to this research study, the identification, measurement and impact of these factors on the costs per kilowatt for the widely differing utilities will prove invaluable to the regulatory commission.

[5]Existing asset mixes are given and assumed to be sunk and therefore uncontrollable. However new asset acquisitions are controllable and are of interest. This factor will be discussed further in Chapter IV.

Efficiency defined. The economic literature has dealt with the problem of efficiency measurement in the regulated industries in detail. Using as a definition of efficiency location along the expansion path --the loci of points where the ratio of marginal costs of factor inputs is equal to the ratios of their marginal physical products--it was shown that in a regulatory environment firms may develop a regulatory bias. That is, faced with a constrained return on investment capital, to maximize profit they will substitute capital for labor, causing a movement from the expansion path. Thus, using the economic definition, they are inefficient.

A number of studies have extended this research by (1) investigating the underlying assumptions of the model and (2) empirically testing its validity. These models will be discussed in detail, but their major value will not be as a theory base, but rather as a guide in identifying the research problems that are common to the public utilities area.

It will be argued that the major shortcomings of the economic definition of efficiency are twofold. First, it has a long-run focus when it appears that a short-run focus is more of interest. The economic model measures the relative factor inputs to the production function in order to isolate and identify the overcapitalization resulting from regulation. These factors are seldom controllable in the short run due to the longevity of the capital assets in the utility sector. For example, 38 percent of Holyoke Water Power's and 11 percent of Western Massachusetts Electric's hydroelectric generation plant are over fifty years old. Thus any inefficiencies as measured by the economic model would be in part due to decisions made by management of generations past. The objective of this thesis is to develop a model that focuses on the performance of current management, not past management. As has been stated, to be a valid measure of efficiency, management must be able to control the factors being measured.

The second, but equally important shortcoming of the economic definition is its profit maximization assumption. However, where the product market is insulated from the conditions of the competitive market by regulation, the absolute necessity to be efficient is erased since the natural selection process is no longer applicable. Management behavior is no longer constrained and a range of discretionary behavior becomes possible. It will be argued that this discretionary opportunity set affects efficiency in the short run and therefore a behavioral theory rather than a classical theory of the firm is appropriate when dealing with the public utility sector.

As an alternative to the classical theory Oliver Williamson [1964, 1970] has meticulously developed a behavioral theory which he suggests is applicable to the public utilities. Drawing freely from the work of Barnard, Cyert, March, Simon and others, he rejects the "Economic Man" concept and instead adopts Simon's "Social Man" concept --an adaptive organism constantly seeking an equilibrium among competing personal goals in a continually changing environment. Reviewing the literature, Williamson identifies the multitude of elements thought to be determinates of behavior and factors them into three groups:

size of staff, emoluments, and professional excellence.[6] It is these factors, it is hypothesized, that will be manifested by the discretionary opportunity set available to the management in a regulated utility.

In summary, Williamson's model sugests that management, freed from the constraints of a competitive environment, is no longer motivated to be efficient, but rather will attempt to reach an equilibrium among their own personal goals, even if contradictory to stockholders' interests. This behavior will manifest itself through the increasing of staff, the addition of emoluments, or a striving for professional excellence. Efficiency in the short run is hypothesized to be a function of these variables, and thus a behavioral model of the firm will be employed.

To operationalize this model, the traditional engineering definition of efficiency, the output obtained per unit of input, will be employed. Solomons states, when discussing this productivity index in the context of nonprofit measures of performance, that

> . . . productivity measurement is not quite so simple as this in real life because inputs and outputs are seldom, if ever, homogeneous. The basic problem, which statistical ingenuity has gone a long way toward solving, is to select characteristics of inputs and outputs which can be expressed in homogeneous units and which are, therefore, aggreable. Ideally the characteristics sought will be physical ones, for it is physical productivity which is to be measured. However, it is usually impossible to exclude altogether the use of prices and unit costs as weights [1965, p. 279].

Since factor inputs are not homogeneous in the utility industry, they

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[6]Williamson entitled his third factor "discretionary profits," not professional excellence. Since this factor will be made more robust and will encompass more than discretionary profits in this thesis, professional excellence seemed the more applicable name.

will be homogenized by using dollar surrogates and the resulting costs per kilowatt will be used as an index of efficiency in an accounting context.

Methodology

Extraneous variables. Since the focus of this thesis is on short-run efficiency, dealing with those factors controllable by management, the derived cost per kilowatt definition measuring efficiency must be carefully applied because of various methodological problems.

First, the utility sector is made up of amorphous firms differing over many dimensions. To have a comparable measure over any sample of firms, the effects of these differences must be extracted. Many of these elements have been identified in the literature as well as in rate hike hearings and will be discussed in detail in Chapter III; therefore only a brief mention will be made here. The most common problem encountered in any empirical research is vertical integration. In the utility industry, firms are involved in varying degrees with three distinct activities--generation, transmission, and distribution. Another difficulty is that those who generate may use steam, water, nuclear or gas turbines to do so, again to any degree. In addition, some belong to power exchanges, where they can draw power at peak demands, and to which they may supply power to residential, commercial, or industrial users--identified by size of demand. And last, but by no means least important, the literature is constantly citing the economies of scale available to the larger firms. Since it is questionable whether these factors are controllable in the short-run, the cost per kilowatt calculations must be purged of their effects.

Identification of the above variables is not difficult; however arriving at measurement devices is. Although the variables have been discussed in the literature, little has been said on how to quantify them. Consequently one of the major subjects of this thesis and one of the most important contributions to research in the public utility sector will be the development of a measurement system that will quantify the effects of the abovementioned extraneous variables on the cost per kilowatt output.

Of particular interest is the impact of changing prices. If dollars are to be compared, an attempt must be made to make them comparable. This very topic was explicitly addressed in a recent Financial Accounting Standards Board pronouncement [1979] and a general framework was suggested for treatment of the changing price levels problem. This framework will be tested and its success discussed in Chapter V.

<u>Engogenous variables</u>. Recognizing that the regulatory environment of the utility sector affords management discretionary opportunities, Williamson's model will be used to identify the behavioral traits which are postulated to result. Should management be inefficient and the model is correct, the costs per kilowatt, after being purged of all extraneous factors, would have a direct relationship, in relative terms, to size of staff and emoluments. That is, these factors are incurred not for their effect on output, but rather for the satisfaction of personal goals and thus should rise in a disproportionate manner to output.

Conversely, the third factor, professional excellence, should have the opposite result. If management chooses to satisfy personal goals through this avenue, efficiency should result, therefore driving the cost per kilowatt down. An inverse relationship should also be exhibited between the professional excellence variable and the above size of staff and emoluments variables.

Other factors which conceivably may affect the cost per kilowatt calculations and are controllable to some degree by management will also be tested (see footnote 5). Capital asset growth rates have been used as evidence of inefficiency in rate hike hearings and will be included as an endogenous variable. Likewise payout ratios and financial leverage ratios have been suggested as shedding some light on efficiency of operations and therefore will be tested for explanatory power.

As was discussed in the extraneous variables section, although Williamson has identified his expense preference factors, measurement devices are not as obvious. Data as to the effect of size of staff are readily available; however, data on emoluments are not reported as a separate item. Likewise, professional excellence is a very nebulous factor not readily measured. Again, these problems will be discussed in detail in Chapter IV.

Date base. An additional extraneous variable not previously mentioned is the effect of the regulatory environment. Some states constrain return on total assets, while other the return on stockholders' equity. Some require historical cost figures, while others use replacement cost estimates. To use a broadly based sample across many regulatory environments would subject this research to extreme problems with respect to comparability of data, over and above those mentioned in the previous paragraphs. This problem will be circumvented by choosing as a sample only those electric utility companies in Massachusetts, since the reporting requirements are standardized within the state.

Analytical model. Due to the nature of the utility industry, this necessary sample constraint leads to an additional research problem. Statistically, controlling for the effect of a large number of variables requires a large number of observations. However, due to the fact that there are only thirteen electric utility firms in Massachusetts, the possibility of any cross-sectional analysis is eliminated. Likewise, due to changing environmental conditions within the industry, any time series analysis would be subject to severe criticism. To assume stable relationships over any long time series (say, twenty years) would be highly questionable and, in fact, has been questioned in the few attempts at this type of analysis.

One method that has been suggested as a solution to the limited number of observations problem is the pooled regression model which will be employed here. Both time series and cross-sectional observations are pooled to attain a more reliable result. However, in using this model, procedural questions as to the appropriateness of and the proper way of pooling must be addressed. These will be discussed at length in Chapter IV and again in Chapter V.

From a procedural point of view the following steps will be taken.

1. Various means of measurement on both the dependent variables and the independent variables will be made. Since the literature in this area is sparse at best, this stage will be based almost solely on logic and reason and therefore will be thoroughly discussed.

2. A correlation analysis will be performed to identify those measurement methods which appear most fruitful. Again, recognizing the lack of concrete theories, of particular interest will be the signs rather than the strength of the relationships. The literature does hypothesize (or at least suggest) the type of relationships, but not the strength. For example, economies of scale suggest an inverse relationship between the cost per kilowatt and size of facilities (e.g., capacity or output). However, the strength of the relationship is not clear and thus the relative size of the correlation coefficient is not the question. In addition, relationships between the independent variables will be scrutinized (a) to avoid the problem of multicollinearity and (b) to support any secondary hypotheses. For example, Williamson's theory suggests an inverse relationship between size of staff and professional excellence. Likewise, hydropower has been suggested as being one of the least costly with respect to generation. Similar relationships have been suggested and will be examined.

3. Through the analysis in step 2 on both relationships between

dependent and independent variables and also among the independent variables, a set of independent variables and their corresponding methods of measurement will be attained. These will be analyzed using the pooled regression model with particular emphasis placed on the endogenous variables. The extent of the variation of the costs per kilowatt explained by the endogenous variables will be hypothesized as a measure of short-run management efficiency in the electric utility industry in Massachusetts.

Data collection. Observations on both the dependent and independent variables were gathered from the annual reports on file with the Department of Public Utilities in Boston, Massachusetts. The time series 1966-1978 was chosen due to (1) the availability of data and (2) the stability assumption previously mentioned. By dividing this thirteen-year series into a seven- and six-year series and repeating the above analysis, the appropriateness of the thirteen-year series will be tested with respect to stability.

Recognizing that Massachusetts is an historical cost jurisdiction, indices will be used in step 1 above to convert historical dollars into constant dollars for comparability purposes. All indices were taken from the Business Statistics publications of the U.S. Department of Commerce, Office of Business Economics. The one exception is the nuclear fuel index, which is not compiled and therefore was generated from data on file with the DPU.

The Following Chapters

Chapter II contains a review of the literature with respect to theoretical development and is divided into three sections: first, since the classic study on regulation in the utility sector is the Averch and Johnson thesis, this will be discussed in detail. Included will be subsequent studies it fostered which delve into the underlying assumptions of the model. Secondly, the Williamson model will be presented and shown to be based on a less stringent set of assumptions than the Averch and Johnson model. Finally, the two models will be analyzed with respect to the objectives of the research study at hand.

The review of the literature concludes with Chapter III, where empirical studies and articles in the utility area are presented. The purpose of this chapter is to identify the research problems plaguing the public utility sector and one result is the generation of a list of extraneous variables that must be treated in some manner. A few factors under the control of management will also be delineated.

Chapter IV examines the methodology that is used and concludes with specific statements of all hypotheses. Problem areas such as construction of variables and measurements thereon, *a priori* hypotheses as to signs and strength of the relationships between variables, and the use of the pooling model will be covered in detail.

Analysis of the results follows in Chapter V, which is divided into two sections. First, the preliminary findings concerning the correlation analysis and, thus, the selection of the variables from the regression model is presented. Next the final results of the pooled regression model will be enumerated.

Chapter VI discusses the overall conclusions, limitations and implications for further research in the area. Recognizing that this model is meant as a prototype and is based on what some may consider a radical theory of the firm, the limitations and implications of this thesis will be extensive.

CHAPTER II

THEORETICAL DEVELOPMENT OF EFFICIENCY MODELS IN THE REGULATED SECTOR

Introduction

The traditional accounting approach to efficiency measurement has been nicely capsulized by Anthony and Reece: "Since profit is influenced both by how effective a manager is and also how efficient he is, then profit measures both effectiveness and efficiency" [1975, p. 774]. Thus, in order to evaluate management performance, the key figure the control system must generate is some measure of profit. Solomons devoted the majority of his work, Divisional Performance: Measurement and Control, to this area and concluded that the proper measurements to be used are the excess of net earnings over the cost of capital in the short run and the discounted present value of the enterprise in the long run. However he did note that in the area of regulated public utilities this model is of limited use [1965, p. 124].

In general, when dealing with the regulated sectors, the traditional accounting measures of evaluating management performance based on profitability fail because, since management has only limited control over profit, they cannot be held responsible. Thus in a regulated industry, performance measurement becomes two dimensional, concerned with both effectiveness and efficiency, and their relative importance must be judged. The attaching of weights to these two measures is beyond the scope of this project; of primary importance is the emergence of efficiency as a separate and distinct measure of performance. In rate hike hearings for public utilities, in the Chrysler Congressional hearings and in the numerous studies on municipal health care systems, the key question being asked concerns efficiency of operations.

Efficiency measurement in the regulated sectors has been developed theoretically to a high degree; regretfully the majority of this work is outside the accounting discipline. The economic literature has made major contributions in the specific area of regulated industries and in the following section the most freqently cited and relevant works will be explained and critiqued as to their applicability to this study. Next a well developed theory of the firm advanced by Williamson [1964, 1970], although general and not concerned with the regulated sector, will then be discussed and shown to be, in fact, more relevant to this research.

The Economic Model

The economic literature has dealt in detail with the problem of efficiency measurement in regulated sectors and the classic study is that by Averch and Johnson entitled "Behavior of the Firm Under Regulatory Constraint" [1965]. Given the assumptions of the neoclassical theory of the firm, they demonstrate that a constraint on the rate of return on capital will cause a firm to develop what they call a regulatory bias, resulting in the inefficient use of relatively more capital to other inputs than would be the case without the regulatory constraint.

Assuming a simple two-factor input production function, Figures 1 and 2 illustrate the Averch and Johnson thesis. Referring to Figure 1, the labor and capital axes are in the horizontal plane and the usual interpretation is attached to them: as one moves out from the origin along either axis more labor or capital is represented, any point in the quadrant, such as C', represents a particular capital and labor combination, and plugging the C' factor mix into the production function will yield some output level, O'. Multiplying the price of output by this quantity of output and the prices of inputs by the quantities used will yield total revenue and total cost, respectively. Revenue minus cost leaves profit, expressed by the vertical axis in Figure 1. Thus, continuing the example, producing at point C' results in profit C_{max}. Translating every input-output combination into profit results in the profit hill of Figure 1. Without the constraint on the return on capital, the firm would operate at the efficient point P_{max}, where profits are maximized. But, given the constraint on capital, which can be viewed as hinged on the labor axis, the firm cannot reach P_{max} and will operate instead at the highest profit point attainable. Since the constraint plane rises continuously from the labor axis and cuts through the profit hill, the highest constrained profit level that can be reached will occur along the intersection of the constraint plane and the profit hill at that point that is furthest from the labor axis (or along the capital axis), in this case at the inefficient point C_{max}. Why P_{max} is efficient and C_{max} inefficient will be explained by Figure 2.

Referring to Figure 2, the labor and capital axis and any point in the quadrant between them have the same meaning as in Figure 1.

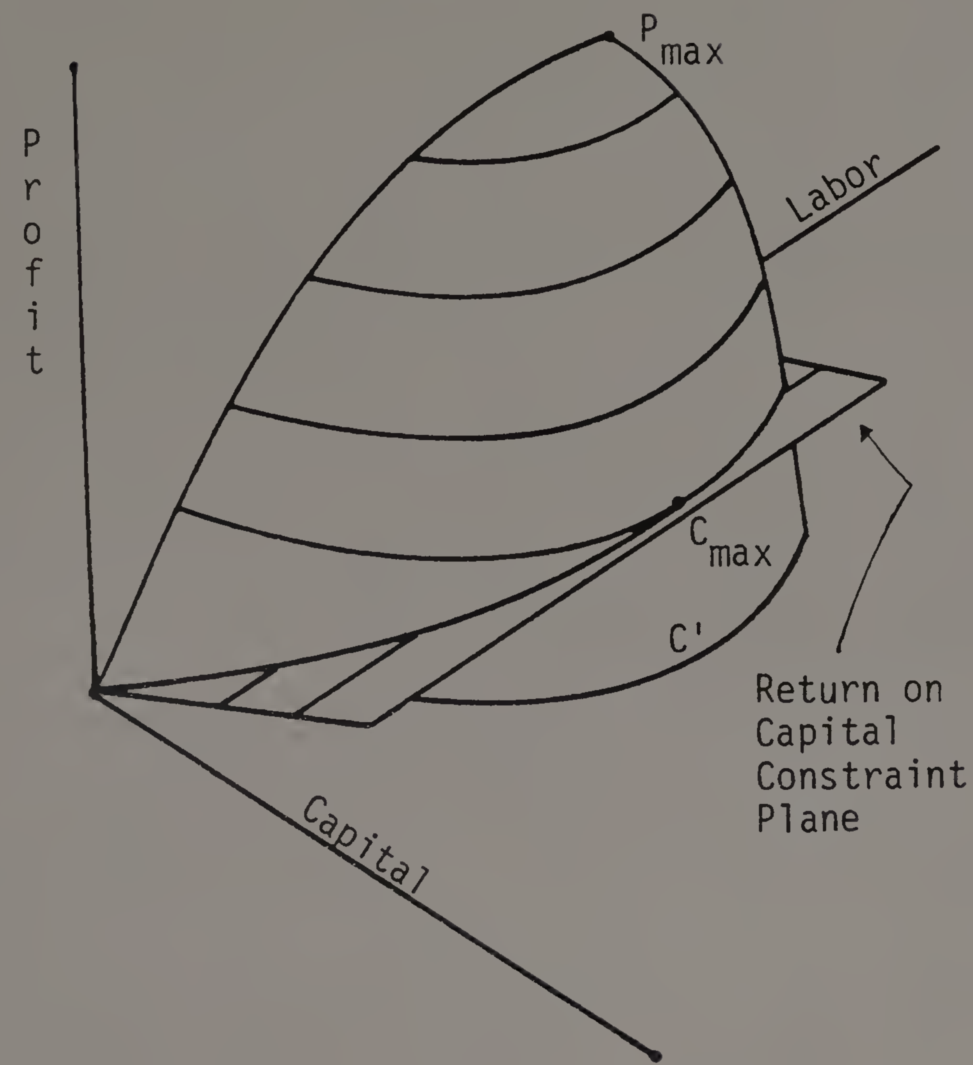

Figure 1. A three-dimensional illustration of the Averch and Johnson thesis.

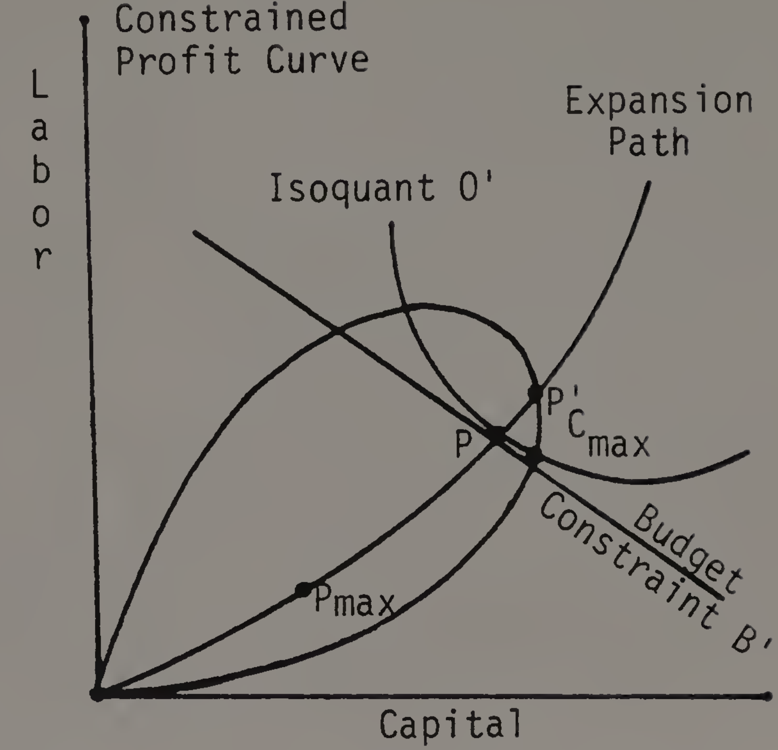

Figure 2. The constrained profit curve projected on the capital and labor axes.

And, just as a particular capital and labor combination yields some output level, there are many input combinations that will give the same output level. The locus of all such input mixes producing the constant output O' is represented by the isoquant O'. Isoquants representing lower levels of output are closer to the origin, while those representing higher levels are further out. The slope of an isoquant (which continually changes in this case) at any point is the ratio of the marginal physical product of capital to that of labor, or MPP_C/MPP_L. Given a budget and the prices of labor and capital, a budget constraint (or isocost line) whose constant slope is the ratio of the price of capital to that of labor, can be represented by the line B'. As in the case of isoquants, budget constraints representing lower budgets are closer to the origin, while those representing higher budgets are further out. To attain efficiency, given any budget, the goal is to combine inputs so as to maximize output and this is achieved in Figure 2 where the budget constraint B' hits the highest isoquant it can, O'. This will occur at point P, where the budget constraint is just tangent to the isoquant O', meaning that their slopes are equal and that the ratio of the marginal productivities of inputs, MPP_C/MPP_L (as represented by the isoquant), or what they're worth in terms of output, is equal to the ratio of the prices of inputs, P_C/P_L (as represented by the budget constraint), or what they cost. Thus point P is an efficient point. Lower budget constraints would be tangent to isoquants closer to the origin, while higher budget constraints would be tangent to isoquants further out. The locus of tangency for the isocosts and isoquants, representing efficiency, is called the expansion path of Figure 2.

If one is to project the intersection of the capital constraint and the profit hill onto the labor-capital plane--conceptually the view one would have by looking directly down from the profit axis of Figure 1, the profit curve of Figure 2 results. As stated, the firm will elect to operate at C_{max}, an inefficient point. The constraint on the rate of return on capital will cause an excess substitution of capital for labor, resulting in movement from the expansion path. For the given output, O', which is constant along the isoquant, the point P would be the efficient point--that is, where the output is produced at the least cost--but it is not obtainable due to the constraint. In addition, the firm would not operate at P', the intersection of the constrained profit curve and the expansion path. Although P' is efficient, higher constrained profits can be realized by moving to the right along the profit curve until C_{max}, the constrained maximum profit point, is reached (remember profits are highest further from the labor axis or along the capital axis). The result in either case is a movement to the right of the expansion path as capital is substituted for labor.

Numerous articles were stimulated by the Averch and Johnson study and two, in particular, delved into the underlying assumptions of the model. Bailey and Coleman [1971] studied the effects of a time lag in the regulatory process and found that the behavior of management may be a function of such a lag. Averch and Johnson assumed continuous regulation where management had no opportunity for excess profits. However, if a lag is introduced, management does have the opportunity for excess profits by violating the regulatory constraint. If this is the case, the firm will operate at the efficient point (i.e., point P in Figure 2). Only when the regulatory agency discovers this violation would the firm be forced to move from this point.

Zajac [1970] investigated the assumptions of the Classical Theory in some detail. First he questioned the static equilibrium and perfect information assumptions. Accepting the possibility of perfect information for inputs due to engineering technology, he studied the opportunities for management discretion assuming uncertainty of the demand function. Essentially two strategies were delineated. Since perfect information as to costs was assumed, management could operate at the intersection of the expansion path and the return on capital constraint. Thus strategy one was hypothesized as seeking out the efficient point, P'. Conversely, strategy two hypothesized that management would attempt to reach that point where profit was maximized subject to the constraint. To do this they would experiment with price changes and capital structures striving to reach an unknown maximum profit point. Zajac showed that this strategy would eventually reach the exact same point as the Averch and Johnson findings, C_{max}. No conclusion was drawn as to which strategy was optimal and no empirical evidence was presented.

Also of interest to Zajac was the profit maximization assumption. By substituting the maximization of stockholders' equity from the finance literature, he demonstrated results somewhat contradictory to the Averch and Johnson findings. Assuming a constant debt to equity ratio (where the fraction of debt and equity financing is constant such that $f_d + f_e = 1$), the return on stockholders' equity, r_s is

$$r_s = (Pq - wL - if_dK) / f_eK$$

where P = price

q = quantity

w = labor cost

L = labor quantity

i = interest on debt

K = capital

f_d = fraction of debt financing

f_e = fraction of equity financing

Given the constraint on capital is less than some percentage, c,

$(Pq - wL) / K \leq c$, then r_s can be rewritten

$$r_s = 1/f_e(Pq - wL)/K - if_d/f_e$$

To maximize stockholders' return the manager would operate where the constraint on capital is just met. Again, referring to Figure 2, any point on the intersection of the constrain and the profit hill would satisfy this condition, thus maximizing stockholders' equity.

As before, when such an opportunity set is available, hypotheses as to management strategies were suggested. First, recognizing the probability of perfect information as to factor inputs, management could seek the efficient point P' (see Figure 3). However, another plausible strategy was to maximize output (e.g., to increase market share). Given this strategy, the firm would operate at the tangency of the outermost isoquant, 0^2, and the constrained profit curve, at point P'' (see Figure 3). Since this input is to the

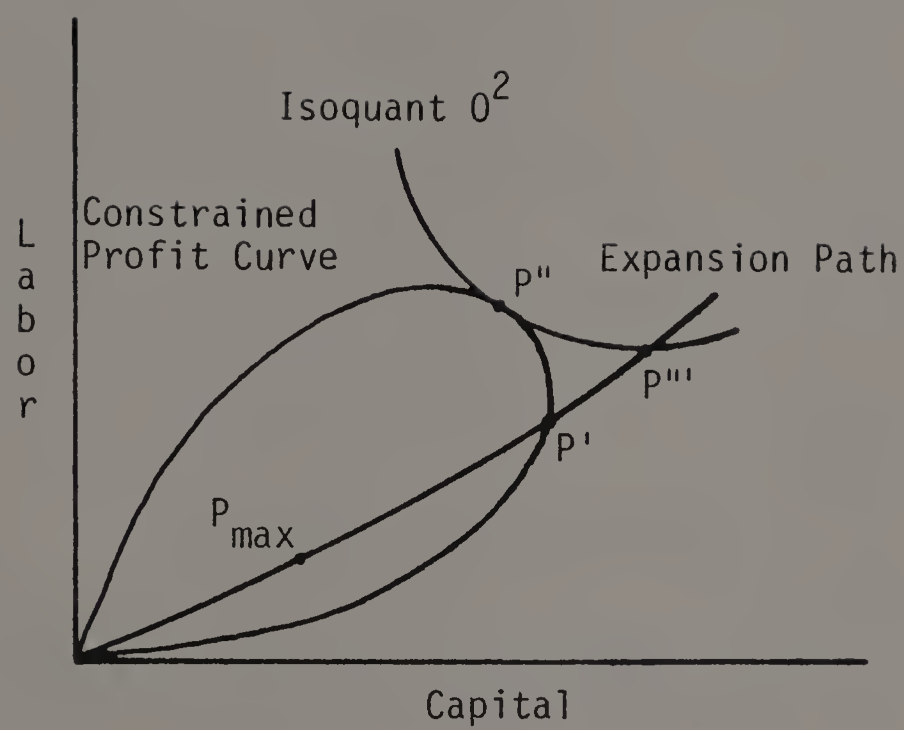

Figure 3. The constrained profit curve projected on the capital and labor axes--return on stockholders' equity substituted for profit.

northwest of P''', the most efficient point at which to produce O^2, it means that too much labor and too little capital is being used. Thus this strategy would lead to conclusions opposite to those of Averch and Johnson and it can be shown mathematically that, as long as $c \leq i$, this substitution of labor (or other factor inputs) for capital will result using this model.

Two empirical studies have investigated the Averch and Johnson hypothesis. Since the definition of inefficiency was variance from the expansion path, a production function was defined ex ante, first order conditions were derived, and the ratios of the marginal physical products of factor inputs were compared to the ratios of the marginal costs. If equal, the firms were on the expansion path, and Averch and Johnson were disproven.

Courville [1974] assumed a Cobb-Douglas production function, $Q_i = A_i^{\gamma} K_i^{\beta} F_i^{\lambda} \varepsilon_i$ (K = capital, F = fuel, L = labor) and found that the ratio of the marginal product of capital to that of fuel was not equal to the ratio of the marginal costs, thus supporting Averch and Johnson. However, he noted that the Cobb-Douglas function was chosen only because it outperformed other alternative production functions and his results may thereby be subject to specification error. In addition, the marginal cost of capital was estimated using the average yield to maturity for AAA public utility bonds for the preceding year. This is a questionable procedure which subjects his findings to specification bias.

Likewise, Spann [1974] assumed the marginal cost of capital to be the same for all firms in his sample and assumed other variables to be estimated by overall industry averages. As above, while his results supported the Averch and Johnson hypothesis, specification problems must be recognized.

A Behavioral Model

Although dealing with neither efficiency nor regulated public utilities, a much more indirect track that was suggested as readily applicable to them is the work of Oliver Williamson [1964, 1970] concerning the impact of the opportunity for discretion on management behavior. Essentially he has developed a theory of the firm that is dependent upon market conditions and diffusion of shareholders rather than the strict competitive market assumptions of the classical (or neoclassical) model.

The idea that as one relaxes the assumptions of the classical model factors influencing management performance change is not new or radical. In the competitive market, any departure from profit maximization (that is, straying from the expansion path) leads to extinction--the natural selection theory. Yet in 1932 Berle and Mean questioned

> . . . have we any justification for assuming that those in control of a modern corporation will also choose to operate it in the best interests of the stockholders? The answer to that question will depend on the degree to which the self-interest of those in control may run parallel to the interests of ownership and, insofar as they differ, on the checks and balances on the use of power which may be established by political, economic, or social conditions [1932, p. 121].

Stating it slightly differently, Keynes [1931, p. 316] said that ". . . when stockholders are almost entirely disassociated from management, the direct interest of the latter in making a profit becomes quite secondary." And, in 1935, Hicks suggested that the ". . . best of all monopoly profit is the quiet life" [1935, p. 694]. Calling his model the Discretionary Theory of the Firm, Williamson abandoned the stewardship assumption of management behavior and replaced it with a self-interest assumption. In reviewing the literature, he then identified two approaches, called "Realism in Process" and "Realism in Motivation." Each of these will be briefly discussed and then the Williamson model will be presented.

Realism in Process deals with the relationship between behavior and the business environment. An excellent example of a study in this area is the Cyert and March [1963] "Budgetary Slack" model. Defined as the difference between the total assets available to the firm and the total necessary to maintain the firm, budgetary slack is hypothesized to be a function of the formal control system of the organization.

If the control system is rigid and unyielding, the manager will build slack by understating revenues and overstating costs. There are two reasons for this accumulation of slack; in times of prosperity, these slack items satisfy personal goals not otherwise attainable through the formal organization and, in hard times, the slack can be reconverted providing ". . . a pool of emergency resources that enable aspirations to be achieved" [Onsi, 1963, p. 536]. Thus slack leads to the satisfaction of personal goals in good times and minimizes stress in bad times.

Should this model be used, the entity concept would have to be expanded to encompass the regulatory agency. If this theory is correct, the individual utilities would build slack into their budgets as a result of the rigid and unyielding control system of the regulatory agency. The problem area would be the empirical testing of this model.

Empirical tests usually measure the relationship between attitude toward slack and attitude toward the control system, attitude toward the budgetary system and the slack detection system. An example of such tests is the Onsi study [1963] where factor analysis, with slack attitude as the dependent variable and attitudes toward the control system and budgetary system as independent variables, was employed. Data were gathered using personal interviews and questionnaires. Since the data were confidential as to respondent and firm, his results cannot be considered startling. Eighty percent of the managers interviewed explicitly confirmed the existence of slack, and the Cyert and March model was found to be an accurate portrayal of the budgetary process.

However, any result using this approach has to be viewed with some skepticism. In that it is almost impossible to conceal the intent of such a study, any participation (personal interview and/or questionnaire) is susceptible to subject bias. Given the pressure on management of utilities, it is doubtful that any type of objective participation can be expected.

<u>Realism in Motivation</u> involves the study of management behavior as a function of opportunity for management discretion. An excellent example of studies in this group is the work of Simon

[1957], who investigated the effects of personal goals on decision making. He rejected the assumption of "Economic Man" seeking to maximize profits and instead suggested a "Social Man" concept describing an adaptive organism constantly trying to reach an equilibrium with regard to personal goals in an ever changing environment. Maximization of profit was not the primary goal of the manager unless he was faced with pure competition where any other behavior would lead to extinction.

Two additional studies extended this discretionary theory into the regulated sector of the economy. Kaysen [1960] found that protection from competition resulted in a wide range of discretionary choice for management. As long as stockholders were satisfied, management could concern itself with other personal, nonprofit goals. Alchian and Kessel [1967] developed a theoretical model for regulated firms which again resulted in the maximization of personal goals rather than profits.

The Expense Preference Model

To develop his model, Williamson first reviewed the literature to identify the major intermediate determinants of behavior and found that the most common elements were salary, security, status, power, prestige, social service, and professional excellence. Next these were grouped into three factors called "expense preferences" which he explained were

> . . . incurred not merely for their contribution to production (if any) but, in addition, for the manner in which they enhance the individual and collective objectives of managers [1964, p.33].

The first factor was size of staff which, theoretically, loaded heavily on security, status, power, prestige and, to some extent, professional excellence. The second, emoluments, was concerned with compensation over and above a competitive salary and was directly related to status and prestige. Discretionary profits, as measured by the amount in excess of that necessary to satisfy stockholders, was the third factor and was thought to be a function of security and professional excellence.

The thrust of Williamson's study was the theoretical development of an alternative theory of the firm, linking behavior with opportunity for discretion; that is, as stated earlier, with market conditions and diffusion of shareholders. Only a small amount of data was presented and even that was described as "suggestive" rather than "supportive." For example, three case studies were discussed which were clearly described as extremes. In each situation, an established company showing stable growth patterns over a number of years was beset by adversity (e.g., a dramatic drop in sales or earnings). The actions taken revealed an underlying organization as hypothesized by the discretionary behavior model. "Expense preference" factors were immediately slashed; staff was cut back (in one case by 42%) and emoluments (e.g., planes, chauffeurs, dining privileges, private secretaries) discontinued with little effect on output. In three divisions of one large multidivisional firm where this was not possible (i.e., staffs and emoluments were already at a minimum), the managers were described as "exceptional performers"; thus the logical explanation was that they were motivated by recognition through achievement rather than by large staffs or emoluments.

In addition, an attempt was made to explain variations in levels of top executive compensation with explanatory variables such as concentration ratios, barriers to entry, diffusion of shareholders and preferences of management. Using somewhat questionable measurement devices, Williamson did find that all signs were as hypothesized and all correlations significant at the two-and-one-half percent level. Recognizing the methodological problems, he again stressed that these results could only be viewed as suggestive; little confidence in a statistical context was expressed. In a subsequent work, Corporate Control and Business Behavior [1970], Williamson documented several studies that once again were classified as suggestive, since they did not test his hypothesis directly.

Critique as to Applicability

The Averch and Johnson thesis is well known and recognized as the classic work in this area. However its focus is on segment efficiency rather than management efficiency. Factor inputs to the production process are not controllable in the short run and therefore any inefficiencies revealed by the model would not necessarily be due to current management decisions. In addition, the neoclassical assumptions are not applicable to the public utility sector. Management is insulated from competitive market pressures and therefore faces a spectrum of discretionary behavioral opportunities not recognized in the neoclassical foundations. Some have rebutted this argument by noting that, although they are insulated from the product market, management is not insulated from the capital market. Therefore discretionary expenses will be reflected by higher prices (i.e., penalties) in the capital markets. As noted by Williamson, Baumol has examined this argument extensively and found it to be lacking. He concludes that infrequent use of the exchanges as sources of capital has limited their ability to penalize and he did not see any reason for this to change in the near future. In summary Baumol stated

> If we look to the stock market as a direct regulator of the efficiency of America's corporate enterprise, we must find other means for it to accomplish this assignment [1965, p. 76].

Furthermore, to operationalize the economic definition of efficiency is difficult at best. Both Courville and Spann noted that choice of production functions was subjective and specification errors likely. To correctly test this hypothesis marginal costs are needed, but they are not available and the use of industry averages as surrogates for marginal costs is highly suspect. In short, specification errors would cause any results from research based on this assumption to be severely questioned.

On the other hand, the behavioral model, although not as elegant theoretically, does seem more appropriate. It is short-run in focus and deals directly with factors that are controllable by management. This, in fact, is the essence of the model.

Also, as stringent as the economic model is with respect to underlying assumptions, the behavioral model is flexible. There are no assumptions as to necessary market conditions; in fact, the model hypothesizes behavior to be a function of market conditions. Man is not constrained to maximize profits; rather his behavior is viewed as being totally adaptive with respect to the environment he encounters.

The one weakness of the model is the almost total lack of solid empirical research supporting it. Williamson readily admits that the cases he used and the works he cited can only be classified as suggestive. Yet it cannot be overlooked that the model is based upon voluminous studies done by researchers well known in their fields, all of which has been extensively tested. In this research effort, Williamson's model will be tested empirically.

CHAPTER III

EMPIRICAL RESEARCH ON EXTRANEOUS VARIABLES

Introduction

The Williamson model reveals expense preference factors that are theorized to be short-run determinates of behavior. Given an environment where these can be manifested, it is hypothesized that they will affect efficiency in a predetermined manner. By establishing that these factors do influence the cost per kilowatt in the prescribed manner, the hypothesis would be supported and the expense preference factors endorsed as measures of short-run efficiency.

However, to establish this relationship, an ex post research design is required which must be carefully constructed if it is to be effective. Any factor, although irrelevant from a short-run viewpoint, if it has an impact on the cost per kilowatt, must be specifically treated. To the extent that the costs per kilowatt are purged of the effects of these extraneous factors, the model should succeed in establishing the existence or non-existence of the predetermined relationships. The purpose of this chapter is to review the literature in an attempt to identify these extraneous factors and their hypothesized effect on the costs per kilowatt. Measurement problems will be discussed in the following chapter.

The Variables

Regulatory environment. Livingstone [1967], in his research on functional fixation, noted that regulatory processes across all states are not consistent. Some states regulate return on capital assets, while others return on stockholders' equity. Some recognize current costs with respect to plant and equipment, while others recognize historical cost. There is no one uniform standard for reporting as one crosses state boundaries.[7] The effect of this variable on the cost per kilowatt cannot be generalized; it would depend on the standards set by the particular jurisdiction.

Technology and economies of scale. The economic literature in general, and the rate hike hearings in particular, refer to the alleged availability of economies of scale and to technological advances being made. Courville stated: "The literature on electricity generation indicates that there was significant technological progress over the last thirty years or so . . . it also indicates the existence of increasing returns to scale" [1974, p. 63]. It is thought that the larger and newer the plant, the more cost efficient it will be due to these advantages. Little data have been cited to support these contentions. And, in fact, in a recent rate hike hearing, the hearings officer for the DPU stated

> . . . The trend of technology has also changed. Until the 1970's, the industry was able to meet increased cost by economies of scale and technological change. Important

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[7]Some might say that there are a multitude of uniform standards and that much depends upon for what agency the report is being prepared. For example, Boston Edison files reports which cover much the same material to the Federal Power Commission (FPC), the Federal Energy Regulatory Commission (FERC), the Nuclear Regulatory Commission (NRC), and finally, the Department of Public Utilities in Massachusetts.

> economies of scale had been realized in the generation of power. By the 1970's, at the latest, this long term trend was at an end [1977, p. 4].

Thus, although these factors seem self-evident, they may have little impact on the cost per kilowatt. As a result, it is hypothesized that both technology and size should have either an inverse relationship or no relationship at all to cost per kilowatt.

Vertical integration. Both Courville [1974] and Spann [1974] identified vertical integration as a major research problem if any type of comparative analysis is done in the utility industry. Electric utilities are engaged in two distinct activities, generation and distribution, and each firm may be involved in each activity to a varying degree. For example, it is common for one firm solely to generate and sell its output wholesale with the second firm acting solely as a distributor. Conversely, it is also common for a utility to generate some portion, if not all, of its own needs and to distribute as well. In addition, a third activity, transmission of the electricity from generation site to distribution point, is sometimes coupled with the generation activity and at other times with the distribution activity. There is no pattern or rule; each utility can enter into each activity to any degree. *A priori* it would seem that as a firm becomes more vertically integrated, the cost per kilowatt should rise in recognition of the additional services being provided the consumer.

Type of generation. It is not enough to identify the activity; generation must be further identified by source of power--fossil fuel (coal or oil), hydropower, gas turbine, or nuclear fission.[8] Again both Courville [1974] and Spann [1974] noted that the generation mix is thought to have a direct bearing on the cost per kilowatt. Likewise, Moody's Public Utility Manual specifically warns of the dangers of comparing companies with dissimilar properties. In the controversies involving nuclear power, advocates have stated how clean (the ratio of energy consumed to energy produced) nuclear power is versus other sources.[9] However, since little empirical data are available, specific hypotheses as to the effects of generation mix will not be made.

Market mix. The sale of electricity involves four markets: a wholesale market called "resale" and three retail markets--residential, commercial (small businesses), and industrial (larger industries). The larger the percentage of resale, the lower the cost per kilowatt should be, again due to the minimum of service provided the consumer --i.e., recognizing the transaction as a wholesale one. Thus market mix should be highly correlated with the aforementioned activity mix and, if nothing else, can be used as a good cross check.

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[8]It is recognized that other types of generation are possible, but in New England their total effect is negligible.

[9]It should be noted that the area of social costs is entirely ignored in the study. For example, the media have noted the increased feasibility of small hydroelectric plants due to the free fuel inputs as compared to other generation types. Environmentalists, however, are quick to point out the geothermal pollution and the social costs due to the loss of the natural free flowing river which, although they cannot be measured, are nevertheless real.

Variability of demand.

Generation. Due to the nature of the good, demand for electricity varies within a period. Regardless of the extent of variability, due to charter conditions, the utility must be prepared to meet the maximum demand called the peak demand. For instance, in a recent hearing before the DPU [1976], Boston Edison attempted to justify the need for additional generation capacity (Pilgrim II) by providing statistics on the growth of peak demand for the summer periods. It was projected that short periods, called needle peaks (characterized as hot, humid days when the heavy use of air conditioners causes excessive demand), would necessitate Pilgrim II's being on line by 1983. The intervenors argued that this would result in large charges for excess and/or idle capacity in off peak periods. Thus variability is of prime importance and is thought to have a major impact on the cost per kilowatt for generation.

Distribution. Although not as critical, variability of demand can also be analyzed from an end market viewpoint. When discussing factors of importance in the utility sector, Moody's [1978] noted the significance of the residential sales with respect to stability. The higher the residential sales, the more stable the demand; conversely, the higher the industrial sales, the more variable the demand. As a result, it is hypothesized that the higher the industrial proportion, the higher the variability of demand and consequently the higher the cost per kilowatt reflecting the idle distribution plant.

Pools. By linking all generating utilities in a loose network called the New England Power Pool (NEPOOL), average capital utilization ratios can be increased. For example, rather than acquiring facilities that would only be used during peak demand, a utility could rely on the pool to meet these rare occurrences by simply drawing the excess needed from the pool network. Likewise, those having excess capacity would stand ready to supply energy if the need arose. Which facility to call upon to meet pool demand is dictated by data kept centrally on all pool members--the one that would supply power at the cheapest cost is automatically chosen. Consequently, pool membership should draw the cost per kilowatt down.

Specific price level problems. In any type of comparative analysis on dollar aggregates, recognition must be given to the impact of changing price levels. The recent statements of Financial Accounting Standards No. 33 [1979] covered this area in detail and concluded with a general framework on how to address this problem. Essentially, two price levels are of importance: (1) general, which has to do with the changes in purchasing power of the dollar in the market as a whole; and (2) specific, which is concerned with changes in the purchasing power of the dollar due to shifts in consumer preferences in identified submarkets. To arrive at proper measures of income, both price levels must be treated. On the other hand, the balance sheet, if it is to be of any use, must show assets and equities at their current value, which recognizes only specific price levels. Of importance to this thesis is the definition of current values with respect to plant and equipment. Three possibilities are suggested for those assets defined as used and useful (i.e., not to be sold). The first is reproduction cost, the cost to replace the exact same asset, which can then be adjusted for depreciation if desired. The second is replacement cost which is defined as that amount of cash required to purchase the best available asset that would perform the same function, again adjusted for depreciation if desired. The last, current cost, concerns replacing the services of the asset rather than the asset itself and therefore recognizes technological change. Whereas replacement cost could result in the best available asset being more efficient by providing more services or services at a lower cost, current cost is concerned only with replacing the exact same services. Technological advance, therefore, could cause wide disparity between replacement and current cost. The accompanying pronouncement concluded that current cost was the proper current value measure for plant and equipment.

For this thesis, general price levels are irrelevant since they would affect all utilities in the same manner. Of importance is the effects of the specific price levels, expressly in two areas.

Plant and equipment. The importance of both the type of activity and the type of generation was discussed in preceding sections. In the following chapter it will be suggested that a logical way to measure these factors is by the relative dollars invested in each activity and/or generation type. However, this may be of little benefit, and may even obscure the true relationships, if dollars are simply aggregated and compared. The dollars invested in plant assets in years past versus those invested more currently are not additive. Recognition must be given to the effect of specific price level increases in the utility sector if any type of relative dollar investment analysis is to be done. Only after these investment dollars are made comparable will the analysis be beneficial.

Factor input costs. Of the factor inputs, only labor can be ignored with respect to the changing price levels, since all utilities in the study would be affected in the same manner. However, capital and fuel factors must be specifically treated.

To analyze costs per kilowatt for the various utilities without adjusting the depreciation portion therein would be tantamount to making the implicit assumption that all assets for all firms were acquired at the same time. As was discussed in the prior sections, recognition must be given to the fact that this assumption is most likely false; the depreciation charges for assets acquired in more recent periods should be higher, reflecting the increased price levels, and vice versa. However, technology may confound this effect (at least up to the 1970's) by driving the cost of new acquisition down. The problem is an interesting one which may have a very simple solution (to be discussed in the following chapter).

In addition, expert witnesses and hearing officers both have stressed that the relative fuel input costs must be recognized when costs per kilowatt are compared. Although all have increased dramatically over the past years (see Appendix B), the rates of increase are in some cases substantially different. For example, both oil and coal have increased almost five hundred percent over the past thirteen years (oil, 474%; coal, 452%), with oil making a massive jump in 1973, while in coal there was more of a steady rise over the entire span. On the other hand, nuclear fuel remained relatively stable until 1975 and then increased more than seventy percent in the next three years. And gas, although increasing two hundred fifty percent over the same time span, did so at a relatively constant rate, excepting a fifty percent increase in 1973. Thus, although they have all increased, if the cost per kilowatt is to be compared, the relative increases of the fuel inputs must be treated.

To Close

The fact that this chapter is so short should in no way reflect upon its importance. The very reason that the literature review has been designated a separate chapter is to emphasize its importance.

The methodology discussed in the following chapter will reveal a pooling model where the costs per kilowatt for the thirteen electric utility companies will be compared over a thirteen-year span. Although a pooling model has not been employed in testimony before the DPU, numerous time series and cross-sectional models have been. The problems discussed in this chapter have been cited in numerous cases as substantiation for the lack of any credibility given to the results of such studies. For example, in Western Massachusetts 18204, the DPU notes

> . . . in a period as markedly inflationary as the past few years, reliance on an earlier period (sic 1965-1975) for this purpose (sic growth rate projects) is likely to be ill-fated [p. 75].

Again in Boston Edison 18515, the DPU commented on testimony given by a Mr. Miller pertaining to a study on cost of capital, utilizing a sample of sixty-nine public utilities

> . . . The 69 companies cover a wide range as to every test that is applicable to them. To ignore these variations by suggesting that the average can reasonably be applied to each of the companies is a method that would only appeal to Procrustes. Individual differences are not to be so lightly disregarded [p. 72].

Finally, of the studies cited in recent rate hike hearings, one that is most similar in a methodological sense to this thesis is by a Mr. Marcussen from Theodore Barry & Associates (a firm specializing in operational auditing), who compares various ratios concerning work force management for Boston Edison to ten other utilities from across the nation over a short (but unspecified) number of years. Noting that identification of the sampling technique employed was not clarified, the DPU concluded

> . . . From yet another analytical perspective, Mr. Marcussen's comparison of the Company with ten other utility companies is almost as unsatisfactory. No details are offered as to size, generation mix, customer density or operating environment. The study's conclusion that Boston Edison's practices compare favorably with those generally found in the electric utility industry is not quantified [1977, p. 83].

For this research project to achieve any credence, the problem areas cited above must be clearly delineated and treated. In addition, little empirical research has been mentioned with respect to the relative importance of these factors; their major support is intuition and logic. Any research finding, although extraneous to the primary objective of this study, with respect to this area should prove valuable in the electric utility area in general.

CHAPTER IV

METHODOLOGY

Introduction

The problem that has been discussed in the prior chapters deals with the effect of regulation on management efficiency. By guaranteeing the firms a specific return on equity, regulation affects management behavior, but in what fashion? The argument that has been developed is synopsized by Kenneth Arrow:

> In general, any system, which, in effect, insures against adverse final outcomes, automatically reduces the incentives to good decision making [1969, p. 55].

However, the development to this stage has been theoretical and/or speculative; no empirical evidence has been presented which demonstrates the inefficiency that is alleged to exist due to the opportunities for discretionary behavior afforded management. A number of approaches could be advocated as the next logical step.

First, recognizing the weaknesses of the regulatory process and accepting the behavioral implications of the discretionary behavior model, the process itself could be changed. Some might suggest that the constraints be altered or even removed and a competitive market reinstituted. There appears to be some sentiment that less regulation is better as witnessed by the recent relaxing of controls in the airline, interstate commerce and oil industries. However, the design of a better regulatory system is far beyond the scope of this work. The regulatory system as it exists will be assumed and emphasis will be placed, instead, on the design of a control system which recognizes the behavioral implications of the regulatory process.

The next logical question is: Should the control system be external or internal to the individual utility? Williamson suggests an internal control system constructed on an organizational design which promotes least cost behavior and, thus, self regulation. In his summary he states

> . . . discretionary behavior is a function of discretionary opportunities and situational incentives. The M-form organization alters behavior by changing the situational (role) incentives at the top and by limiting the discretionary opportunities available to lower level participants through the operation of a powerful internal compliance machinery [1970, p. 175].

Essentially he reasoned that, by divisionalizing a large firm, an internal subeconomy would materialize where resource allocations and rewards would be made based on relative performance. Thus his M, or multidivision, form promotes competition within a firm and, therefore, approaches the neoclassical economic model. Efficiency is reintroduced through organizational design rather than market structure. Again, as logical and intuitive as this model is, organizational design is far beyond the scope of this work and is noted only as a unique and interesting way to deal with the problem at hand.

The most pragmatic approach, given the actions of the utility firms in Massachusetts, would seem to be the development of a control system external to the individual utility. Placing the burden of proof on the individual firms has not been successful; therefore more stringent methods are needed.

One technique may be to require more information, if it is thought to be useful, through additional mandatory disclosures. For example, in 1978 the Securities Exchange Commission, in Releases No. 33-6003 and 33-5949, require that information on management remuneration, especially any benefits not directly connected to operations, and management security holdings, which were hitherto spread throughout the annual filings of the S-K forms, now be compiled and reported under one heading in item four. This ruling was further clarified in Releases No. 33-6027 and 33-6166 the following year. Likewise The Company Act of 1967 in Great Britain required separate reporting of all contributions, employee remuneration and exports. It was recognized that theoretically

> A proper system would require measurement not just of costs to the entity but of both costs and benefits to society of particular programmes or units and of the entity as a whole [Perks and Gray, 1979, p. 22].

Yet this information, even though not complete, was thought to be in the public interest and, at least, a step in the right direction.

Although this method is in common use today, it must be viewed with some skeptism. Regulatory compliance costs are close to one-half-million dollars for larger utilities in Massachusetts today. Since additional disclosure requirements would inevitably lead to higher expenses, which, in turn, would be passed on to the consumers in the form of rate increases, this approach is not a true solution. Simply stating that the information is <u>thought</u> to be of public interest is not enough; before the costs of compiling and reporting are incurred, the benefits of such disclosures should be substantiated.

This thesis does advocate that additional items be reported, specifically the expense preference items discussed prior, but not on an ad hoc basis. Rather than just suggesting that some information is of value or will "benefit society", this research paper states the exact nature of the information, the hypothesized relationship it has to efficiency and then tests this relationship empirically. By establishing the theory base which justifies the additional disclosures, a cost benefit criterion can be applied.

The purpose of this chapter is to explain the analytical techniques employed to ascertain the expected benefits from the additional disclosures that are advocated. The first section deals with the measurement techniques used on both the dependent and independent variables, with the second section then discussing the procedure employed to choose between these alternative measures. The pooled regression model, used to examine the relationship between the costs per kilowatt and the expense preference factors, while simultaneously controlling for the effects of the extraneous variables, is then explained, and the chapter concludes with a specific statement of all hypotheses to be tested--both primary and secondary.

Variable Measurement

Dependent variable. Cost per kilowatt, the dependent variable, seems almost self-explanatory; yet there are at least two ways to construct this variable. The first is to simply total all costs--categorized in the annual filings as operating, maintenance, property taxes, depreciation and interest--and then divide by the kilowatt output. By using the dollar surrogates, as Solomons suggested, heterogeneous inputs are converted into homogeneous units--dollars--but are they truly additive? Since Massachusetts is a historical cost jurisdiction, the depreciation charge reflects a weighted average of acquisition year dollars and this could add considerable variation to the cost per kilowatt computation. To purge these calculations of this extraneous variation the depreciation charge could be converted to current year dollars for each utility by using specific price level indices for each year (i.e., 1966 to 1978). However, because the variation of the costs per kilowatt caused by depreciation is not controllable by management in the short run and is, therefore, irrelevant to the primary objective of this work, depreciation can also be simply eliminated from the cost per kilowatt computation. Since the latter approach is far easier, a second cost per kilowatt calculation which ignores the depreciation charge will also be used (i.e., operating expense plus maintenance plus property taxes plus interest divided by kilowatt output).

Independent variables.

Endogenous. Chapter II covered Williamson's expense preference items on a conceptual level and left the more pragmatic and difficult problem of measurement for this chapter. As has been stated in prior sections, since little empirical testing of his model has been done, Williamson's factors have not been quantified and the measurement devices that will be constructed in order to accomplish this task are based solely on logic and reason. The endogenous variables to be developed are size of staff, emoluments, professional excellence (all based upon Williamson) and capital expansion (a new variable).

The first factor, size of staff, can be measured any number of ways. Of importance, however, are relative rather than absolute measures. It is not enough to measure staff expense in dollars, it must be related to some causal indicator. Logically, salary and wages of staff per kilowatt output or as a percentage of sales should be satisfactory. Such data are available and therefore each will be generated and tested.

Even though it is as clearly defined as size of staff, emoluments is more difficult to measure due to the lack of availability of data. Total compensation is buried in any number of accounts[10] (e.g., management salaries, pensions and benefits, miscellaneous expense) and cannot be reconstructed. Williamson did recognize this problem and used top management salary as a surrogate when discussing empirical studies in this area. But even this figure is not always available. All utilities in Massachusetts are not separate entities; many share a common management through holding companies (e.g., Northeast Utilities, Eastern Utility Associate, New England Power Service Company). Although operated as distinct segments, a flat management fee levied by the holding company is reported in lieu of top management salaries. Since this fee may contain any variety of items (e.g., a charge for invested capital), top management salaries for these companies are sometimes not available. Nonetheless, where these

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[10]As was noted previously, disclosure of this information is now required for those firms under the jurisdiction of the SEC.

figures are attainable, they will be tested for their effect on the costs per kilowatt. As above, with relative rather than absolute measures being called for, top management salary per kilowatt and as a percentage of sales will be used.

Williamson's third factor, discretionary profits, has been expanded and entitled professional excellence. Regardless of what it is called, measurement of this factor is difficult due to its lack of substance. Williamson argued that its existence would be manifested by discretionary profits--that amount which is over and above the minimum level of stockholder satisfaction. However, how to measure stockholder satisfaction was not mentioned.

Clearly this factor attempts to identify those managers that strive to attain recognition (self-actualization?) not by the size of their staff or by their emoluments but rather by their achievement. Since return on equity is constrained at 13%, any type of profit measure seems a poor index of performance. Yet few utilities yield the constrained 13% return on equity and it may be that this factor, achieving the allowed 13% return, does, in fact, indicate professional excellence. Thus one measure that will be tested is the difference between the actual return on equity and 13%; the closer this is to zero, the better the performance of management.[11]

Recognizing that any measure based on profit is weak, another measure of professional excellence that may be helpful is return on

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[11]Thirteen percent is not an absolute. As was noted previously, Boston Edison was allowed an additional one-half-of-one percent as an incentive to be efficient. Likewise, there are slight variations for other utilities which should have no material effect.

sales. Although all returns on equity are theoretically equal, a management motivated by recognition may attempt to earn this return in a least cost manner, thereby maximizing return on sales. A high return on sales could indicate professional excellence and therefore will be so tested (see footnote 11).

An additional variable, not developed by Williamson, may also be germane with respect to management behavior. In the DPU hearings concerning the need for the Pilgrim II power plant, it was insinuated that the management's desire to expand cannot be substantiated by demand requirements, but rather reflects the desire for prestige, status and power. A rationale of "bigger is better" was used to characterize management. Although existing facilities are not controllable by management, expansion is controllable and of concern here.

To quantify this behavior, the growth rate relative to excess capacity must somehow be compared. Since this accusation has to do with the generation activity, a percentage rate of growth can be obtained by dividing the change in capacity for a year by the total capacity for that year. Likewise the excess capacity rate or percentage can be computed by subtracting demand from capacity and dividing by capacity. To then arrive at a measure of unwarranted growth, u for short, the growth rate is multiplied by the excess capacity rate. That is

$$\text{Unwarranted Growth} = \text{Growth Rate} \quad \times \quad \text{Excess Capacity Rate}$$

$$= \frac{\text{Capacity}_t - \text{Capacity}_{t-1}}{\text{Capacity}_t} \times \frac{\text{Capacity}_t - \text{Demand}_t}{\text{Capacity}_t}$$

and the larger the u factor, the greater the unwarranted growth. For example, since these two rates are multiplied, if the excess capacity percentage is small, then any growth would not be unwarranted and u would be small. Likewise if the excess capacity rate is large, but the growth rate is small, then again u would be small, indicating no unwarranted growth. It is only when both the excess capacity and growth rates are large that the unwarranted growth variable, u, is large. Thus, if the above measurement device does measure the "bigger is better" characterization of management, a positive correlation with cost per kilowatt is expected.

The influence of these factors on the costs per kilowatt are of primary concern. If it can be demonstrated that they do affect the costs per kilowatt in the hypothesized manners, it would then be management's task to explain why they are not short-run indications of efficiency. However, since management's prevailing argument against any statement about efficiency is that firms are not comparable, the next section rebuts this allegation by explaining how comparability is achieved via controlling for extraneous factors.

Extraneous. Extraneous variables are a common problem in any type of research and three methods which can be used to control for their effects are recognized. First, by choosing a sample that is homogeneous with respect to a particular variable, the effect of that variable can be eliminated. In the aforementioned Theodore Barry and Associates study concerning Boston Edison's work force productivity, this approach was attempted by selecting as a sample only those firms comparable to Boston Edison. The DPU rejected this method, citing the disparate nature of the utilities and, therefore, the number of extraneous factors that would have to be controlled for by homogeneity. Thus this approach is just not a feasible way to treat all of the extraneous factors in the electric utility sector.[12]

A second method commonly used is randomization, where subjects are assigned to various treatment groups in a random manner. However, due to the small sample size and the purpose of this study, this technique is not possible.

Conversely the third method, controlling for the effects of the extraneous variables by entering them into the design as independent variables, is ideal. Not only will the effects of these variables on the costs per kilowatt be extracted, but, as Kerlinger notes, it will also yield

> . . . additional research information about the effect of the variables on the dependent variable and about their possible interaction with other independent variables [1969, p. 285].

However, before these variables can be entered into the design, one faces the difficult task of measuring and/or dealing with them. In the section to follow the extraneous factors and the methods developed to quantify and/or treat them are presented. In addition, the section ends with an example incorporating the variables and, as each variable is discussed reference is made as to its location in the example.

1. Regulatory environment--If one were to choose a sample of

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[12]However, due to the exploratory nature of this study, one factor, regulatory environment, will be controlled by choosing as a sample only those utilities in Massachusetts.

utility firms from across various jurisdictions, the data would first have to be standardized with respect to the different reporting requirements. Although this may be possible, the task would be extremely time consuming. The method used to control for this factor, therefore, will be the first approach; a homogeneous sample--the large electric utility firms in Massachusetts--will be selected rather than a more extensive sample. Since the present research is a feasibility study probing a nebulous and undefined area, such a restriction is not viewed as having a major impact on the conclusions of this thesis. If the findings do support the discretionary behavior hypothesis, a more definitive study would be necessary across all jurisdictions before these conclusions could be generalized.

2. Market mix--As was discussed in Chapter III, there exists both a wholesale market and a retail market with the latter being subdivided into residential, commercial and industrial sectors. Logically, the more services one provides the consumer, the higher the cost per kilowatt. Consequently, the wholesale market supplier should show the lowest cost per kilowatt and, conversely, the residential and commercial the highest. The industrial supplier should fall in between, recognizing certain distributional economies of scale with respect to the large industrial users. The number of kilowatts supplied to each market is reported, and, thus, percentages of the total kilowatts supplied to each market segment will be used to identify the market mix.

3. Vertical integration (activity mix)--The activity or activities engaged in by each utility will be measured by the percen-

tage of the total dollars invested in each--generation, transmission and distribution--and this is referred to as the activity mix. It should be noted that an individual company has several plants, each of which usually has a different activity mix, and by aggregating over all plants the activity mix of a particular utility company is calculated. In addition, although an individual plant generates in only one fashion, a utility company consisting of several plants can accordingly generate in several ways. This is called the generation mix and it is treated in detail in section 3. In this section the activity mix is developed according to the portion of investment dollars represented by each. Recognizing the specific price level problems discussed prior, these dollars will first be converted to current dollars using the Handy-Whitman Public Utility Index for electric utilities published by the census bureau.[13] This is treated in parts A and H of the example.

Ideally each asset should be adjusted individually; however, due to data constraints, this cannot be done. For generation assets, weighted--average age is used as a surrogate and is derived in the following manner. For each generation type (steam, hydro, nuclear or gas), the kilowatt capacity for each plant is multiplied by the age of that plant (as of the given year) and aggregated. By then dividing by the total kilowatts for the generation type, the average

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[13]The Handy-Whitman Index is a reproduction cost index which reflects the current cost to replace the exact same facility. A more appropriate index would be the replacement cost index which reflects the cost to replace the service provided by the asset rather than the asset itself. Unfortunately, this index is not available at the present time for the electric utility sector.

age is derived. For example, if in 1975 the total steam capacity for a utility is as follows:

Plant	Age	Kilowatt Capacity
Steam 1	40	500
2	25	1000
3	4	5000
		6500

The average age of the steam plant would be computed by

$$[500\ (40) + 1000\ (25) + 5000\ (4)]\ /\ 6500 = 10 \text{ years}$$

which in essence states that the dollars invested in the steam plants reflect, on average, 1965 price levels. To convert to current dollars the total dollars invested in the steam plants is multiplied by the usual conversion factor using the Handy-Whitman Indices (i.e., 1975 index/1965 index). This is treated in parts B, F and G of the example.

Although this data is available for all generation facilities, it is not available for transmission and distribution plants. Yet the major specific price level problem concerns the generation plant investments since they are, in some cases, over fifty years old. In that transmission plants--high voltage lines, transformers and capacitors--and distribution plants--meters, poles and low voltage transformers--are much shorter lived, this problem may not be as critical as first thought.

As a result, the percentage used to identify the activity or activities engaged in by each utility will be based on a total investment comprised of generation plant at current dollar and transmission and distribution plant at nominal dollar. The measurement inconsistancy cannot be avoided and to ignore the price level factors entirely would be even more problematic.

4. Type of generation (generation mix)--To measure the generation mix of a utility at first seems very straight forward. Having converted the generation plant into current dollars, all that is needed now is to divide each generation type--steam, hydro, nuclear or other (gas)--by the total generation expressed in current dollars. Thus generation mix would be expressed by the percentage of total current generation investment in each generation type. This is treated in part I of the example.

However, should generation mix have the same inpact on cost per kilowatt if the firm totally generates versus a firm that is involved in all three activities? Thus the question of activity mix discussed in the previous section comes into play. For example, assume Firm 1 totally generates and its generation types are 50% steam and 50% hydro, whereas Firm 2 has only 10% of its assets involved in the generation activity but it, too, uses 50% steam and 50% hydro. Clearly the impact of the generation mix should be much less for Firm 2 than for Firm 1. To capture this effect, the percentage type of generation (from the generation mix) will be multiplied by the percentage generation plant to total plant (from the activity mix) computed in the preceeding section to arrive at a weighted measurement on type of generation. Using the activity mix concept of the previous example to illustrate, and given the following data,

	Firm 1	Firm 2
Total Plant - current dollar	$50,000,000	$50,000,000
Generation Plant - current dollar	50,000,000	5,000,000
Steam Plant - current dollar	25,000,000	2,500,000
Hydro Plant - current dollar	25,000,000	2,500,000

the calculations would be as follows:

	Generation Mix %		Generation % of Activity Mix		Weighted Generation Mix
Firm 1 - steam =	$\frac{25,000,000}{50,000,000}$	X	$\frac{50,000,000}{50,000,000}$	X 100% =	50%
hydro =	$\frac{25,000,000}{50,000,000}$	X	$\frac{50,000,000}{50,000,000}$	X 100% =	50%
Firm 2 - steam =	$\frac{2,500,000}{5,000,000}$	X	$\frac{5,000,000}{50,000,000}$	X 100% =	5%
hydro =	$\frac{2,500,000}{5,000,000}$	X	$\frac{5,000,000}{50,000,000}$	X 100% =	5%

Thus to get a more meaningful measure of the impact of the generation mix it must be weighted by the generation activity percentage of the activity mix. The result is called the weighted generation mix and this is treated in part J of the example.

5. Technology and Economies of Scale--While Courville noted the significant technological advances made in the thirty year period prior to 1974, it was also noted in a DPU hearing that the era of significant technological change with respect to electrical generation had ended by the 1970's at the latest. Therefore the impact of technology on the period 1966-1978 might be considered to be of limited importance. But since the majority of capital assets were acquired prior to the period under investigation, the effect of technology cannot be dismissed quite so easily. As stated earlier in the discussion of the dependent variable, the cost of capital can be

either eliminated or incorporated in the calculation of cost per kilowatt. If the depreciation charge is ignored, which seems to be a rational approach (and consequently will be taken here) since management has no control over it, the impact on cost per kilowatt should be eliminated and technology would have little impact on this study. If it is included technology should have a significant effect on the capital costs reflected in the cost per kilowatt calculation. In addition, this supposition itself shall be tested by entering the average ages of the generation types as independent variables and checking their relationships with the dependent variable--cost per kilowatt. As in the prior section on "type of generation", since all utilities do not have the same portion of assets invested in the generation activity, the average ages must first be weighted by the generation activity percentage of the activity mix.

Like technology, the existence of significant economies of scale has been questioned for the time period under investigation. To test for any effect, two common measures of size will be used, namely kilowatt output and capacity. Since kilowatt output reflects all activities, there is no need to weight this factor, but since capacity is only with respect to generation, it will be weighed by the generation activity percentage of the activity mix.

6. Variability of demand--With respect to generation, the load factor, defined as the ratio of average demand to peak demand, is the accepted measure of variability. Peak demand is reported on a sixty minute integrated reading and average (hourly) demand can be computed by taking annual output and dividing by the number of hours

in a year[14]--i.e., 365 X 24 = 8760. Thus the average demand per hour divided by the maximum (peak) demand per hour yields the load factor. Theoretically it should vary between zero and one. The closer the factor to zero, the higher the variability, the greater the excess capacity and consequently the higher the cost per kilowatt. Conversely, the closer the factor to one, vise-versa, since one would indicate constant demand or no variability. Therefore an inverse relationship between the load factor and the cost per kilowatt will be expected. This is referred to in parts C, D and K of the example.

For those utilities that distribute, the measure of variability, called the distribution factor, used by Moody's Public Utility Manual is the ratio of residential sales to industrial sales. This information is readily available and will therefore be used in this study. It is thought that the higher the industrial portion, the more unstable or variable the demand and therefore the greater the excess facilities or capacity. Since the market in Massachusetts is divided into residential, commercial, industrial and resale, the Moody's distribution factor will be somewhat modified. To have its interpretation parallel that of the load factor, the variability here will be measured by the ratio of residential plus commercial to the total retail market--residential, commercial and industrial. Once again, the ratio should vary between zero and one. The closer the

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[14]Although peak demand is reported, average hourly demand is not. The simple assumption that all plants operate continuously will introduce some error into this compilation since occasional shutdowns are common--nuclear plants for refueling and inspection; steam plants for boiler maintenance and inspection; gas fueled for turbine cleaning and inspection.

ratio to zero, the higher the industrial portion, and therefore the more unstable the demand. Conversely, the closer the ratio to one, vise-versa, since one would indicate total residential and commercial sales. Commercial is combined with residential, not industrial, since it reflects the smaller businesses, characterized as professionals, which are more stable in their demand patterns than the large industrial users. Resale is ignored since only the retail market is of concern.

As before, since the impact of these variability indicators, both the load factor and the distribution factor, are relative to the extent each utility is involved in each activity, these factors will be multiplied (weighted) by their respective activity percentages from the activity mix. This is treated in parts E and K of the example.

7. Pool Member--To understand and measure the effect of this variable the mechanism of the power exchange must be made clear. Firms that have excess capacity would price their power supplied at the incremental cost for the highest cost type of generation available. That is, when called upon to supply power, a multi type generation (i.e., steam, nuclear, hydro and/or gas) firm would first cost their output at the generation level without the pool demand and then at the higher generation level recognizing the pool demand--assuming the most expensive generation type was used to meet this incremental pool demand. This would be the price of the power supplied to the exchange. Conversely, the price paid to the exchange by the user is the cost that would have been incurred had that utility generated its own

power rather than drawing it from the exchange. The difference between the cost of the power to the exchange (i.e., the estimated incremental cost of the supplier) and the price paid to the exchange (i.e., the estimated incremental cost to generate by the user) would be the profit on the exchange, and this would then be split between the two participants to the transaction. The exchange itself acts solely as an agent and receives no commission. This complicated procedure is simplified by the centralized data bank of the exchange (NEPOOL) and, where many suppliers stand ready to meet pool demand, that utility which would provide power at the least cost is automatically selected. In addition, the firm drawing from the pool need not be at full capacity; if it can draw power at a cheaper cost than it can generate it, the exchange would automatically be made!

To measure this factor, pool membership, a number of methods can be used. First, since membership can be dichotomized into suppliers or users, simple dummy variables identifying this characteristic can be employed. Next, if the extent of pool membership is of importance, then the kilowatts either supplied to or drawn from the pool could be used--with "supplied" entered as a positive and "drawn" as a negative. However, since pool membership is a symbiotic relationship where both participants benefit from the exchange, the absolute value of the pool participation, kilowatts supplied or drawn, would seem most appropriate. This would capture or measure the effect of the pool membership factor as well as recognize the mutual benefit. If these measures are correct there should be a negative relationship with the load factor.

8. Specific Price Level Impact On Fuel Inputs--If all fuel prices rose at the same rate, there would be no need to recognize this factor since any comparative analysis being performed would not be affected. In that this is not the case, the indices for coal, oil, nuclear and gas fuel must be tested for their effect on the cost per kilowatt. These indices are not as straightforward as they would seem and a brief description of how they were developed or dealt with follows.

First, steam generation can either use coal or oil depending upon the particular plant. To complicate this problem, some steam facilities are flexible enough such that either coal or oil can be used. Fortunately the coal and oil indices are quite close and an average oil/coal index should suffice for steam generation.

Gas turbine generation presents no problem and a simple gas index will be used. Nuclear fuel, however, is unique. Whereas coal, oil and gas are burned and replaced in a continuous cycle, nuclear fuel has a much longer life. Fuel rods are purchased and used over a longer time span, usually somewhere in the vicinity of a year to fifteen months, and therefore a nuclear fuel index is not available. For the three utilities using nuclear generation a crude index was devised by simply averaging the nuclear fuel costs for each year (when reported) and dividing by the designated base year, 1966, the same year used for the other indices.

Once again, to recognize that not all firms wholly generate, the relative impact of these fuel indices is computed by multiplying the specific index by the weighted generation mix explained in section 3.

For example, if in 1977, Firm 1 had a 30% generation activity, of which 20% was by steam and the other 80% by nuclear generation, the relative fuel impact variables would be computed as follows:

	Fuel Index[15]		% Generation		% Generation Type		
Steam	(4.98 + 4.09)/2	X	.30	X	.20	=	.272
Nuclear	1.47	X	.30	X	.80	=	.353
Gas	2.35	X	.30	X	0.00	=	0.000

This is treated in part L of the example.

9. To illustrate--In an attempt to make this complicated and involved area clear, a short hypothetical example will be worked through. Assume in 1977 Utility 1 has the following data:

Part		Generation	Transmission	Distribution
A	Activity Mix--Nominal Dollars (Vertical Integration)	$50,000,000	$4,000,000	$12,000,000

B Generation Mix--Nominal Dollars

	Plant	Age	Killowatts(000)
Steam 1	$8,000,000	5	30,000
2	5,000,000	10	30,000
Hydro 1	3,000,000	10	12,000
2	2,000,000	15	12,000
3	2,000,000	20	6,000
Nuclear	20,000,000	3	100,000
Other (Gas)	10,000,000	6	35,000
	50,000,000		225,000

C Peak Demand Per Hour--175,800 Kilowatts

D Annual Output--1,200,000,000 Kilowatts

E Market Residential 40%

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[15] Since steam generation requires either coal or oil and the specific fuel is not always reported, a composite fossil fuel index, computed by averaging the coal and oil indices, will be used. Surprisingly, it should be noted that these indices are quite close (see Appendix B).

Commercial	20%
Industrial	30%
Resale	10%

F To convert to current dollars, average age is first needed.

Steam - [30,000(5) + 30,000(10)]/60,000	=	7.5 = 8 yr.
Hydro - [12,000(10) + 12,000(15) + 6,000(2)]/30,000	=	14 years
Nuclear -	=	3 years
Gas -	=	6 years

G Than, using the Handy-Whitman Index -

Steam	$13,000,000 (227/110)	=	$26,827,272
Hydro	7,000,000 (227/89)	=	17,853,932
Nuclear	20,000,000 (227/171)	=	26,549,707
Gas	10,000,000 (227/127)	=	17,874,015
Total Generation			$89,104,926

H Activity Mix--Total Investment =

$89,104,926 + 4,000,000 + 12,000,000 = $105,104,926

Generation - $89,104,926/$105,104,926 = .848

Transmission - 4,000,000/105,104,926 = .038

Distribution - 12,000,000/105,104,926 = .114

I Generation Mix (Unweighted by Activity Mix)

Steam - $26,827,272/$89,104,926 = .301

Hydro - 17,853,932/89,104,926 = .200

Nuclear - 26,549,707/89,104,926 = .298

Gas - 17,874,015/89,104,926 = .201

J Generation Mix (Weighted by Activity Mix)

Steam - .301 X .848 = .255

Hydro - .200 X .848 = .170

Nuclear - .298 X .848 = .253

Gas - .201 X .848 = .170

K Variability of Demand -

For Generation -

Average Hourly Demand = Annual Output/Number of Hours Per Yr.

= 1,200,000,000/8760 = 136,986 kilowatts

Load Factor = Average Hourly Demand/Peak Demand

= 136,986/175,800 = .779

For Distribution - (.40 + .20)/.90 = .667

And thus the weighted factors for variability are

.779 (.848) = .661

.667 (.114) = .076

L Fuel Index - Weighted

Steam - (4.98 + 4.09)/2 X .255 = 1.156

Nuclear - 1.47 X .253 = .372

Gas - 2.35 X .170 = .400

Of interest are the effects of the activity mix, the weighted generation mix, the weighted variability factors and the weighted fuel factors on the dependent variable, cost per kilowatt.

Choice of Variables for Inclusion in Pooled Regression Model

Prior sections have discussed the dependent and independent variables--both exogenous and extraneous--and measurements thereon using an approach based on logic and reason. In that the thought process is not infallible, the next step is to substantiate these hypothesized causal relationships using a statistical procedure called correlation analysis. In addition, where multiple measurement methods have been suggested for variables, this procedure will aid in the selection of the most appropriate method. It is emphasized that correlation analysis is nothing more than a mechanical procedure used to establish the existence of a linear relationship between variables; no statement is made with respect to one variable "causing" the other. Causality must be established prior, based upon some logic or theory.

Initially, correlation analysis appears straight forward. Since the correlation coefficient measures how close the relationship between two variables is to a linear relationship, it seems that all one must do is choose those variables that have the correct sign and the highest correlation with the dependent variable, cost per kilowatt--with the correct sign being designated a necessary condition. Where two or more measures have been suggested, a rational decision rule would be to choose that measurement which has the highest correlation with the cost per kilowatt, assuming the correct sign. This in fact would be the correct procedure if the independent variables were not correlated with one another. Regretfully, it is almost certain that this is not the case, and the correlation analysis becomes much less mechanical and more intuitive.

Where independent variables are correlated, of importance is the partial correlation coefficients, which, as before, measure the strength of the linear relationship between an independent variable and the dependent variable, but now with the effect of some other independent variable(s) held constant (i.e., removed). Hays and Winkler (1971, p. 661) illustrate this technique using a simple research situation involving the relationship between ability to read and body weight. Although there is evidence of a strong linear relationship between these two factors, they note that this tendency may be due to a third factor, chronological age. Where the effect of this factor is held constant in some manner, the correlation between reading ability and weight may vanish. Thus this observed correlation may be a spurious one due solely to the fact that both reading ability and weight are correlated to age. It must be noted once more that correlation analysis is but a mechanical procedure; which variable(s) to control for is (are) not identified by the partial correlation model.

Therefore, fully expecting these problems, the procedural steps will be as follows. First a correlation matrix will be generated for all the dependent and independent variable measures discussed in the prior "Variable Measurement" section. Of particular interest will be the correlations among the independent variables that exhibit a significant correlation with the dependent variable. Where significant correlations between independent variables are encountered, usually termed multicollinearity, partial correlations will be generated with the controlled variables being identified in some logical manner based upon the data present. For example, the exogenous variable, size of staff, measured either by staff salaries as a percentage of total revenue or cost per kilowatt output, should logically vary with the type of market--residential, commercial, industrial or resale, and, hence, a high correlation is expected between these variables. Therefore to find the true linear relationship between cost per kilowatt and size of staff, a partial correlation will probably be needed controlling for type of market. Should additional problems develop, they will be treated as encountered in a similar manner. Where variables are significantly correlated, which one(s) to control for--that is, the true causal factor(s)--can only be identified by a reasoning process given the constraints on data availability. If spurious relationships are found, these variables will not be entered into the pooled regression model regardless of their high correlation with the dependent variable.

Also of interest will be the relationship involving the two measurements of cost per kilowatt. Ideally the one that will be used is the computation that ignores the depreciation charge since, as stated, current management has no control over past investment decisions. In addition, this would avoid the problem involving technology discussed in Chapter III. Although the argument for elimination of depreciation is logical, this cost per kilowatt definition will only be used if the correlations, both simple and partial, of this measure of cost are as meaningful (again both in sign and strength) as the alternate measure of cost per kilowatt which included the depreciation charge.

The results of this correlation analysis will be twofold. First, where multiple measures for both dependent and independent variables were identified as possible, choices will be made based upon sign and strength of correlations. And secondly, a set of independent variables will be identified for inclusion in the pooled regression model. Where multicollinearity is present, partial correlation analysis will be used to identify and exclude all spurious relationships.

The Pooled Regression Model

The output of the correlation analysis--both simple and partial--will be a dependent variable, cost per kilowatt--using either measure discussed prior, and a set of independent variables that (1) exhibit a significant relationship with the dependent variable in the hypothesized manner, and (2) are minimally correlated among themselves (i.e., little multicollinearity). A regression model will now be employed to test the explanatory power of the extraneous and exogenous variables included in the set of independent variables. Of particular interest will be the explanatory power of the exogenous variables--those controllable by management, for these are hypothesized to be indicators of efficiency in the short run.

Although seemingly the ideal computational tool, the regression model must be carefully applied. Should care not be exercised, a serious problem involving degrees of freedom would result due to lack of observations. For example, if a time series model is used, the validity of the results would increase by increasing the number of observations (i.e., years). But in a recent rate hike hearing (1976), results of a study based upon observations spanning 1961-1968 were discounted due to systematic changes in the utility environment since that period. To the extent that these systematic changes are not reflected in the identified extraneous variables, the present study would be subject to the same criticism. Likewise, a cross sectional model would experience the same problem regarding number of observations. To control for the effect of the regulatory environment, electric utilities in Massachusetts only were used as a data base. Due to the nature of the industry, there are only thirteen such utilities.

But by pooling the time series observations for each cross section, the above problems can be circumvented with the result being a more reliable estimate of the relationship between the dependent variable, cost per kilowatt, and the above mentioned independent variables. Specifically, by pooling observations on the thirteen utilities for thirteen years, 1966-1978 (the period for which data is (1) available, and (2) acceptable concerning the risk of influence from systematic factors), a tremendous increase in the degrees of freedom would result. For example, assuming eight independent variables are finally included in the regression, the degrees of freedom would be increased from four to 160 by pooling (d.f.=T-K-1). The additional advantage of having a more representative sample would also result. By pooling cross sectional observations, a wider range of variation is attained than by solely using time series data on individual firms, again increasing the reliability of the coefficient estimators.

Regretfully, the use of the pooling model is not without its drawbacks. First the appropriateness of pooling must be ascertained, and secondly, if appropriate, the question of how to pool must also be answered.

By pooling, one is either explicitly or implicitly making the assumption of homogeneity of the coefficient vector. Using matrix notation:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ \cdot \\ X_n \end{bmatrix} \beta + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_n \end{bmatrix}$$

$$(NT \times 1) \quad (NT \times K+1) \quad (K+1 \times 1) \quad (NT \times 1)$$

N = number of firms, 13 in this study
T = number of time periods, 13 in this study
K = number of independent variables

where:

Y_i is a vector of dependent variables; cost per kilowatt for 13 years for firm i, i = 1 to 13,

X_i is a matrix of independent variables; extraneous variables plus expense preference variables for 13 years for firm i, i = 1 to 13,

ε_i is a vector of error terms for 13 years for firm i, i = 1 to 13,

β is a vector of coefficients assumed common for all firms.

To property apply the pooling model, the assumption that $\beta_1 = \beta_2 = \ldots \beta_n = \beta$ must be tested. In the event that the hypothesis is rejected, even though the above model would lack meaning in a strict sense, if one is willing to trade bias for reliability (i.e., reduction of variance), the model may still be applied.

Pooling when the hypothesis is rejected will result in aggregation bias. To illustrate we have:

$$Y_i = X_i\beta_i + \varepsilon_i$$

and by summing

$$Y = \Sigma Y_i = \Sigma(X_i\beta_i + \varepsilon_i)$$

It follows using ordinary least squares that:

$$E(\hat{\beta}) = (X'X)^{-1}X'Y = \Sigma(X'X)^{-1}X'X_i\beta_i$$

and unless $\beta_i = \beta$ for all i, the expectation of an element of $\hat{\beta} \neq \beta$.

In summary, if the hypothesis as to the stability of the Beta vector between cross sections is not rejected, pooling is appropriate and the model is properly specified. In addition, if the hypothesis is rejected, but the differences still considered small, an argument for pooling can still be made based on a tradeoff of additional bias for variance reduction. But if the hypothesis is conclusively rejected, pooling is not appropriate.

Given that pooling is deemed appropriate, regardless of whether the stability hypothesis on the tradeoff is accepted, the next question is: How to pool? The major point is whether the coefficient vectors are fixed parameters, random variables, or some combination of the two.

If it is assumed that the vectors are fixed, as would be the case if the stability assumption is supported, then the covariance method of pooling would be used. For example, if the Beta vectors are not stable but the variation is assumed due to systematic factors, dummy variables could be employed. Time period and cross sectional intercepts as well as slope parameters could be varied in this manner. It should be noted that although the systematic effect is treated, the reason for it is not explained.

However, due to the careful, and hopefully exhaustive, procedure of identification of extraneous variables and expense preferance items, all systematic factors should be already purged from the data.

Although the covariance method does not seem to apply to this study, the two other pooling models do seem appropriate. The variance components method assumes the slope coefficients to be fixed, but the intercepts random. This model would be applicable where the overall stability of the Beta vector is rejected, but the hypothesis excluding the intercept term is not. By omitting the intercept the error term is now assumed to be comprised of three components--a time period, a cross section, and an interaction term. An estimating procedure based on Aitken's [1934] generalized least squares is then applied.

The third method, random coefficient regression, is a generalization of the variance components method where the slope coefficients are now also considered random variables. Any variation from one cross section to another is not assumed to be due to systematic factors but rather to be totally random. Specifically

$$Y_i = X_i(\bar{\beta} + \delta_i) + \varepsilon_i$$

where δ_i is a vector of random fluctuations.

The choice of this method for pooling has two distinct advantages. First, since it is assumed that all systematic variance has been purged, the variance should now be due solely to random factors. Thus if one accepts this premise, pooling under the random coefficient procedure would be appropriate even when the homogeneity of the Beta vector is rejected.

In addition, the use of the model eliminates the worry of aggregation bias. Given:

$Y_i = X_i(\bar{\beta} + \delta_i) + \varepsilon_i,$

by summing $\Sigma Y_i = \Sigma X_i \bar{\beta} + \Sigma X_i \delta_i + \Sigma \varepsilon_i,$

yields $Y = X\bar{\beta} + \Sigma X_i \delta_i + \Sigma \varepsilon_i.$

Using ordinary least squares estimator as before,

$$
\begin{aligned}
E(\hat{\beta}) &= (X'X)^{-1}X'Y \\
&= (X'X)^{-1}X'(X\bar{\beta} + \Sigma X_i \delta_i + \Sigma \varepsilon_i) \\
&= \bar{\beta}
\end{aligned}
$$

Again using matrix notation, the model is specified as follows:

$$
\begin{bmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ \cdot \\ X_n \end{bmatrix} \bar{\beta} + \begin{bmatrix} X_1 & & & & 0 \\ & X_2 & & & \\ & & \cdot & & \\ & & & \cdot & \\ 0 & & & & \cdot \\ & & & & X_n \end{bmatrix} \begin{bmatrix} \delta_1 \\ \delta_2 \\ \cdot \\ \cdot \\ \cdot \\ \delta_n \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_n \end{bmatrix}
$$

or

$$Y = X\bar{\beta} + D\delta + \varepsilon,$$

where

$$
D = \begin{bmatrix} X_1 & & & & 0 \\ & X_2 & & & \\ & & \cdot & & \\ & & & \cdot & \\ 0 & & & & \cdot \\ & & & & X_n \end{bmatrix}
$$

The error term now has two components:

$D\delta$	due to random fluctuations of the Beta vector,
ε	due to random fluctuations resulting from choice of cross section and/or time period.

The assumptions of the model are:

(1) $E(\varepsilon_i) = 0, \; E(\varepsilon_i \varepsilon_j) = \begin{cases} \sigma_i^2 I & \text{for } i = j \\ 0 & \text{for } i \neq j \end{cases}$

(2) $E(\beta_i) = \beta$

(3) $E\,(\beta_i - \bar{\beta})(\beta_j - \bar{\beta}) = \begin{cases} \Delta & \text{if } i = j \\ & \text{if } i \neq j \end{cases}$ where $\beta_i - \bar{\beta} = \delta_i$

(4) β_i and ε_i are independent

(5) β_i and β_j are independent for $i \neq j$

It follows that:

$$U = \begin{bmatrix} X_1 \Delta X_1' + \sigma_1^2 I & & & 0 \\ & X_2 \Delta X'_2 + \sigma_2^2 I & & \\ & & \ddots & \\ 0 & & & X_n \Delta X'_n + \sigma_n^2 I \end{bmatrix}$$

and using Aitken's generalized least square estimator:

$$\hat{\bar{\beta}} = (X'U^{-1}X)^{-1}X'U^{-1}Y$$

After having established the proper pooling method, one final problem must be addressed: efficiency of the estimate. The objective of this study is to purge those factors that are uncontrollable by management from the cost per kilowatt and to focus on the portion of the variance explained by the controllable items--expense preference items. To be efficient, the variance of the Beta vector must be minimized which is accomplished by using all data that are available.

The first assumption of the random coefficient model is:

$$E(\varepsilon_i \varepsilon_j) = \begin{cases} \sigma_i^2 I & \text{for } i = j \\ 0 & \text{for } i \neq j \end{cases}$$

When i = j, this assumption states that (1) the variance of the error term within a cross section is constant (i.e., homogeneity), and (2) the error terms over time are not correlated (i.e., absence of autocorrelation). Although the former assumption is reasonable, the latter is not. Autocorrelation of the error term is common and, by specifically treating this, the efficiency of the estimate can be increased. Using a first order process:

$$e_{i,t} = \rho e_{i,t-1} + \nu_{i,t}$$

the variance of the error terms within each cross section can be purged of the autocorrelation.[16]

Thus, by using autocorrelation coefficients which are readily measured, a more efficient estimate of the Beta vector is obtained. The covariance matrix of the error term can now be rewritten as:

$$U = \begin{bmatrix} X_1 \Delta X_1' + \sigma_{11} V_{11} & 0 & \cdots & 0 \\ 0 & X_2 \Delta X'_2 + \sigma_{22} V_{22} & \cdots & 0 \\ \vdots & \vdots \ddots & & \\ 0 & 0 & \cdots & X_n \Delta X'_n + \sigma_{nn} V_{nn} \end{bmatrix}$$

---

[16]An additional assumption, $|e| < 1$, is needed to insure convergence.

where

$$V_{ii} = \begin{bmatrix} 1 & \rho_i & \rho_i^2 & \cdots & \rho_i^{t-1} \\ \rho_i & 1 & \rho_i^1 & \cdots & \rho_i^{t-2} \\ \rho_i^2 & \rho_i & 1 & \cdots & \rho_i^{t-3} \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \rho_i^{t-1} & \rho_i^{t-2} & \rho_i^{t-3} & \cdots & 1 \end{bmatrix}$$

Aitken's generalized least squares estimator is once again used:

$$\hat{\hat{\beta}} = (X'U^{-1}X)^{-1}X'U^{-1}Y$$

with the covariance matrix now corrected for autocorrelation.[17]

A brief summary of the computation steps is as follows:

1. Ordinary least squares is run on each cross section using $Y_i = X_i\beta_i + \varepsilon_i$
2. Estimates of the error terms are derived: $\hat{\varepsilon}_i = Y_i - X_i\hat{\beta}_i$ and the autocorrelation coefficients, ρ_i, are computed.
3. Generalized least squares is run on each cross section using $Y_i = X_i\beta_i + U_i$. That is, autocorrelation of the error terms is now specifically treated.
4. Using the error term from step 3, estimators for Δ and σ_{ii} are computed.
5. Form V_i matrices using results from step 2.
6. Estimate $\hat{\hat{\beta}}$ using $\hat{\hat{\beta}} = (X'U^{-1})^{-1}X'U^{-1}Y$.

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[17]As before, only first order autocorrelation has been purged.

Interpretation of the Pooled Regression Results

Having derived the Beta vector, the next step is to interpret the results with respect to the variance explained by the exogenous variables. The relative contribution of these factors is the primary concern of this thesis and now must be investigated. Since many of the independent variables were measured using different scales (i.e., kilowatts, current dollars, costs per kilowatt, percentages), the regression coefficients cannot be compared directly. However, to overcome the impasse, the variables may be standardized--converted into units of standard deviations.

Given a regression function on raw scores

$$Y = a + \beta_1 X_1 + \beta_2 X_2,$$

it can be standardized in the following manner--

$$\frac{Y_i}{\sigma_y} = \frac{a}{\sigma_y} + \beta_1 \frac{\sigma_1}{\sigma_y} \frac{X_{1i}}{\sigma_1} + \beta_2 \frac{\sigma_2}{\sigma_y} \frac{X_{2i}}{\sigma_2}$$

The equality should be evident. The transformed Betas ($\beta_1 \frac{\sigma_1}{\sigma_y}$, $\beta_2 \frac{\sigma_2}{\sigma_y}$) are called Beta coefficients, standardized Betas, or Beta weights, and can be interpreted in the following manner[18]--a one standard deviation change in X_i would be reflected by a β_i^* standard deviation change in the dependent variable, Y. Thus, since the independent variables are all expressed in comparable units--units of standard deviations, they can now be compared in the following manner: The larger the absolute value of the standardized Beta, the more that

[18] The transformed betas will be denoted by an asterisk(*).

independent variable explains the variance in the dependent variable.

However, when discussing these Beta coefficients, Cooley and Lohnes note that

> . . . we have to temper our interpretations with the realization that the obtained prediction results from a system of predictors in which the elements interact in complex fashion. (1971, p. 53).

They illustrate this by considering the variance of the regressed standard scores where

$$R^2 = \frac{\frac{1}{n}\sum_{i=1}^{n} \hat{Y}_i^2}{\frac{1}{n}\sum_{i=1}^{n} Y_1^2}$$

$\hat{Y}_i$ = regressed standard score,

Y_i = observed standard score.

R^2 = squared multiple correlation coefficient--the ratio of the explained variance to the total variance.

$$= \frac{1}{n}\sum_{i=1}^{n} \hat{Y}_1^2$$

Since $\frac{1}{n}\sum_{i=1}^{n} Y_1^2 = 1$; the variance of a standardized variable being 1.

$$= \frac{1}{n}\sum_{i=1}^{n} (\beta_1^* X_{1i} + \beta_2^* X2i)^2$$

for a two parameter system.

$$= \frac{1}{n}\sum_{i=1}^{n} (\beta_1^{*2} X_{1i}^2 + \beta_2^{*2} X_{2i}^2 + 2\beta_1^*\beta_2^* X_{1i} X_{2i})$$

$$= \beta_1^{*2} \frac{1}{n}\sum_{i=1}^{n} X_{1i}^2 + \beta_2^{*2} \frac{1}{n}\sum_{i=1}^{n} X_{2i}^2 + 2\beta_1^*\beta_2^* \frac{1}{n}\sum_{i=1}^{n} X_{1i}X_{2i}$$

$$= \beta_1^{*2} + \beta_2^{*2} + 2\beta_1^*\beta_2^* r_{12}$$

$\frac{1}{n}\sum_{i=1}^{n} X_{1i}^2 = \frac{1}{n}\sum_{i=1}^{n} X_{2i}^2 = 1$ and

$$r_{12} = \frac{1}{n}\sum_{i=1}^{n} X_{1i}X_{2i}$$

If multicollinearity is absent--i.e., $r_{12}=0$, the importance of the independent variables is indicated by the square of the Beta coefficients--

$$R^2 = \beta_1^{*2} + \beta_2^{*2}$$

and a perfect measure of the relative contributions of the independent variables is attained. However as multicollinearity increases, the joint contribution--$2\beta_1^*\beta_2^*r_{12}$, confounds this technique and interpretation must proceed accordingly. Since multicollinearity will be specifically treated and hopefully minimized via the partial correlation analysis discussed prior, the effect of this confounding factors should be minimal with the Beta coefficients then yielding a good measure of the relative importance of the individual independent variables.

Stability

Stability of the Beta vector over cross sections has been specifically treated and, in fact, was a major question regarding choice of the proper pooling model. However, stability of the vector over time periods when cross sections are not stable has not been dealt with yet although it has been mentioned as a research problem.

When pooling observation from the time period, 1966-1978, the implicit assumption is being made that the effects of the independent variables on the cost per kilowatt have remained constant. As discussed prior, this assumption has been shown to be questionable in other studies and cannot be accepted at face; it must be tested.

The efficient market research in the finance and accounting disciplines is an excellent example where this implicit assumption has been specifically tested. Time series regressions were used to establish an individual firm's return relative to some market measure with the implicit assumption being that the relative measure remained constant, or stable, over the time period in question. If changes in the market environment within the time series could be postulated, it followed that the research conclusion could be questioned due to specification error.

Initially attempts were made to test this assumption by dichotomizing the time periods in question into two shorter spans and comparing the relative measures. If they were not significantly different, the stability assumption could not be rejected. For example, both Beaver, Kettler, and Scholes (1970) and Blume (1971) found that the correlation between the two sets of Beta coefficients was approximately .60, and thus concluded that this "high" degree of association supported the stability assumption. However, Meyers (1973), using a like sample, showed that a high correlation coefficient does not necessarily indicate stability. Although the correlation coefficient for his sample was .54, in analyzing each individual Beta coefficient, he found that twenty five percent of these more than doubled and fifty percent changed by at least ten percent. Levy (1975) replicated these findings and in addition, found the stability problem to be worse for shorted time periods. Both Meyers and Levy concluded that this instability was enough to question any research conclusions drawn. Thus a simple correlation coefficient for the Beta vectors generated from the dichotomized time series is not sufficient; yet to merely itemize the percentage changes is not statistically valid. To circumvent this impasse, the Chow and Box tests from the statistics literature will be applied.

Statement of Hypotheses

The primary objective of this study is to develop a short run efficiency measurement model for the electric utility industry. Due to the nature of the industry, a very precise methodology was required based upon suppositions concerning both exogenous and extraneous variables. Consequently, for this model to be consistent and cohesive, a number of hypotheses must be tested--designated primary and secondary.

Primary hypothesis.

> The impact of the expense preference items on the cost per kilowatt can be used as a short-run measure of efficiency in the electric utility industry, given that extraneous factors are properly controlled.

Hypotheses to be tested with respect to the individual expense preference items are as follows:

H_1: There is a positive relationship between relative staff cost and cost per kilowatt.

H_2: There is a positive relationship between relative management salaries and cost per kilowatt.

H_3: There is a positive relationship between unwarranted growth and cost per kilowatt.

H_4: There is a negative relationship between return on sales and cost per kilowatt.

Secondary hypotheses. To validate measurement devices used a number of secondary hypotheses must also be tested.

With respect to the endogenous variables:

H_{s1}: There is a negative relationship between return on sales and size of staff, management salaries and unwarranted growth.

With respect to extraneous variables:

H_{s2}: There is a positive relationship between market integration and cost per kilowatt.

H_{s3}: There is a positive relationship between vertical integration and cost per kilowatt.

H_{s4}: There is either a positive relationship or no relationship at all between age of facilities and cost per kilowatt.

H_{s5}: There is either a negative relationship or no relationship at all between economies of scale and cost per kilowatt.

H_{s6}: There is a negative relationship between the load factor and cost per kilowatt.

H_{s7}: There is a negative relationship between the market variability factor and cost per kilowatt.

H_{s8}: There is a negative relationship between pool transactions and cost per kilowatt.

H_{s9}: There is a positive relationship between the fuel indices and cost per kilowatt.

CHAPTER V

ANALYSIS AND RESULTS

Data Problems

Data were gathered on the thirteen electric utilities reporting to the Massachusetts DPU (for a list of their names see Appendix A) for the time period 1966-1978. However, one utility, Canal Electric Company, was just organized in 1966 and at least the first three years data reflect construction in progress rather than normal activity. Thus a choice was necessary: either to use only twelve utilities for the thirteen years or to use the thirteen utilities for only ten years (1969-1978). Since it was not clear at what year "normal" activities commenced, the former option was taken.

Results of the Correlation Analysis

The simple correlation analysis.[19]

Cost per kilowatt. Pertaining to the endogenous and extraneous variables, there is little difference between the two measurements of cost per kilowatt (see Appendix D). All correlations are of the same sign and are of the approximate same significance.[20] Except with respect to the average age variables, which were conceptualized as

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[19]All discussion in this section refers to the correlation matrix in Appendix D.

[20]Unless otherwise specified, all tests of significance will refer to the .05 level. In addition, one may argue that the use of inferential statistics is not appropriate in that the utilities used in this study comprise a population and not a sample on which popula-

measures of technological advancement, this is not surprising. The first measure of cost per kilowatt includes a charge for depreciation and thus the negative correlations between this cost per kilowatt and the age variables probably reflects the significantly lower depreciation charges for the older capital assets. Yet with the second cost per kilowatt calculation, which omits the depreciation charge, the signs are the same and the significance levels virtually identical. This result is puzzling because, if the age variables properly reflected technological advances, a positive relationship should exist --the older the facility, the more obsolete and, therefore, the higher the cost per kilowatt. As a result, the second measurement of cost per kilowatt, that ignoring depreciation (since it is uncontrollable), will be used in the analysis to follow.[21]

Endogenous variables. The correlation of both measures of size of staff and management salary (i.e., as a percentage of sales and per kilowatt output) to cost per kilowatt are as hypothesized: significant positive relationships. However, the high degree of multicollinearity among these variables suggests that only one variable be entered into the regression model. Since the staff expense per kilowatt output variable is the most signfiicant, and given the aforementioned problems[22] with the reliability of the management

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tion parameters may be inferred. However, the observations do represent a sample over time, and, thus, the use of inferential statistics is supported.

[21]It may be assumed that any subsequent reference made to cost per kilowatt is based upon the measurement omitting the depreciation charge.

[22]See the Exogenous Variable section in Chapter IV.

salary data, the former seems the likely candidate.[23]

The unwarranted growth factor displays no significant relationship to the cost per kilowatt and consequently the hypothesis with respect to this variable is rejected. As a result, unwarranted growth is excluded from any further analysis.

Of the two measures of professional excellence, the first, variance from the thirteen percent rate of return allowed on equity, manifests exactly the opposite behavior as hypothesized while the second, return on sales, exhibits the hypothesized significant negative relationship to cost per kilowatt. However, both measures are positively correlated to both measures of size of staff and management salary whereas significant negative relationships were hypothesized. Clearly, the first measurement device for professional excellence does not meet the task and the second, although having the correct relationship to cost per kilowatt, is suspect due to its positive relationship to the other expense preference items. Yet this problem may be due to an intervening variable(s) and will be discussed further in the partial correlation section.

Extraneous variables. As was hypothesized regarding market mix, residential and commercial percentages have almost identical significant positive correlations to cost per kilowatt while resale has a significant negative relationship. Likewise, as was hypothesized, concerning activity mix, generation percentage exhibits a significant inverse relationship to cost per kilowatt and distribution

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[23]This choice will be further supported in the Partial Correlation section to follow.

percentage a significant direct relationship. Transmission percentage, being negatively correlated to cost per kilowatt, probably reflects that it is more likely found in conjunction with the generation rather than the distribution activity. Finally, as was postulated in Chapter III, the activity and market mixes are highly correlated--generation percentage highly correlated with the resale percentage and distribution percentage with the residential and commercial percentages. The partial correlation analysis section to follow will suggest a solution to this problem.

The types of generation all display significant correlations to cost per kilowatt but with steam, hydro and nuclear being negative and gas positive. The negative relationships may reflect the dominance of the generation activity--that is, any type of generation would have an inverse relationship to cost per kilowatt when compared to non-generating utilities. Likewise, the gas generation correlation probably reflects the small utility[24] (note the -.5160 correlation between gas generation and economies of scale-output). Additional results will be discussed in the partial correlation section.

As was discussed in the cost per kilowatt section above, age was not proven to be a good surrogate for technology as evidenced by the negative correlations between age of the generation facilities and cost per kilowatt. However, both measures of economies of scale, log of output and log of weighted capacity, did reveal the expected negative correlations to cost per kilowatt. Which measure to choose

[24]The only utility that solely relies on gas generation is the tiny Nantucket Electric Company.

will be discussed further in the partial correlation section.

Concerning the variability factors, the load factor has, as hypothesized, a significant negative correlation to cost per kilowatt. However, this may reflect the fact that load factors are only relevant for generating utilities which have lower costs per kilowatt (note the .7339 correlation between the load factor and the generation percentage). Likewise, the distributional factor, although it exhibits a relationship to cost per kilowatt exactly opposite to that hypothesized, may be simply reflecting the distribution activity rather than the hypothesized variability factor. Again, the following partial correlation analysis will help to solve the problem.

In contradiction to the hypothesis, pool transactions had absolutely no relationship to cost per kilowatt. As curious as this first seems, this may make sense in that only those firms that could benefit took advantage of the pool membership. Those firms that already were the least expensive would have no use for the pool. Thus, if anything, the pool may tend to decrease the variability in the cost per kilowatt.

Probably the most puzzling results were those of the fuel indice correlations. There is no relationship between the fossil fuel index and cost per kilowatt and a significant <u>negative</u> relationship between the nuclear fuel index and the cost per kilowatt. Only the gas fuel index was as hypothesized--a significant positive relationship. At first, it was thought that this was due to the influence of the negative relationship of generation to cost per kilowatt--that is, since the fuel indices were weighted by the generation percentage, the negative correlation of the generation activity may be confounding the correlations. Yet when the unweighted (or raw) fuel indices were used the correlations were almost exactly the same (-.0016, -.2600, .4238). This problem will also be discussed in the succeeding partial correlation section.

The partial correlations analysis.

Extraneous variables. Since the interrelationship of the market mix and the activity mix is the most important, the unraveling of the multicollinearity problems inherent in this study will begin here. In addition, the results of this analysis will be used in further partial correlation analyses.

Essentially, the question is which is (are) the true causal factor(s) and which is (are) the spurious factor(s)? Or, rephrased with respect to the interplay of the activity and market mixes, does the market mix dictate the activity mix or, vis versa?

By first controlling for the activity mix (generation and/or distribution) it is apparent that the market mix is still highly significant--barring the industrial percentage which never was significant (see Table 1). Conversely, when the market mix is controlled, the activity mix becomes insignificant. Thus it seems that the market mix is dominant but this is not equivalent to causality. As was discussed in Chapter IV, causality implies a base in logic. In this situation, it makes sense that the activity mix does follow from the market a utility is engaged in.

The next question is which of the market mix variables, since

TABLE 1

PARTIAL CORRELATION OF COST PER KILOWATT

To		Controlling For
Residential %	.3908 (.001)	
Commercial %	.4086 (.001)	Generation %
Industrial %	.0467 (.282)	
Resale %	-.4469 (.001)	
Residential %	.3809 (.001)	
Commercial %	.4036 (.001)	Distribution %
Industrial %	.0310 (.351)	
Resale %	-.4385 (.001)	
Residential %	.3898 (.001)	
Commercial %	.4045 (.001)	Generation % and
Industrial %	.0291 (.360)	Distribution %
Resale %	-.4396 (.001)	
Generation %	-.0082 (.460)	Residential %
Distribution %	.0329 (.342)	
Generation %	-.0309 (.352)	Resale %
Distribution %	-.0409 (.307)	
Generation %	.0161 (.422)	Residential % and
Distribution %	.0047 (.477)	Industrial %
Generation %	.0711 (.191)	Resale % and
Distribution %	-.0477 (.278)	Industrial %

Number within the parentheses denotes the level of significance.

they are highly intercorrelated, should be entered into the regression (once again refer to Appendix D). Clearly all four cannot be entered. In addition, residential and commercial are significantly correlated and both have a significant negative correlation with the resale percentage. Thus either residential or resale or each paired with industrial should (1) circumvent the major multicollinearity problems within the market mix variables and (2) capture the explanatory powers of the activity mix variables. Any of the four choices would seem appropriate as can be seen from Table 1, and the final choice, resale and industrial percentage, was made not only with regard to the results of this partial correlation analysis[25] but, in addition, with regard to the analyses which follow.

Furthermore, not only is it plausible that the type of market dictates the activity mix, but it may also dominate the type of generation. That is, the significant negative relationships between the cost per kilowatt and steam, hydro and nuclear generation probably reflect the generation activity rather than the type of generation. In addition, since the market mix dominates the activity mix, a partial correlation of the type of generation to the cost per kilowatt controlling for market mix seems reasonable. The results of this analysis suggest that only gas generation has any significant relationship to the cost per kilowatt or, put in another way, that there is

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[25]It should be noted that the pair, resale and industrial percentage, outperform the other three candidates in that the activity mix variables are now opposite in sign to their simple correlations with cost per kilowatt.

no competitive advantage among steam, hydro or nuclear generation (see Table 2).

TABLE 2

PARTIAL CORRELATION OF COST PER KILOWATT

To		Controlling For
Steam generation %	-.0390 (.316)	Resale % and Industrial %
Hydro generation %	.0179 (.413)	
Nuclear generation %	-.0798 (.162)	
Gas generation %	.2563 (.001)	

The same logic can be applied to the variability factors. It was suggested in the previous section that the negative correlation of the load factor may be due to the dominance of the generation activity. In fact, a partial correlation analysis of the load factor to cost per kilowatt, controlling for generation percentage, does reveal a lower negative relationship (-.1603), but one that is still significant at the .05 level. However, the partial correlation controlling for resale and industrial percentage is -.0014 (significance .444), probably reflecting that the explanatory power of the load factor with respect to cost per kilowatt is due to the relative stability of the resale market versus the retail market. Likewise, it was suggested that the significance of the market variability factor was due to the dominance of the distribution activity. A partial correlation analysis of this factor to cost per kilowatt, controlling for resale and industrial percentage, yields -.0576 which, although it is now of the hypothesized sign, is not significant. Thus neither of the variability factors would contribute any explanatory power to the regression analysis to be performed.

In a similar vein, the negative relationship between economies of scale and cost per kilowatt can be explained by the market mix variables. The partial correlation is .1024 (.103 significance) when the resale and industrial percentages are controlled for, once again probably reflecting that the utilities in the wholesale market are the ones that enjoy any large economies of scale.

Finally, the puzzling fossil and nuclear fuel indices may also be explained in a like manner. Since these are weighted by the generation activity, the only fuel indices in the data base would be those utilities engaged in the generation activity--that is, if the generation percentage is zero, the weighted fuel index would be zero since the appropriate fuel index (fossil, nuclear, or gas) would be multiplied by zero. When generation is controlled via controlling the resale and industrial percentages, the fossil fuel index is as hypothesized--positive and significant--and the significance of the gas index does not change. The nuclear index, however, is not significant (see Table 3).

TABLE 3

PARTIAL CORRELATION OF COST PER KILOWATT

To		Controlling For
Fossil fuel (weighted)	.4127 (.001)	Resale % and Industrial %
Nuclear fuel (weighted)	-.0773 (.170)	
Gas fuel (weighted)	.2787 (.001)	

Endogenous variables. Although the relationship of the endogenous variables--staff expense at a percentage of sales, staff expense per kilowatt output, salary expense as a percentage of sales and salary expense per kilowatt output--are all of hypothesized sign and significant with respect to cost per kilowatt, it can be argued that this is due to the type of market (for example, a residential market utility requires more staff than a resale market utility due to the larger number of customers). When the market mix is controlled for, the partial correlations are interesting (see Table 4). Whereas the correlations of the relative measures remain positive and significant, the measures expressed as a percentage of sales exhibit either a negative relationship or no relationship at all. Thus these measures of expense preference variables expressed per unit of physical output remain unexplained by the market activity. However, due to the extremely high correlation between these two relative measures (.9195), the staff salary per kilowatt was chosen as the independent variable due to (1) its higher correlation to cost per kilowatt (both simple and partial) and (2) its reliability.[26]

The negative relationship between return on sales (professional excellence) and cost per kilowatt may also be explained by controlling for the market mix. However, as Table 5 reveals, when the market mix is controlled, this negative relationship becomes even more significant. As a result this measure of professional excellence will be entered into the pooled regression model as an independent variable but with some misgivings. Although the relationships between

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[26]See footnote 22.

TABLE 4

PARTIAL CORRELATION OF COST PER KILOWATT

To		Controlling For
Staff1	-.1649 (.020)	Residential %
Staff2	.3739 (.001)	
Salary1	.0064 (.469)	
Salary2	.2212 (.003)	
Staff1	.2273 (.002)	Industrial %
Staff2	.6103 (.002)	
Salary1	.4227 (.001)	
Salary2	.5438 (.001)	
Staff1	-.1829 (.011)	Resale %
Staff2	.3447 (.001)	
Salary1	.1912 (.009)	
Salary2	.3474 (.001)	
Staff1	-.1807 (.020)	Residential % and Industrial %
Staff2	.3886 (.001)	
Salary1	.0712 (.190)	
Salary2	.2968 (.001)	
Staff1	-.2479 (.001)	Resale % and Industrial %
Staff2	.3181 (.001)	
Salary1	.0295 (.405)	
Salary2	.2386 (.001)	

size of staff and professional excellence to cost per kilowatt are as hypothesized, the relationship between these two endogenous variables is not. There is a significant positive relationship between them whereas a negative relationship is postulated by Williamson. This cannot be explained.

TABLE 5

PARTIAL CORRELATION OF COST PER KILOWATT

To		Controlling For
Return on sales	-.3828 (.001)	Residential %
Return on sales	-.2410 (.001)	Industrial %
Return on sales	-.3545 (.001)	Resale %
Return on sales	-.3743 (.001)	Residential % and Industrial %
Return on sales	-.4190 (.001)	Resale % and Industrial %

In summary.

Dependent variable--cost per kilowatt. Of the two measures discussed in Chapter IV, the second measure which omits the depreciation charge will be used as the dependent variable in the pooled regression model.

Independent variable--exogenous. With respect to the primary hypotheses, significant positive relationships were found between size of staff and cost per kilowatt (H_1) and management salary and cost per kilowatt (H_2). Partial correlation analysis yielded no evidence to doubt these findings. However, the two factors were highly correlated, precluding the entrance of both into the pooled regression model. No relationship was found between unwarranted growth and cost per kilowatt (H_3) and this factor has been discarded. Finally, the expected negative relationship between professional excellence and cost per kilowatt (H_4) was found and the additional partial correlation analysis served only to enhance this relationship. Regretfully, the secondary hypothesis (H_{s1}) postulating a negative relationship between size of staff and professional excellence was rejected thereby rendering the primary hypotheses findings somewhat inconclusive. Nonetheless, professional excellence as measured by return on sales and size of staff as measured by staff expense per kilowatt will be entered into the pooled regression model.

Independent variables--extraneous. The findings of the simple correlation analysis supported the secondary hypotheses concerning the positive relationship between the market mix and cost per kilowatt (H_{s2}), the positive relationship between the activity mix (vertical integration) and the cost per kilowatt (H_{s3}), the negative relationship between economies of scale and cost per kilowatt (H_{s5}), and the negative relationship between the load factor and cost per kilowatt (H_{s6}). However, the subsequent partial correlation analysis revealed that these findings may all be dominated by the market mix--that is, when the market mix was controlled, the partial correlations of these factors with cost per kilowatt become insignificant.

Additional findings of the simple correlation analysis rejected the secondary hypotheses concerning the positive relationship between age and cost per kilowatt (H_{s4}), the negative relationship between the market variability factor and cost per kilowatt (H_{s7}) and the negative relationship between pool transactions and cost per kilowatt (H_{s8}). These findings were not reversed by any subsequent partial correlation analysis.

Although the positive relationships between the fuel indices and the cost per kilowatt (H_{s9}) were rejected by the simple correlation analysis, the subsequent partial correlation analysis did yield a positive fossil fuel index while retaining the initial positive gas fuel index. The lack of a relationship between the nuclear fuel index and the cost per kilowatt was not explained.[27]

Consequently, selected for inclusion in the pooled regression model were the market mix variables, resale and industrial percentage, and the fossil and gas fuel indices.

Results of the Pooled Regression Analysis

Due to the extreme stability present in the utility industry the original pooling formulation is not appropriate. As can readily be seen in Appendix F, pooling by utility over time leads to singularity problems and the computational steps requiring either ordinary least squares or generalized least squares analysis on each cross section (utility) cannot be performed. Thus the use of a cross-sectional pooling methodology is not possible. However, this problem can be circumvented if, instead, a time series pooling methodology is employed. That is, if the data are now pooled by year rather than by utility, the singularity problems are avoided (see Appendix E).

The results of the analysis using the time series pooling

[27]However, it was noted that nuclear fuel is not like the other fuels where there are frequent transactions facilitating the compilation of an index. Since no index could be found, one was constructed from the little information contained in the reports of the three nuclear utilities in Massachusetts.

approach are given in Table 6. As can be readily seen, the Swamy Model does not yield straight forward results. Although the beta values are as expected--

β_1 = negative, indicating an inverse relationship between the industry percentage and cost per kilowatt, probably because the larger the industrial percentage, the smaller the residential and commercial percentages, both of which yield higher costs per kilowatt,

β_2 = negative, indicating, as before, the inverse relationship between resale percentage and cost per kilowatt,

β_3 = positive, indicating the hypothesized direct relationship between staff expense and cost per kilowatt,

β_4, β_5 = positive, indicating the hypothesized direct relationship between the weighted fossil and gas fuel indices and cost per kilowatt,

β_6 = negative, indicating the hypothesized inverse relationship between the return on sales and cost per kilowatt--

they are far from conclusive due to the problems concerning the estimated variances, two of which are negative. Although negative variances are theoretically not possible, they can occur when using the Swamy Model and may indicate specification error.

In the Swamy Model the variance of the betas is dichotomized into a within group component and a between group component with the latter hypothesized to be due to random factors. Thus he postulates the existence of n beta vectors (n in this situation referring to time periods) with their differences due to random factors. To estimate

TABLE 6

SWAMY POOLED REGRESSION RESULTS--ALL VARIABLES

Variable:	Constant	Ind %	Resale %	Staff
B Estimate:	.0292	-.0163	-.0146	.0042
Asymptotic Variance:	.0000	.0000	.0000	.0000

Variable:	Fos Fuel	Gas Fuel	Pro Ex
B Estimate:	.0002	.0163	-.0487
Asymptotic Variance:	.0000	-.0000	-.0000

Pooled R^2: .51

Estimate of delta:

.0003	-.0003	-.0002	-.0001	.0000	.0001	-.0003
-.0003	.0002	.0001	.0001	-.0000	-.0001	.0004
-.0002	.0001	.0001	.0000	-.0000	-.0000	.0002
-.0001	.0001	.0000	.0000	-.0000	.0000	.0001
.0000	-.0000	-.0000	-.0000	.0000	.0000	-.0000
.0001	-.0001	-.0000	.0000	.0000	-.0001	-.0001
-.0003	.0004	.0002	.0001	-.0000	-.0001	-.0001

the between group variance-covariance matrix--called the delta matrix --the within group variance-covariance matrix is subtracted from the total variance-covariance matrix. That is--

$$\text{delta} = \frac{\sum_{i=1}^{n} b_i b'_i - \frac{1}{n}\sum_{i=1}^{n} b_i \sum_{i=1}^{n} b'_i}{N-1} - \frac{\sum_{i=1}^{n} s_{ii}(X'_i X_i)^{-1}}{N}$$

where b_i and s_{ii} are estimates of B_i and σ_{ii}. From Table 6 it can be seen that the between group variance caused by the hypothesized random factors (the delta matrix) is almost nonexistent. This has been suggested to be (1) an indication that the Swamy formulation may not be applicable and (2) an explanation of the negative variances.

In this situation a more appropriate pooling methodology may be the one espoused by Zellner (1966) which assumes, like Swamy, that the observations are from independently and identically distributed populations but, in addition, that there exists only one beta vector--the differences due to repeated samples on the same (fixed) population vector. Here the beta vector is estimated from pooled observations that are first transformed or standardized as follows:

$$\hat{B} = \sum_{i=1}^{n} (X_i'X_i/S_i^2)^{-1} (X_i'Y_i/S_i^2)$$

The results of the Zellner methodology are reported in Table 7. Except for the beta values for the fuel indices, the vectors under each pooling methodology are almost identical. Furthermore, since the Zellner method does yield the expected positive variances, t tests for the beta values are also possible. As is shown, all the t values are significant ($t_{.05,154} = 1.66$) except that for the gas fuel index, which is also of the wrong sign. However, the F statistic with respect to the assumption inherent in the pooling model that the beta vectors over time are equal is clearly rejected ($F_{.05,84,65} = 1.51$) and the pooled R^2 is a dismal .51.[28]

Thus the results of the first analyses are far from heartening. The Swamy methodology yields negative variances which probably indicate some specification error and thus generate little confidence in the results. Likewise the Zellner methodology yields both an F

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[28] Although the Swamy methodology is questionable, its pooled beta vector consistantly was the equal of the Zellner vector throughout this analysis as measured by the pooled R^2.

TABLE 7

ZELLNER POOLED REGRESSION RESULTS--ALL VARIABLES

Variable:	Constant	Ind %	Resale %	Staff
B Estimate:	.0228	-.0167	-.0125	.0079
Asymptotic Variance:	.0000	.0000	.0000	.0000
t Value:	45.68	-.11.33	-25.00	15.80

Variable:	Fos Fuel	Gas Fuel	Pro Ex
B Estimate:	.0037	-.0011	-.0498
Asymptotic Variance:	.0000	.0000	.0000
t Value:	12.33	-.73	-12.45

F Statistic: 13.7961

R^2: .51

statistic and an R^2 which indicate that the methodology is not appropriate and explains little of the variance of the cost per kilowatt. All that can be said is that the signs of the beta coefficients are as hypothesized.

However a perusal of the ordinary least squares results for each time period, combined with some common sense, does suggest a somewhat different approach (see Table 8). First, the gas fuel index contributes little to the regressions and should be eliminated. And secondly, there appears to be two distinct time periods within the data--pre 1973 and post 1973. This should come as no surprise given the oil embargo of 1973 and the subsequent skyrocketing fuel costs faced by the utilities.

However, even if the gas fuel index is eliminated, the results are almost exactly the same (see Tables 9 and 10). As a result the data are divided into the two time periods--1966-1972, 1974-1978--

TABLE 8

ORDINARY LEAST SQUARES RESULT BY YEAR--ALL VARIABLES

Year	Constant	Ind %	Resale %	Staff
1966	.0204 (3.89)	-.0134 (-1.82)	-.0094 (- 3.00)	.0089 (2.44)
1967	.0181 (5.15)	-.0122 (-2.19)	-.0090 (- 4.03)	.0087 (3.04)
1968	.0149 (3.98)	-.0141 (-2.43)	-.0083 (- 3.40)	.0112 (3.14)
1969	.0156 (6.67)	-.0147 (-3.38)	-.0077 (- 4.18)	.0113 (4.19)
1970	.0154 (10.97)	-.0141 (-3.44)	-.0080 (- 4.23)	.0114 (4.44)
1971	.0191 (7.79)	-.0196 (-3.46)	-.0138 (- 6.50)	.0052 (1.88)
1972	.0179 (7.50)	-.0107 (-1.71)	-.0081 (- 3.39)	.0105 (3.12)
1973	.0237 (20.05)	-.0156 (-4.41)	-.0141 (-10.61)	.0059 (3.86)
1974	.0402 (5.22)	-.0220 (- .99)	-.0240 (- 2.70)	.0030 (.43)
1975	.0470 (8.58)	-.0415 (-3.15)	-.0300 (- 5.63)	.0019 (.35)
1976	.0525 (5.58)	-.0525 (-2.84)	-.0309 (- 4.41)	.0008 (.09)
1977	.0638 (7.60)	-.0600 (-3.73)	-.0367 (- 5.21)	-.0107 (-1.16)
1978	.0503 (8.49)	-.0426 (-3.30)	-.0278 (- 6.34)	.0021 (.37)

Year	Fos Fuel	Gas Fuel	Pro Ex
1966	-.0022 (-.70)	.0003 (.01)	-.0503 (-1.72)
1967	-.0011 (-.46)	.0009 (.06)	-.0346 (-1.65)
1968	.0000 (.00)	-.0149 (- .82)	-.0216 (- .92)
1969	-.0008 (-.37)	-.0111 (- .95)	-.0265 (-1.55)
1970	.0005 (.39)	-.0128 (-1.18)	-.0224 (-1.56)
1971	.0042 (2.49)	.0041 (.40)	-.0009 (- .05)
1972	.0002 (.08)	-.0178 (-1.73)	-.0179 (-1.21)
1973	.0033 (4.46)	-.0059 (-1.54)	-.0187 (-2.46)
1974	-.0006 (-.30)	-.0054 (- .50)	-.0326 (- .84)
1975	.0034 (3.00)	-.0043 (- .60)	-.0598 (-1.94)
1976	.0029 (1.73)	-.0009 (- .07)	-.0766 (-1.69)
1977	.0025 (1.80)	.0116 (1.05)	-.0932 (-2.32)
1978	.0015 (1.04)	.0016 (.21)	-.0510 (-1.25)

Number within the parentheses denotes the t values where $t_{.05,11} = 1.796$.

TABLE 9

SWAMY AND ZELLNER POOLED REGRESSION RESULTS--GAS FUEL INDEX OMITTED

Swamy Results--

Variable:	Constant	Ind %	Resale %	Staff
Betas:	.0280	-.0149	-.0144	.0063
Asymptotic Variance:	.0000	.0000	.0000	.0000

Variable:	Fos Fuel	Pro Ex
Betas:	.0007	-.0449
Asymptotic Variance:	.0000	-.0000

Pooled R^2: .56

Estimate of delta:

.0002	-.0002	-.0002	-.0001	.0000	-.0003
-.0002	.0002	.0001	.0000	-.0000	.0004
-.0002	.0001	.0001	.0000	-.0000	.0002
-.0001	.0000	.0000	.0000	-.0000	.0001
.0000	-.0000	-.0000	-.0000	.0000	-.0000
-.0003	.0004	.0002	.0001	-.0000	-.0001

Zellner Results--

Variable:	Constant	Ind %	Resale %	Staff
Betas:	.0232	-.0173	-.0128	.0077
Asymptotic Variance:	.0000	.0000	.0000	.0000
t Value:	46.40	-11.53	-25.60	25.67

Variable:	Fos Fuel	Pro Ex
Betas:	.0038	-.0524
Asymptotic Variance:	.0000	.0000
t Value:	12.67	-12.78

F Statistic: 17.013

Pooled R^2: .51

TABLE 10

ORDINARY LEAST SQUARES RESULTS BY YEAR--GAS FUEL INDEX OMITTED

Year	Constant	Ind %	Resale %
1966	.0203 (4.81)	-.0134 (-2.00)	-.0093 (- 4.11)
1967	.0180 (6.43)	-.0122 (-2.41)	-.0089 (- 5.66)
1968	.0168 (6.04)	-.0139 (-2.45)	-.0095 (- 4.96)
1969	.0170 (9.23)	-.0141 (-3.31)	-.0086 (- 5.49)
1970	.0164 (14.57)	-.0143 (-3.41)	-.0095 (- 6.57)
1971	.0186 (9.79)	-.0196 (-3.75)	-.0134 (- 8.13)
1972	.0207 (10.13)	-.0089 (-1.25)	-.0101 (- 4.17)
1973	.0249 (15.02)	-.0160 (-4.09)	-.0150 (-11.41)
1974	.0422 (6.03)	-.0228 (-1.11)	-.0259 (- 3.43)
1975	.0494 (14.10)	-.0440 (-3.74)	-.0320 (- 8.19)
1976	.0530 (8.69)	-.0529 (-3.25)	-.0312 (- 6.51)
1977	.0568 (16.89)	-.0557 (-3.56)	-.0313 (- 6.46)
1978	.0496 (11.09)	-.0435 (-3.95)	-.0275 (- 7.14)

Year	Staff %	Fos Fuel	Pro Ex
1966	.0090 (8.97)	-.0022 (- .77)	-.0503 (-1.88)
1967	.0089 (11.83)	-.0011 (- .50)	-.0346 (-1.80)
1968	.0083 (9.23)	-.0005 (- .17)	-.0252 (-1.12)
1969	.0089 (9.81)	-.0010 (- .48)	-.0279 (-1.65)
1970	.0085 (11.89)	.0007 (.56)	-.0155 (-1.15)
1971	.0062 (6.43)	.0042 (2.67)	-.0012 (- .07)
1972	.0051 (3.64)	-.0001 (- .03)	-.0168 (- .99)
1973	.0038 (4.75)	.0032 (3.95)	-.0180 (-2.13)
1974	.0002 (.06)	-.0005 (- .26)	-.0340 (- .94)
1975	-.0010 (- .47)	.0034 (3.22)	-.0630 (-2.10)
1976	-.0014 (- .48)	.0029 (1.89)	-.0773 (-1.91)
1977	-.0015 (- .56)	.0025 (1.79)	-.0895 (-2.22)
1978	.0032 (1.58)	.0016 (1.23)	-.0499 (-1.34)

and rerun.

The results for the time period 1966-1972, shown in Table 11, are more interesting. It can be seen that the Swamy methodology is still questionable with five of the six estimated variances now negative. As before, the delta matrix is essentially a null matrix indicating the absence of the postulated between group random variation. Nonetheless, the R^2 is a remarkable .94 and the signs of the values are as hypothesized. On the other hand, the Zellner results are consistently excellent. The beta values are of the right sign and significant ($t_{.05,82} = 1.66$)--excepting the fossil fuel index.[29] In addition, the F statistic does not result in rejection of the fixed beta vector hypothesis ($F_{.05,36,42} = 1.71$) and the pooled R^2 is even higher, .96.

In like fashion, the results from the time period 1974-1978 are equally interesting (see Table 12). The Swamy methodology is still questionable--four of the six estimated variances are negative and the delta matrix is again essentially a null matrix. Yet, as before, the betas are all of the correct sign and the R^2 is .85. Likewise, the Zellner model yields betas of the correct sign, an F statistic that cannot be rejected ($F_{.05,24,30} = 1.89$), and an R^2 of .86. Of more interest, however, is the significance of the betas ($t_{.05,58} = 1.66$). As expected, the fossil fuel index is now significant reflecting the almost threefold increase in the index. Moreover, as hypothesized by Cyert and March (1963), Onsi (1963) and others, the staff variable is no longer significant. This slack or, as Williamson terms it, expense preference item has now been converted

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[29]The insignificant t value for the fossil fuel index is not unexpected. If one refers to Appendix B, the reason is quite clear. For the period 1966-1969 the index is virtually constant thereby contributing nothing to the regression. It is only in the subsequent three years (1970-1972) that this index does affect the regression and for this reason it is included.

TABLE 11

SWAMY AND ZELLNER POOLED REGRESSION RESULTS--FOR PERIOD 1966-1972 WITH GAS FUEL INDEX OMITTED

Swamy Results--

Variable:	Constant	Ind %	Resale %	Staff
Betas:	.0178	-.0138	-.0113	.0072
Asymptotic Variance:	-.0000	-.0000	-.0000	.0000

Variable:	Fos Fuel	Pro Ex
Betas:	.0001	-.0157
Asymptotic Variance:	-.0000	-.0000

Pooled R^2: .94

Estimate of delta:

-.0000	.0000	.0000	-.0000	.0000	.0000
.0000	-.0000	-.0000	-.0000	-.0000	-.0000
.0000	-.0000	-.0000	.0000	-.0000	-.0000
-.0000	-.0000	.0000	.0000	-.0000	-.0000
.0000	-.0000	-.0000	-.0000	-.0000	.0000
.0000	-.0000	-.0000	-.0000	.0000	-.0000

Zellner Results--

Variable:	Constant	Ind %	Resale %	Staff
Beta:	.0176	-.0139	-.0098	.0083
Asymptotic Variance:	.000000	.000003	.000000	.000000
t Value:	25.14	-7.72	-16.23	27.67

Variable:	Fos Fuel	Pro Ex
Beta:	.0010	-.0245
Asymptotic Variance:	.000000	.000035
t Value:	1.43	-4.15

F Statistic: 1.5252

Pooled R^2: .96

due to hard times besetting the utility industry.

For ease in interpreting the results, the outputs using the

TABLE 12

SWAMY AND ZELLNER POOLED REGRESSION RESULTS FOR THE TIME PERIOD 1974-1978 WITH THE GAS FUEL INDEX OMITTED

Swamy Results--

Variable:	Constant	Ind %	Resale %	Staff
Beta:	.0486	-.0406	-.0289	.0003
Asymptotic Variance:	.0000	-.0000	-.0000	-.0000

Variable:	Fos Fuel	Pro Ex
Beta:	.0018	-.0532
Asymptotic Variance:	.0000	-.0000

Pooled R^2: .85

Estimate of delta:

.0000	-.0000	.0000	.0000	.0000	-.0000
-.0000	-.0001	-.0000	-.0000	-.0000	.0002
.0000	-.0000	-.0000	-.0000	.0000	.0001
.0000	-.0000	-.0000	-.0000	-.0000	.0000
.0000	-.0000	.0000	-.0000	.0000	-.0000
-.0000	.0002	.0001	.0000	-.0000	-.0009

Zellner Results--

Variable:	Constant	Ind %	Resale %	Staff
Beta:	.0470	-.0388	-.0291	.0008
Asymptotic Variance:	.000004	.000035	.000004	.000001
t Value:	24.74	-6.58	-14.55	.73

Variable:	Fos Fuel	Pro Ex
Beta:	.0027	-.0402
Asymptotic Variance:	.000000	.000207
t Value:	4.50	2.79

F Statistics: 1.64

Pooled R^2: .86

Zellner methodology are synopsized together with the standardized betas in Table 13. The t values and the standardized betas seems to reflect much the same picture for each time period. For 1966-1972, the most important variable was the constant probably indicating the relative stability of the cost per kilowatt (s = .008). The next in terms of relative importance was the staff cost per kilowatt followed closely by the resale percentage. The industrial percentage was of limited importance while the fossil fuel index and return on sales, although significant, seem to contribute little to the regression. In summary, the results for this time period indicated that there was a significant relationship between the independent variables and the cost per kilowatt, as hypothesized, which explained 96% of the variance of the cost per kilowatt.

The results for the time period 1974-1978 clearly show the constant to be the most important--again probably due to the relative stability of the cost per kilowatt (s - .011). However, now the resale percentage is next in importance with the industrial percentage and fossil fuel index contributing somewhat to the regression. The return on sales, although still significant, adds little to the regression and the staff per kilowatt is insignificant. Thus the conclusions for this time period are exactly the same as the prior: a significant relationship was manifested which explained 86% of the variance of the cost per kilowatt.

TABLE 13

SYNOPSIS OF THE RESULTS WITH STANDARDIZED BETAS ADDED

1966-1972	$R^2 = .96$					
	Constant	Ind %	Resale %	Staff	Fos Fuel	Pro Ex
Betas	.0176	-.0139	-.0098	.0083	.0010	-.0245
t Value	25.14	-7.72	16.33	27.67	1.43	4.15
B*	2.2000	-.2120	-.5317	.6796	.0373	-.0980
$t_{.05,82} = 1.66$						

1974-1978	$R^2 = .86$					
	Constant	Ind %	Resale %	Staff	Fos Fuel	Pro Ex
Betas	.0470	-.0388	-.0291	.0008	.0027	-.0402
t Value	24.74	-6.58	-14.55	.73	4.50	-2.79
B*	4.2727	-.3880	-1.1693	.0433	.2533	-.1316
$t_{.05,58} = 1.67$						

Summary

The results of this study can best be aummarized by listing them in order of hypotheses as stated at the end of Chapter IV.

H_1--Supported by the correlation analysis and further supported by the results of the pooled regression analysis where size of staff was found to be the most important factor (aside from the constant) in explaining the variance of the costs per kilowatt in the first time period--characterized as good times--and insignificant in the second--characterized as bad times.

H_2--Although supported by the correlation analysis, little confidence can be expressed due to the multicollinearity with the staff item.

H_3--Rejected.

H_4--Although supported by the correlation analysis, this factor was found to be of limited use in explaining the variance of the costs per kilowatt in the subsequent pooled regression analysis.

H_{1S}--Rejected therefore adding further question to the correlation results with respect to H_4.

H_{2S}--Supported by the correlation analysis and found to be of importance when explaining the variance of the costs per kilowatt in the subsequent pooled regression analysis.

H_{3S}--Supported by the correlation analysis but little confidence can be expressed due to the multicollinearity with the market integration factors.

H_{4S}--Rejected.

H_{5S}--Supported by the correlation analysis but little confidence can be expressed due to the multicollinearity with the market integration factors.

H_{6S}--Supported by the correlation analysis but little confidence can be expressed due to the multicollinearity with the market integration factor.

H_{7S}--Rejected.

H_{8S}--Rejected.

H_{9S}--For nuclear fuel rejected; for gas and fossil supported by the correlation analysis but found to be of limited use in the subsequent pooled regression analysis.

C H A P T E R V I

CONCLUSIONS, LIMITATIONS AND IMPLICATIONS FOR FURTHER RESEARCH

Conclusions

Due to the shortcomings with the conventional measures of management efficiency based upon profitability, the purpose of this study was to develop a prototype efficiency measurement model for the regulated utility sector. The Massachusetts electric utility industry was selected as a data base and, given the failure of past attempts to deal with the problem of efficiency measurement, the analysis proceeded in three stages.

First, the focus was narrowed to top management efficiency because this, in fact, was the crux of the problem. Studies reporting on all levels of management are helpful but tend to focus on lower levels of management where efficiency models are well defined (for example, simple variance analysis). Top management efficiency always seems to be ignored due both to its nebulous nature and to the methodological problems that must be surmounted.

Secondly, the traditional economic definition of efficiency in the regulated sector was abandoned because of its total lack of concern with control. Clearly management can only be held accountable for that which they control; yet the economic definition focuses on factor inputs to the production process over which current management has limited control. As a result a behavioral definition of efficiency espoused by Williamson (1964) was adopted which focused on expense preference items fully controllable by top management. It was postulated that management, freed from competitive pressures, would seek personal goals manifested by an increasing of staff, the addition of emoluments or a striving for professional excellence. And, using the traditional accounting input/output definition of efficiency, the first two would be indicative of inefficient management and the third of efficient management.

Although theoretically preferable, physical measures of inputs consumed to kilowatt output were not practical and, thus, dollar surrogates were used yielding cost per kilowatt as the operationalized measure ofefficiency for this model. Thus it was hypothesized that if it could be shown that high costs per kilowatt were consistant with high staff costs and/or high emoluments and conversely low costs per kilowatt were consistant with high measures of professional excellence, then it could be concluded that the Williamson model was supported yielding short-run measures of top management efficiency.

However, to compare costs per kilowatt for various utilities necessitated a rigorous methodology and thus the third stage was required. Too many previous studies in the utility sector had been invalidated due to poor research design. Utilities differ over many dimensions which must be controlled in order to accomplish any comparative analysis. Consequently, a survey of the literature was undertaken to identify these dimensions and their relationship with cost per kilowatt.

The results of the analysis do support the above hypothesis--but to varying degrees. For the period 1966-1972, a time which Cyert and March (1963) might describe as a "good time" or one which Williamson (1964) might describe as a time where "discretionary opportunities are available," the staff variable (1) was positively correlated with cost per kilowatt and (2) when entered into the pooled regression model was the most important variable, aside for the constant, in explaining the variance of the cost per kilowatt. In addition, during 1974-1978, which can be characterized as "bad times" where "discretionary opportunities" are not available, the staff variable exhibits no relationship to cost per kilowatt, further supporting the use of the expense preference theory in this thesis.

One may argue that the finding only proves the obvious--that in bad times discretionary expenses are curtailed. Yet this is the very essence of the problem. Since the measures used in this thesis are relative measures (that is, expressed on a cost per kilowatt basis), if a drastic cut in their relative expenses has no effect on performance, then this would indicate that the initial level cannot be supported as being efficient. For the time period 1974-1978, there is no indication that the drop in discretionary costs caused any change in the effectiveness of the utilities.

However, the results with respect to the emoluments variable, operationalized as management salary per kilowatt due to the lack of data on emoluments, are inconclusive because of the high degree of correlation with the staff variable. It cannot be said with any confidence that the observed positive correlation between this variable and cost per kilowatt supports the use of the expense theory and is not due to the confounding effect of the staff variable.

Likewise, the results of the professional excellence variable, operationalized as return on sales, is somewhat inconclusive. Even though the correlation analysis does yield the hypothesized direct relationship to cost per kilowatt, when entered into the pooled regression model, this factor explains little of the variance in the cost per kilowatt. In addition, the expected negative correlation between this variable and the previous two expense preference items was not found, further weakening the results of the correlation analysis with respect to this variable.

The lack of support for the unwarranted growth factor is not all that damaging to the other conclusions in that it was not culled from the Williamson model but rather was identified from testimony before the Massachusetts DPU. There was no theory base for this factor.

Before one concludes that firm support for one item out of three is not particularly strong support for the hypothesis as a whole, it should be recognized that the high correlation between the first two items is not that unexplainable. If a manager feels that professional excellence is not a viable means of achieving personal goals, there is no reason why both size of staff and emoluments cannot be selected as alternatives since both are thought to be indicative of achievement or success. Thus the high correlation between the first two items may be construed as a positive finding in itself.

As a result, since the direct relationship(s) between size of staff and/or emoluments to cost per kilowatt cannot be explained by the varying dimensions of the utilities in this study, it can be concluded that it (they) is (are) indicative of top management inefficiency. Recognizing that the purpose of any variance analysis is attention directing rather than problem solving, a less forceful conclusion might be to substitute the word "could" for "can" in the above sentence, arguing that it is now the task of the utilities to explain why this is not the case. However, since the customary rebuttal of the utilities--that they are not comparable--has been negated by the methodology employed and the results of the pooled regression analysis indicate that essentially all of the variance in the cost per kilowatt has been explained by this model, any explanations other than this lack of efficient management should prove difficult.

Therefore the major contributions of this thesis is to demonstrate that short-run top management efficiency measurement is possible in the regulated utility sector. By controlling for the extraneous factors that have plagued previous works in this area,[30] it has been shown that at least one expense preference item--size of staff--can be used to explain high costs per kilowatt and, consequently, can be used as a measure of efficiency for the Massachusetts electric utility industry.

However, an exact methodology to be used to assess top management efficiency on a firm by firm basis for any given year has not

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[30] In addition, the methodology employed in this study is, in itself, a major contribution to research in this area. It has been shown that dissimilarities among utilities can be treated and that observations can be pooled creating a data base upon which conclusions can be drawn with a high degree of confidence.

been discussed. To simply conclude that high staff costs per kilowatt are indicative of inefficient management is not sufficient, again due to the varying dimensions of these utilities. As before, these differences must be controlled before any meaningful comparisons can be made.

In addition, it should be understood that a continuous measure of efficiency is not sought but, rather, categorical groupings of, say, "indicative of inefficient manage,ent," "questionable with respect to efficient management," and "indicative of efficient management" are more in order. For example, after controlling for the varying characteristics, if it could be shown that high staff costs per kilowatt-purged of the effects of the varying characteristics--are consistant with high costs per kilowatt--also purged of the effects of the varying characteristics, then these firms could be categorized as "indicative of inefficient management." If continuous measures were to be used, this test for association would be no more than a partial correlation analysis which would be interpreted as the higher the partial correlation, the higher the confidence one could express that high staff costs are indicative of inefficient management and, vice versa. However, since categorical groupings seem more appropriate, the non-parametric index of predictive association, λ, as developed by Goodman and Kruskal[31] will be used where λ is defined as

$$\frac{P(\text{Error}/A_j \text{ unknown}) - P(\text{Error}/A_j \text{ known})}{P(\text{Error}/A_j \text{ unknown})}$$

[31] An excellent discussion of the Goodman and Kruskal Index is contained in Statistics: Probability, Inference, and Decision by Hays and Winkler (1971), pp. 805-810.

Essentially, if one were to guess whether a utility would exhibit a high, medium or low cost per kilowatt given no information, out of the twelve utilities in any given year one would, on average, guess four correctly and eight incorrectly; that is, P (error/A_j unknown) = 8/12. However, if one were given some information, A_j defined as the category the utility exhibits with respect to staff costs, the index λ will express how many of the eight errors would now be categorized correctly. Thus, a λ of 8/8 or 1 would indicate a perfect correspondence between the staff category and the cost per kilowatt category. Conversely, a λ of 0/8 or 0 would indicate that the staff cost category has no association with the cost per kilowatt category, and a negative λ would indicate that there exists a negative relationship or that one would be better off guessing blindly than categorizing the cost per kilowatt based upon the staff cost category.

To apply this methodology requires three steps. First, since it was found that the dominant factor which captured the effects of the varying dimensions was the market mix, two ordinary least squares analyses will be performed for each year with the market variables--industrial percentage and resale percentage--as independent variables and staff cost and operating cost[32] per kilowatt, respectively, as the dependent variable. Secondly, using the results of these regressions, both the staff costs and operating costs per kilowatt will be standard-

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[32]Operating cost per kilowatt is used here rather than the previous cost per kilowatt to focus on those items most likely to be controllable by top management.

ized by purging them of the effects of the varying market percentages. That is, the betas can be interpreted as the advantage a particular utility would enjoy with respect to either its operating costs or its staff costs by not being solely a residential supplier, but rather by being involved to some degree in either the industrial or resale markets. To standardize the utilities, or to make them comparable, these advantages will be added back to both the staff cost and operating cost per kilowatt. Finally, a three-by-three contingency table will be employed to test the degree of association between the high, medium, and low staff costs and the high, medium and low operating costs per kilowatt using the index of predictive association.

Since these steps are complicated, they will be illustrated using the 1966 data. First, the ordinary least squares analyses are performed on the twelve firms with the staff costs and operating costs per kilowatt as dependent variables. The data as well as the computations for all the time periods are presented in Appendix G. Table 14 contains the results which can be interpreted in the following manner: staff cost per kilowatt is expected to be 1.3399 but will decrease 2.4492 per unit of industrial percentage and 1.3024 per unit of resale percentage. Since both the industrial and resale variables are expressed as decimals between 0 and 1.00, the absolute maximum decrease is 2.4492 and 1.3024, respectively with the industrial being substantially less since the maximum industrial market share is 38% or .38.

Next, both the staff cost and operating cost per kilowatt for each utility are standardized using the results from Table 14. For example, since Firm 1 sells fourteen percent of its output to industrial

TABLE 14

ORDINARY LEAST SQUARE RESULTS: STAFF COST AND OPERATING COST PER KILOWATT AS DEPENDENT VARIABLES--1966

Dependent variable	Staff/kw	Operating cost/kw
Betas:		
Constant	1.3399	.0206
Industrial percentage	-2.4492	-.0250
Resale percentage	-1.3024	-.0160
R^2	.43	.64

customers and thirteen percent in the wholesale market it should exhibit both a lower staff cost and a lower operating cost per kilowatt than a firm distributing one hundred percent of its output to residential customers (that is, industrial = resale percentage = 0). Thus to make Firm 1 comparable, this advantage is added back to its observed staff cost and operating cost per kilowatt:

$$.4642 + (.14)(2.4492) + (.13)(1.3024) = .9764$$

and $$.0101 + (.14)(\ .0250) + (.13)(\ .0161) = .0157.$$

It is assumed that these numbers are now purged of any effects with respect to market mix and are comparable to other firms in this time period.

Lastly, these standardized costs are ranked and the contingency table constructed. See Table 15.

TABLE 15

STANDARDIZED COSTS AND THE RESULTING CONTINGENCY TABLE FOR 1966

Firm	Standardized Operating Cost	Rank	Standardized Staff Cost	Rank
1	.0157	11	.9764	10
2	.0144	12	.4348	12
3	.0208	5	1.5446	2
4	.0175	9	.8019	11
5	.0186	8	1.2396	8
6	.0204	6/7	1.1618	9
7	.0259	2	1.4180	4
8	.0217	4	1.3486	6
9	.0224	3	1.5075	3
10	.0204	6/7	1.4042	5
11	.0171	10	1.3071	7
12	.0317	1	2.9341	1

Operating cost \ Staff cost	H	M	L
H	3	1	
M	1	2	1
L		1	3

$$\lambda = \frac{8 - 4}{12 - 4} = .50$$

Table 16 summarizes the results for all years (see Appendix G for the intermediate computations).

TABLE 16

GOODMAN AND KRUSKAL INDEX OF PREDICTIVE ASSOCIATION--
1966-1978 OPERATING COST/KW TO STAFF COST/KW

Year	λ	Year	λ
1966	.50	1972	.25
1967	.50	1974	.00
1968	.50	1975	-.38
1969	.63	1976	-.13
1970	.25	1977	-.13
1971	-.13	1978	.00

As can readily be seen, this methodology does not generate perfect results; at best this method will classify nine of twelve utilities correctly yielding a λ of 5/8 or .63. However these results are not unexpected. For the time period 1966-1972, this categorical procedure does reveal useful information--excepting 1971--which is consistant with the previous findings that the staff/kw variable was the most important variable when attempting to explain the variance of the cost per kilowatt. Likewise, for the time period 1974-1978, this procedure was found to be totally worthless. This, too, is consistant with the previous finding that the staff/kw contributed nothing when attempting to explain the variance of the cost per kilowatt for this period.

Before one draws any conclusions from these results, it should be noted that this test of association is tentative at best. A close reading of Appendix G reveals that the simple ranking where the top four are designated "high" cost and the next four "medium" is questionable. There are many occurances where it would be hard to justify the rankings. For instance, in 1966 the fourth highest staff cost was 1.4180 and the fifth, 1.4042. Is this difference large enough to justify one being called "high" and the other "medium"? However, the problems were even more numerous when quartile rankings were attempted and subjective rankings by "apparent" clusters were subject to extreme bias. Thus the three group ranking was adopted.

Yet, if the tentativeness of the ranking procedure was the only problem, this would not be too unsettling. Additional research with respect to alternative ranking procedures would probably yield a solution that would be acceptable. The unsettling feature that is highlighted by Table 16 is the complete failure for the 1974-1978 time period. The ramifications with respect to designing a control system to monitor top management efficiency in this area are immense. It would seem that for the system to be operative one must first ascertain whether the time period in question can be described as a "good" time where expense preference items can be expected or as a "bad" time where these items are now minimal and immaterial. Although this problem is discussed here in the "Conclusions" section, it may be that it could equally as well be included in the "Limitations" and/or the "Implications for Further Research" sections which follow.

Limitations

First and foremost, the above conclusions are sample specific and, as stated, pertain solely to the Massachusetts electric utility industry. Generalizing these conclusions would require a much larger sample over many jurisdictions. However one general conclusion that can be drawn from this project is that the results justify a more comprehensive study. But, due to the immense problems concerning data compilation, any further research is almost necessarily predicated upon access to a centralized data bank.

Secondly, this study is probably one of the first to specifically treat the many extraneous factors that affect research in this area. The results of any analysis are only as good as the assumptions upon which the analysis is based. Consequently great care was taken to describe the processes used to define and measure these extraneous variables. Many may disagree with the methods employed and espouse alternative procedures. This, in itself, should be considered a contribution to this research area for it will only be through such constructive communication that proper definitions and measurement devices for these differing dimensions will be attained.

Likewise regarding the endogenous variables, Williamson attached construct definitions to his expense preference items. Size of staff, emoluments and discretionary profits are not easily operationalized given the information that is available to the public for the regulated utilities. As above, attempts have been made to measure these variables with which many may not agree. For example, since discretionary profits probably does not apply to a regulated sector, the factor was expanded to capture what Williamson seemingly was attempting to identify--management motivated by achievement or "professional excellence." Using return on sales as a surrogate may not be correct as indicated by the lack of an inverse relationship between it and the first two preference items. However, the attitudinal approach used by Onsi (1963) did not seem appropriate and there seemed no other logical alternatives. Thus it is recognized that further research in this area is needed and constructive criticism is expected and desired.

The last limitation deals more with the methodology than with the problems inherent in the variable measurement area. This study is founded on a variance analysis based on historical data rather than on any type of standard. If, in fact, all utilities included in this data base were inefficient, this methodology would not reveal such a situation. It is only when the data reflect the whole spectrum of efficiency that the methodology will be appropriate. It would be theoretically more correct to use an engineering approach where standards would be set for each item and variance than analyzed. This, however, is not realistic due to the discretionary nature of the costs and, therefore, the historical approach taken can be defended on a pragmatic basis. Nonetheless, to insure confidence in this approach dictates a large sample where the probability is greater than the entire spectrum of efficiency is captured.

Implications for Further Research

Aside from the implications referred to in the prior section, additional avenues for further research do suggest themselves. As discussed in Chapter IV, the availability of additional, more refined data now required by the SEC in Releases 33-6003 and 33-5949 (issued in 1978) will permit (1) more accurate measurement of one variable--

emoluments--and (2) the inclusion of one additional variable that was captured only in an oblique fashion in this study--the opportunity for discretion. It is now necessary to report emoluments distinct from management salary, thus making the measurement of this variable much less troublesome. It would be interesting to discover whether emoluments is a separate item that does capture a different dimension than size of staff or, as hypothesized in the prior section, that either can be used to identify a management that does not perceive professional excellence as its only means of achievement.

In addition, the opportunity for discretion may now be treated in a more direct fashion. Berle and Means (1932) suggested that data on management security holdings may be helpful, postulating that having a significant interest in a company might motivate management to be more efficient. Since this data is now required by the SEC, inclusion of this variable is possible in future studies using utilities registered with the SEC.

Another approach to this problem that might circumvent the extraneous factors problem is to treat the holding companies as one large utility rather than as was done in the study, to ignore them and simply treat the individual subsidiaries--each of which is usually involved in only one activity--as separate utilities. For example, Holyoke Water Power generates power for Northeast Utilities which in turn distributes through Western Massachusetts Electric. Whatever regulating and/or tax advantage that is accrued from this corporate structure is not the issue; although legally distinct entities they, in essence, are divisions of one utility--Northeast Utilities. In

Massachusetts there are five such holding companies which, on a consolidated basis, are probably quite similar over all dimensions and therefore readily comparable. However, many problems with this approach are immediately apparent. First, to produce consolidated information would not be easy unless full information with respect to intercompany transactions is available and, since this corporate structure affords these holding companies some economic advantage, it is unlikely that this information would be made available. Secondly, these holding companies encompass more than one jurisdiction, thus raising the problem of non uniformity of data. Northeast Utilities has holdings in three New England states, all with different reporting requirements. And lastly, all utilities are not wholly owned by the holding companies. It is common practice to buy percentage interests in generating plants, based upon projected demands and this further complicates the consolidated approach. Yet, since these utilities do share a common management, this consolidated approach may be another way to test the feasibility of using the expense preference model to measure top management efficiency.

To End

The introductory chapter of this thesis described the problem of efficiency measurement in the regulated sector and enumerated three major issues: (1) the lack of operational definitions, (2) the varying characteristics which do not facilitate interutility comparisons, and (3) the small number of firms resulting in questionable validity of common statistical methodologies. Each has been treated in detail with the end result being a short-run efficiency management model which, although subject to a number of limitations, successfully dealt with the above problems and performed well, producing significant results. Moreover, due to the availability of desirable, more refined data in the very near future, further research using this methodology appears promising.

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APPENDIX A

MASSACHUSETTS ELECTRIC UTILITIES USED IN THE STUDY

Boston Edison Company
Boston, Massachusetts

Brockton Edison Company
Brockton, Massachusetts

Cambridge Electric Light Company
Cambridge, Massachusetts

Fall River Electric Light Company
Fall River, Massachusetts

Holyoke Water Power Company
Holyoke, Massachusetts

Manchester Electric Company
Manchester, Massachusetts

Massachusetts Electric Company
Westborough, Massachusetts

Montaup Electric Company
Fall River, Massachusetts

New England Power Company
Westborough, Massachusetts

Nantucket Electric Company
Nantucket, Massachusetts

Western Massachusetts Electric Company
West Springfield, Massachusetts

Yankee Atomic Electric Company
Westborough, Massachusetts

APPENDIX B

FUEL INDICES--1966 = BASE YEAR

Year	Oil	Coal	Nuclear	Gas
1966	1.00	1.00	1.00	1.00
1967	.95	1.05	.86	1.05
1968	.91	1.09	.96	1.06
1969	.89	1.18	.96	1.11
1970	1.19	1.60	.86	1.14
1971	1.58	1.94	.77	1.17
1972	1.51	2.08	.83	1.13
1973	1.81	2.34	.92	1.24
1974	4.62	3.57	1.11	1.87
1975	4.72	4.07	.94	2.11
1976	4.31	3.86	1.32	2.19
1977	4.98	4.09	1.47	2.35
1978	4.74	4.52	1.79	2.46

Source: Survey of Current Business--National Income Issue, United States Department of Commerce, Office of Business Economics.

APPENDIX C

GLOSSARY OF ABBREVIATIONS USED IN TABLES AND APPENDICES

Costkw1--cost per kilowatt which includes a charge for depreciation.

Costkw2*--cost per kilowatt which omits depreciation.

Res %--percentage of total output used by residential consumers.

Comm %--percentage of total output used by commercial consumers.

Ind %--percentage of total output used by industrial consumers.

Resale %--percentage of total output sold wholesale.

Pool--total kilowatts either sold to or bought from the energy pool.

Gen %--percentage of total dollars invested in generation plant after adjustment for specific price level factors.

Dist %--percentage of total dollars invested in distribution plant after adjustment for specific price level factors.

SGen %--percentage of total assets invested in steam generation.

HGen %--percentage of total assets invested in hydro generation.

NGen %--percentage of total assets invested in nuclear generation.

GGen %--percentage of total assets invested in gas generation.

Staff1--staff expense expressed as a percentage of sales.

Staff2--staff expense per kilowatt output.

Salary1--management salary expense expressed as a percentage of sales.

Salary2--management salary per kilowatt output.

VarMkt--the ratio of (Res % + Comm %) to (Res % + Comm % + Ind %) multiplied by the Dist %; postulated to be a measure of stability for the distribution activity.

VarLoad--the ratio to peak demand to average demand multiplied by the Gen %; postulated to be a measure of stability for the generation activity.

U--unwarranted growth factor derived from multiplying the growth rate by the excess capacity ratio.

EofS1--economy of scale factor derived by taking the logarithm of capacity and then multiplying it by the Gen %.

EofS2--economy of scale factor derived by taking the logarithm of the output.

FosFuel--the fossil fuel index derived from averaging the coal and oil fuel indices and then multiplying by the Gen %.

NucFuel--the nuclear fuel index derived by multiplying the nuclear fuel index by the Gen %.

GasFuel--the gas fuel index derived by multiplying the gas fuel index by the Gen %.

AgeS--the weighted average age of the steam generation facilities.

AgeH--the weighted average age of the hydro generation facilities.

AgeN--the weighted average age of the nuclear generation facilities.

AgeG--the weighted average age of the gas generation facilities.

ProEx1--the variance of the return on equity from the allowed 13%.

ProEx2--the return on sales.

A P P E N D I X D

CORRELATION MATRIX FOR ALL VARIABLES

	Costkw1	Costkw2	Res %	Comm %	Ind %	Resale %	Pool	Gen %	Trans %	Dist %	SGen %	HGen %	NGen %	GGen %	Staff1
Costkw1	1	.9951	.5928	.5768	.1033	-.6195	.0419	-.4358	-.2376	.4452	-.4002	-.3367	-.2762	.4721	.3018
Costkw2		1	.5833	.5631	.1159	-.6134	.0328	-.4705	-.2205	.4787	-.3789	-.3224	-.3040	.4075	.2409
Res %			1	.6655	.0416	-.8627	-.1127	-.7997	-.2347	.7927	-.6200	-.4326	-.3683	.3362	.5976
Comm %				1	.4592	-.8960	.0541	-.5643	-.1407	.5664	-.3054	-.5390	-.3392	.3498	.5030
Ind %					1	-.4927	.1899	-.1599	-.0936	.1862	.1993	-.1491	-.1897	-.2019	.1537
Resale %						1	-.0112	.7403	.2277	-.7452	.4175	.5114	.4020	-.2566	-.5838
Pool							1	.1479	.3292	-.1940	.1128	.2214	.0104	-.0961	-.0146
Gen %								1	.0955	-.9873	.5304	.4254	.3841	.1584	-.1743
Trans %									1	-.2433	.2766	.3109	-.1786	-.2447	-.3330
Dist %										1	-.5441	-.4617	-.3385	-.1491	.1896
SGen %											1	.2269	-.3093	-.2636	-.3374
HGen %												1	-.1625	-.1572	-.1527
NGen %													1	-.1181	-.2586
GGen %														1	.6966
Staff1															1
Staff2															
Salary1															
Salary2															
VarMkt															
VarLoad															
U															
EofS1															
EofS2															
FosFuel															
NucFuel															
GasFuel															
AgeS															
AgeH															
AgeN															
AgeG															
ProEx1															
ProEx2															

	Staff2	Salary1	Salary2	VarMkt	VarLoad	U	EofS1	EofS2	FosFuel	NucFuel	GasFuel	AgeS	AgeH	AgeN	AgeG	ProEx1	ProEx2
Costkwl	.6629	.4068	.5377	.4516	-.4369	-.0045	-.4126	-.4715	-.0427	-.2833	.4457	-.3408	-.3393	-.2727	.4664	.2772	-.2093
Costkl2	.6001	.3467	.4739	.4826	-.4414	-.0081	-.3777	-.4968	-.0187	-.3072	.4032	-.3143	-.3301	-.2971	.4064	.2767	-.2512
Res %	.6204	.5872	.5566	.8212	-.6161	.0622	-.5834	-.8494	-.5093	-.3646	.3149	-.3898	-.4011	-.3604	.3405	.3082	.0997
Comm %	.5315	.2312	.2972	.5255	-.6066	.0363	-.2028	-.6206	-.2872	-.3630	.2853	-.0727	-.5053	-.3585	.3336	.3258	.0931
Ind %	-.0472	-.3715	-.3223	.0503	-.2500	.1075	.3057	-.1376	.0731	-.2200	-.2033	.2475	-.1076	-.2177	-.2188	.0715	-.1168
Resale %	-.5557	-.3331	-.3543	.7103	.6759	-.0747	.3533	.7812	.3758	.4192	-.2189	.1802	.4705	.4145	-.2478	-.3293	-.0464
Pool	-.0504	-.2314	-.1825	-.2106	.0423	.1342	.3428	.2475	.0304	-.0874	-.1102	-.0634	.2026	-.0838	-.1082	-.0449	.1363
Gen %	-.1604	-.1629	-.1128	-.9792	.7339	-.0018	.2312	.9749	.4263	.3649	.1384	.2964	.4040	.3608	.1469	-.3294	.0418
Trans %	-.3540	-.4457	-.3810	-.2294	-.0528	.0901	.5737	.2426	.1505	-.2153	-.2330	.0616	.2393	-.2149	-.2515	.1241	.3778
Dist %	.1771	.1931	.1340	.9862	-.6985	-.0165	-.2825	-.9821	-.4267	-.3143	-.1248	-.2845	-.4294	-.3104	-.1378	.2919	-.1141
SGen %	-.4160	-.4550	-.4184	-.5616	.4234	-.0043	.4095	.5732	.7586	-.2989	-.2586	.8333	.2236	-.2945	-.2756	-.1488	-.2353
HGen %	-.2690	-.2789	-.2451	-.4503	.6434	.0046	.3018	.4933	.0622	-.1539	-.1395	-.0726	.9617	-.1518	-.1556	-.2496	.0580
NGen %	-.2267	-.0621	-.1344	-.3258	.1794	-.0555	.0515	.3675	-.1805	.9497	-.0982	-.2803	-.1681	.9377	-.1104	-.2239	.1624
GGen %	.8839	.7090	.8234	-.1201	-.0677	-.0794	-.5160	.0130	-.1400	-.1047	.9115	-.2390	-.1521	-.1032	.9838	.1419	.1506
Staff1	.8390	.7261	.7266	.1939	-.2713	.1189	-.5993	-.2851	-.4088	-.2626	.5732	-.2698	-.1121	-.2700	.6659	.2025	.3400
Staff2	1	.8277	.9195	.2074	-.3036	.0556	-.6877	-.2861	-.2729	-.2244	.7678	-.3480	-.2512	-.2218	.8583	.2461	.1594
Salary1		1	.9425	.2750	-.2144	-.0432	-.8621	-.2920	-.3083	-.0313	.5838	-.3576	-.2631	-.0140	.6900	.1754	.1947
Salary2			1	.2026	-.2123	-.0163	-.7965	-.2449	-.2558	-.1062	.6886	-.3539	-.2323	-.1003	.7907	.2005	.1644
VarMkt				1	-.4030	.1115	.3652	-.4551	-.1297	-.2155	-.1949	.0076	-.2307	-.2130	-.2186	.1084	-.2323
VarLoad					1	-.0690	.1701	.2125	.2809	.1824	-.0509	.1900	.6436	.1735	-.0643	-.5058	-.1954
U						1	.1072	.0196	.0340	-.0715	.0802	-.0580	-.0116	-.0716	.0514	.0262	.0627
EofS1							1	.3762	.2530	.0074	-.4490	.2087	.2510	.0037	-.5113	-.0947	-.0275
EofS2								1	.4617	.3343	.0085	.2760	.4512	.3304	.0027	-.3085	.0621
FosFuel									1	-.1696	-.1512	.6211	.0573	-.1663	-.1501	-.0591	-.3905
NucFuel										1	-.0822	-.2587	-.1513	.9755	-.0961	-.1770	.1548
GasFuel											1	-.2297	-.1331	-.0810	.9222	.1460	.0791
AgeS												1	-.0396	-.2554	-.2496	-.1085	-.2848
AgeH													1	-.1489	-.1520	-.3023	.0171
AgeN														1	-.0947	-.1827	.1392
AgeG															1	.1370	.1314
ProEx1																1	.4865
ProEx2																	1

APPENDIX E

DATA POOLED BY UTILITY

Utility 1

Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1966	.0139	14.00	13.00	.4642	27.66	12.69
1967	.0134	14.00	15.00	.4240	24.68	12.89
1968	.0131	14.00	14.00	.4159	23.96	12.48
1969	.0139	14.00	13.00	.4520	22.75	12.54
1970	.0155	14.00	15.00	.4847	29.11	12.26
1971	.0201	14.00	15.00	.5640	28.70	12.25
1972	.0211	14.00	13.00	.5558	18.45	12.44
1973	.0210	14.00	17.00	.5040	19.48	9.58
1974	.0355	15.00	16.00	.5676	44.20	6.59
1975	.0372	14.00	13.00	.6224	74.84	6.73
1976	.0389	15.00	14.00	.6661	62.24	7.19
1977	.0403	15.00	13.00	.7351	76.85	6.28
1978	.0385	14.00	13.00	.7639	77.47	8.55

Utility 2

Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1966	.0170	1.00	1.00	.3973	4.20	15.19
1967	.0166	2.00	1.00	.3604	3.80	14.25
1968	.0164	2.00	1.00	.3546	3.61	11.55
1969	.0168	1.00	1.00	.3246	3.70	9.67
1970	.0176	1.00	1.00	.3135	4.97	2.70
1971	.0200	3.00	1.00	.3367	6.47	8.86
1972	.0198	3.00	1.00	.3256	6.26	7.42
1973	.0237	4.00	5.00	.3177	0.00	4.58
1974	.0350	5.00	14.00	.3053	0.00	6.09
1975	.0372	6.00	6.00	.3840	0.00	9.82
1976	.0406	6.00	0.00	.4211	0.00	13.29
1977	.0461	6.00	0.00	.4952	0.00	11.17
1978	.0437	7.00	0.00	.5249	0.00	15.50

Utility 3

Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1966	.0136	38.00	7.00	.5227	51.84	9.06
1967	.0134	38.00	7.00	.5440	51.55	10.20
1968	.0137	38.00	6.00	.5903	50.55	8.06
1969	.0140	38.00	6.00	.6129	52.62	6.86
1970	.0153	34.00	6.00	.6299	68.85	7.07
1971	.0183	34.00	6.00	.6450	86.28	6.76
1972	.0202	33.00	7.00	.6619	81.28	4.42
1973	.0240	31.00	6.00	.4980	85.75	1.57
1974	.0333	31.00	8.00	.7524	182.84	3.51
1975	.0365	32.00	7.00	.5239	211.22	4.72
1976	.0350	33.00	7.00	.5027	198.84	5.59
1977	.0382	34.00	7.00	.5385	225.77	4.93
1978	.0378	33.00	7.00	.6413	233.07	4.45

Utility 4

Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1966	.0147	7.00	21.00	.3570	13.76	11.17
1967	.0140	6.00	22.00	.3384	13.84	11.63
1968	.0132	6.00	24.00	.3110	13.47	10.56
1969	.0134	7.00	25.00	.2840	13.25	7.79
1970	.0143	7.00	26.00	.2888	18.40	7.43
1971	.0169	6.00	29.00	.3209	23.33	7.46
1972	.0170	5.00	29.00	.3276	23.94	5.74
1973	.0209	6.00	23.00	.3559	0.00	4.32
1974	.0381	11.00	6.00	.6203	0.00	6.01
1975	.0401	10.00	3.00	.6947	0.00	6.80
1976	.0402	10.00	0.00	.6595	0.00	7.03
1977	.0435	11.00	0.00	.7562	0.00	3.52
1978	.0416	14.00	0.00	.7900	0.00	6.32

Utility 5

Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1966	.0063	0.00	85.00	.1326	25.39	9.07
1967	.0064	0.00	88.00	.1333	25.22	11.82
1968	.0064	0.00	87.00	.1441	25.40	6.50
1969	.0073	0.00	86.00	.1565	26.42	8.25
1970	.0088	0.00	89.00	.1782	36.48	8.67
1971	.0103	0.00	90.00	.1740	46.02	5.06
1972	.0107	0.00	89.00	.1633	47.11	2.92
1973	.0128	0.00	90.00	.1760	53.44	1.07
1974	.0211	0.00	90.00	.1425	122.24	-7.30
1975	.0242	0.00	91.00	.1798	133.46	-.43
1976	.0232	10.00	89.00	.2679	113.18	2.25
1977	.0254	9.00	90.00	.2008	91.08	1.61
1978	.0206	24.00	74.00	.8417	91.07	9.63

Utility 6						
Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1966	.0242	0.00	0.00	1.1618	0.00	13.17
1967	.0229	0.00	0.00	1.0983	0.00	13.20
1968	.0237	0.00	0.00	1.0015	0.00	9.66
1969	.0235	0.00	0.00	.9382	0.00	9.50
1970	.0231	0.00	0.00	.8885	0.00	9.61
1971	.0235	0.00	0.00	1.0001	0.00	9.15
1972	.0257	0.00	0.00	.9302	0.00	8.37
1973	.0290	0.00	0.00	1.0683	0.00	5.75
1974	.0413	0.00	0.00	1.3397	0.00	5.72
1975	.0453	0.00	0.00	1.0996	0.00	5.41
1976	.0467	0.00	0.00	.9726	0.00	7.03
1977	.0501	0.00	0.00	.9052	0.00	5.68
1978	.0514	0.00	0.00	.9590	0.00	4.07

Utility 7						
Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1966	.0198	32.00	5.00	.5691	2.62	5.14
1967	.0193	23.00	3.00	.5395	2.59	5.49
1968	.0186	23.00	0.00	.5607	2.53	6.16
1969	.0185	22.00	0.00	.5430	2.33	5.85
1970	.0185	21.00	0.00	.5521	.39	6.69
1971	.0187	20.00	0.00	.5375	4.07	7.50
1972	.0211	20.00	0.00	.5618	0.00	5.83
1973	.0226	21.00	0.00	.5270	0.00	5.70
1974	.0334	23.00	0.00	.3865	0.00	4.33
1975	.0364	22.00	0.00	.3684	0.00	4.50
1976	.0386	22.00	0.00	.3870	0.00	2.60
1977	.0426	22.00	0.00	.3881	0.00	3.36
1978	.0411	23.00	0.00	.3759	0.00	4.34

Utility 8						
Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1966	.0065	0.00	100.00	.0462	81.54	7.79
1967	.0062	0.00	100.00	.0469	83.36	8.07
1968	.0062	0.00	100.00	.0448	77.97	7.40
1969	.0062	0.00	100.00	.0538	81.43	7.75
1970	.0073	0.00	100.00	.0557	108.83	6.27
1971	.0097	0.00	100.00	.0539	119.79	5.49
1972	.0102	0.00	100.00	.0590	124.40	4.04
1973	.0132	0.00	100.00	.0584	144.66	6.52
1974	.0087	0.00	100.00	.0762	300.64	5.15
1975	.0243	0.00	100.00	.0971	332.49	4.34
1976	.0239	0.00	98.00	.1096	314.53	4.95
1977	.0275	0.00	98.00	.1046	351.97	4.48
1978	.0241	0.00	98.00	.0944	352.49	5.69

Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
			Utility 9			
1966	.0077	2.00	98.00	.1822	8.06	14.41
1967	.0075	2.00	98.00	.1772	7.83	15.58
1968	.0076	2.00	98.00	.1915	7.66	14.64
1969	.0075	2.00	98.00	.1816	13.87	14.69
1970	.0076	1.00	99.00	.1846	19.22	11.79
1971	.0081	1.00	99.00	.1990	24.39	12.38
1972	.0090	0.00	99.00	.2148	32.62	14.44
1973	.0113	1.00	99.00	.2336	38.18	11.07
1974	.0207	1.00	99.00	.1319	109.48	7.66
1975	.0223	0.00	98.00	.1430	125.68	7.63
1976	.0216	1.00	98.00	.1504	119.89	10.49
1977	.0250	0.00	98.00	.1709	135.62	9.35
1978	.0230	0.00	98.00	.1623	127.02	9.43

Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
			Utility 10			
1966	.0050	0.00	100.00	.1018	0.00	10.78
1967	.0044	0.00	100.00	.1119	0.00	11.05
1968	.0041	0.00	100.00	.1161	0.00	11.16
1969	.0052	0.00	100.00	.1129	0.00	11.04
1970	.0048	0.00	100.00	.0999	0.00	11.20
1971	.0044	0.00	100.00	.0757	0.00	9.03
1972	.0108	0.00	100.00	.1822	0.00	11.57
1973	.0088	0.00	100.00	.1529	0.00	8.24
1974	.0109	0.00	100.00	.0879	0.00	4.78
1975	.0084	0.00	100.00	.0578	0.00	9.90
1976	.0094	0.00	100.00	.0622	0.00	11.65
1977	.0133	0.00	100.00	.0995	0.00	11.23
1978	.0140	0.00	100.00	.1346	0.00	12.32

Year	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
			Utility 11			
1966	.0133	26.00	3.00	.6312	12.69	12.92
1967	.0133	26.00	4.00	.4598	12.63	12.32
1968	.0127	26.00	3.00	.5303	12.26	12.31
1969	.0131	25.00	3.00	.5061	11.55	12.66
1970	.0145	24.00	4.00	.5353	11.06	13.06
1971	.0154	24.00	4.00	.5369	5.81	14.35
1972	.0160	23.00	4.00	.5335	6.70	15.22
1973	.0200	23.00	4.00	.6037	8.07	13.31
1974	.0286	25.00	4.00	.6771	17.92	9.81
1975	.0322	21.00	4.00	.7056	14.42	10.14
1976	.0289	21.00	3.00	.7230	13.25	8.76
1977	.0289	21.00	3.00	.7664	14.77	9.86
1978	.0309	22.00	3.00	.7798	15.10	9.94

Year	Costkw	Ind %	Utility 12 Resale %	Staff	FosFuel	Pro Ex
1966	.0399	0.00	0.00	2.9341	.11	13.60
1967	.0394	0.00	0.00	2.9263	.10	13.61
1968	.0372	0.00	0.00	2.8419	.08	11.80
1969	.0334	0.00	0.00	2.2841	.06	12.86
1970	.0351	0.00	0.00	2.4242	.07	10.23
1971	.0323	0.00	0.00	2.2106	.08	10.99
1972	.0288	0.00	0.00	2.1209	.05	10.81
1973	.0305	0.00	0.00	2.0484	.02	10.10
1974	.0385	0.00	0.00	2.0739	.03	8.81
1975	.0408	0.00	0.00	2.2170	.02	9.32
1976	.0437	0.00	0.00	2.2247	.02	7.79
1977	.0471	1.00	0.00	2.4703	.01	7.21
1978	.0534	1.00	0.00	2.5928	.01	8.80

APPENDIX F

DATA POOLED BY YEAR

1966

Utility	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1	.0139	14.00	13.00	.4642	27.66	12.69
2	.0170	1.00	1.00	.3973	4.20	15.19
3	.0136	38.00	7.00	.5227	51.84	9.06
4	.0147	7.00	21.00	.3570	13.76	11.17
5	.0063	0.00	85.00	.1326	25.39	9.07
6	.0242	0.00	0.00	1.1618	0.00	13.17
7	.0198	32.00	5.00	.5691	2.62	5.14
8	.0065	0.00	100.00	.0462	81.54	7.79
9	.0077	2.00	98.00	.1822	8.06	14.41
10	.0050	0.00	100.00	.1018	0.00	10.78
11	0.133	26.00	3.00	.6312	12.69	12.92
12	.0399	0.00	0.00	2.9341	.11	13.60

1967

Utility	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1	.0134	14.00	15.00	.4240	24.68	12.89
2	.0166	2.00	1.00	.3604	3.80	14.25
3	.0134	38.00	7.00	.5440	51.55	10.20
4	.0140	6.00	22.00	.3384	13.84	11.63
5	.0064	0.00	88.00	.1333	25.22	11.82
6	.0229	0.00	0.00	1.0983	0.00	13.20
7	.0193	23.00	3.00	.5395	2.59	5.49
8	.0062	0.00	100.00	.0469	83.36	8.07
9	.0075	2.00	98.00	.1772	7.83	15.58
10	.0044	0.00	100.00	.1119	0.00	11.05
11	.0133	26.00	4.00	.4598	12.63	12.32
12	.0394	0.00	0.00	2.9263	.10	13.61

1968

Utility	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1	.0131	14.00	14.00	.4159	23.96	12.48
2	.0164	2.00	1.00	.3546	3.61	11.55
3	.0137	38.00	6.00	.5903	50.55	8.06
4	.0132	6.00	24.00	.3110	13.47	10.56
5	.0064	0.00	87.00	.1441	25.40	6.50
6	.0237	0.00	0.00	1.0015	0.00	9.66
7	.0186	23.00	0.00	.5607	2.53	6.16
8	.0062	0.00	100.00	.0448	77.97	7.40
9	.0076	2.00	98.00	.1915	7.66	14.64
10	.0041	0.00	100.00	.1161	0.00	11.16
11	.0127	26.00	3.00	.5303	12.26	12.31
12	.0372	0.00	0.00	2.8419	.08	11.80

Utility	Costkw	Ind %	1969 Resale %	Staff	FosFuel	Pro Ex
1	.0139	14.00	13.00	.4520	22.75	12.54
2	.0168	1.00	1.00	.3246	3.70	9.67
3	.0140	38.00	6.00	.6129	52.62	6.86
4	.0134	7.00	25.00	.2840	13.25	7.79
5	.0073	0.00	86.00	.1565	26.42	8.25
6	.0235	0.00	0.00	.9382	0.00	9.50
7	.0185	22.00	0.00	.5430	2.33	5.85
8	.0062	0.00	100.00	.0538	81.43	7.75
9	.0075	2.00	98.00	.1816	13.87	14.69
10	.0052	0.00	100.00	.1129	0.00	11.04
11	.0131	25.00	3.00	.5061	11.55	12.66
12	.0034	0.00	0.00	2.2841	.06	12.86

Utility	Costkw	Ind %	1970 Resale %	Staff	FosFuel	Pro Ex
1	.0155	14.00	15.00	.4847	29.11	12.26
2	.0176	1.00	1.00	.3135	4.97	2.70
3	.0153	34.00	6.00	.7299	68.85	7.07
4	.0143	7.00	26.00	.2888	18.40	7.43
5	.0088	0.00	89.00	.1782	36.48	8.67
6	.0231	0.00	0.00	.8885	0.00	9.61
7	.0185	21.00	0.00	.5521	.39	6.69
8	.0073	0.00	100.00	.0557	108.83	6.27
9	.0076	1.00	99.00	.1846	19.22	11.79
10	.0048	0.00	100.00	.0999	0.00	11.20
11	.0145	24.00	4.00	.5353	11.06	13.06
12	.0351	0.00	0.00	2.4242	.07	10.23

Utility	Costkw	Ind %	1971 Resale %	Staff	FosFuel	Pro Ex
1	.0201	14.00	15.00	.5640	28.70	12.25
2	.0200	3.00	1.00	.3367	6.47	8.86
3	.0183	34.00	6.00	.6450	86.28	6.76
4	.0169	6.00	29.00	.3209	23.33	7.46
5	.0103	0.00	90.00	.1740	46.02	5.06
6	.0235	0.00	0.00	1.0001	0.00	9.15
7	.0187	20.00	0.00	.5375	4.07	7.50
8	.0097	0.00	100.00	.0539	119.79	5.49
9	.0081	1.00	99.00	.1990	24.39	12.38
10	.0044	0.00	100.00	.0757	0.00	9.03
11	.0154	24.00	4.00	.5369	5.81	14.35
12	.0323	0.00	0.00	2.2106	.08	10.99

Utility	Costkw	Ind %	1972 Resale %	Staff	FosFuel	Pro Ex
1	.0211	14.00	13.00	.5558	18.45	12.44
2	.0198	3.00	1.00	.3256	6.26	7.42
3	.0202	33.00	7.00	.6619	81.28	4.42
4	.0170	5.00	29.00	.3276	23.94	5.74
5	.0107	0.00	89.00	.1633	47.11	2.92
6	.0257	0.00	0.00	.9302	0.00	8.37
7	.0211	20.00	0.00	.5618	0.00	5.83
8	.0102	0.00	100.00	.0590	124.40	4.04
9	.0090	0.00	99.00	.2148	32.62	14.44
10	.0108	0.00	100.00	.1822	0.00	11.57
11	.0160	23.00	4.00	.5335	6.70	15.22
12	.0288	0.00	0.00	2.1209	.05	10.81

Utility	Costkw	Ind %	1973 Resale %	Staff	FosFuel	Pro Ex
1	.0210	14.00	17.00	.5040	19.48	9.58
2	.0237	4.00	5.00	.3177	0.00	4.58
3	.0240	31.00	6.00	.4980	85.75	1.57
4	.0209	6.00	23.00	.3559	0.00	4.32
5	.0128	0.00	90.00	.1760	53.44	1.07
6	.0290	0.00	0.00	1.0683	0.00	5.75
7	.0226	21.00	0.00	.5270	0.00	5.70
8	.0132	0.00	100.00	.0584	144.66	6.52
9	.0113	1.00	99.00	.2336	38.18	11.07
10	.0088	0.00	100.00	.1529	0.00	8.24
11	.0200	23.00	4.00	.6037	8.07	13.31
12	.0305	0.00	0.00	2.0484	.02	10.10

Utility	Costkw	Ind %	1974 Resale %	Staff	FosFuel	Pro Ex
1	.0355	15.00	16.00	.5676	44.20	6.59
2	.0350	5.00	14.00	.3053	0.00	6.09
3	.0333	31.00	8.00	.7524	182.84	3.51
4	.0381	11.00	6.00	.6203	0.00	6.01
5	.0211	0.00	90.00	.1425	122.24	-7.30
6	.0413	0.00	0.00	1.3397	0.00	5.72
7	.0334	23.00	0.00	.3865	0.00	4.33
8	.0087	0.00	100.00	.0762	300.64	5.15
9	.0207	1.00	99.00	.1319	109.48	7.66
10	.0109	0.00	100.00	.0879	0.00	4.78
11	.0286	25.00	4.00	.6771	17.92	9.81
12	.0385	0.00	0.00	2.0739	.03	8.81

			1975			
Utility	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1	.0372	14.00	13.00	.6224	74.84	6.73
2	.0372	6.00	6.00	.3840	0.00	9.82
3	.0365	32.00	7.00	.5239	211.22	4.72
4	.0401	10.00	3.00	.6947	0.00	6.80
5	.0242	0.00	91.00	.1798	133.46	-.43
6	.0453	0.00	0.00	1.0996	0.00	5.41
7	.0364	22.00	0.00	.3684	0.00	4.50
8	.0243	0.00	100.00	.0971	332.49	4.34
9	.0223	0.00	98.00	.1430	125.68	7.63
10	.0084	0.00	100.00	.0578	0.00	9.90
11	.0322	21.00	4.00	.7056	14.42	10.14
12	.0408	0.00	0.00	2.2170	.02	9.32

			1976			
Utility	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1	.0389	15.00	14.00	.6661	62.24	7.19
2	.0406	6.00	0.00	.4211	0.00	13.29
3	.0350	33.00	7.00	.5027	198.84	5.59
4	.0402	10.00	0.00	.6595	0.00	7.03
5	.0232	10.00	89.00	.2679	113.18	2.25
6	.0467	0.00	0.00	.9726	0.00	7.03
7	.0386	22.00	0.00	.3870	0.00	2.60
8	.0239	0.00	98.00	.1096	314.53	4.95
9	.0216	1.00	98.00	.1504	119.89	10.49
10	.0094	0.00	100.00	.0622	0.00	11.65
11	.0289	21.00	3.00	.7230	13.25	8.76
12	.0437	0.00	0.00	2.2247	.02	7.79

			1977			
Utility	Costkw	Ind %	Resale %	Staff	FosFuel	Pro Ex
1	.0403	15.00	13.00	.7351	76.85	6.28
2	.0461	6.00	0.00	.4952	0.00	11.17
3	.0382	34.00	7.00	.5385	225.77	4.93
4	.0435	11.00	0.00	.7562	0.00	3.52
5	.0254	9.00	90.00	.2008	91.08	1.61
6	.0501	0.00	0.00	.9052	0.00	5.68
7	.0426	22.00	0.00	.3881	0.00	3.36
8	.0275	0.00	98.00	.1046	351.97	4.48
9	.0250	0.00	98.00	.1709	135.62	9.35
10	.0133	0.00	100.00	.0995	0.00	11.23
11	.0289	21.00	3.00	.7664	14.77	9.86
12	.0471	1.00	0.00	2.4703	.01	7.21

Utility	Costkw	Ind %	1978 Resale %	Staff	FosFuel	Pro Ex
1	.0385	14.00	13.00	.7639	77.47	8.55
2	.0437	7.00	0.00	.5249	0.00	15.50
3	.0378	33.00	7.00	.6413	233.07	4.45
4	.0416	14.00	0.00	.7900	0.00	6.32
5	.0206	24.00	74.00	.8417	91.07	9.63
6	.0514	0.00	0.00	.9590	0.00	4.07
7	.0411	23.00	0.00	.3759	0.00	4.34
8	.0241	0.00	98.00	.0944	352.49	5.69
9	.0230	0.00	98.00	.1623	127.02	9.43
10	.0140	0.00	100.00	.1346	0.00	12.32
11	.0309	22.00	3.00	.7798	15.10	9.94
12	.0534	1.00	0.00	2.5928	.01	8.80

APPENDIX G

COMPUTATIONS SUPPORTING THE GOODMAN AND KRUSKAL INDICES FROM TABLE 16

--1966--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results		Standardized Variables and Rankings: Staff/kw		Standardized Variables and Rankings: Opcost/kw		Contingency Table and λ
1	.4642	.0101	.1400	.1300			.9764	10	.0157	11	
2	.3973	.0140	.0100	.0100	Dep. Var.	= Staff/kw	.4348	12	.0144	12	
3	.5227	.0102	.3800	.0700	Cons.	= 1.3399	1.5446	2	.0208	5	
4	.3570	.0124	.0700	.2100	B_1	=-2.4492	.8019	11	.0175	9	3 1
5	.1326	.0049	.0000	.8500	B_2	=-1.3024	1.2396	8	.0186	8	1 2 1
6	1.1618	.0204	.0000	.0000			1.1618	9	.0204	6/7	1 3
7	.5691	.0171	.3200	.0500	Dep. Var.	=Opcost/kw	1.4180	4	.0259	2	
8	.0462	.0056	.0000	1.000	Cons.	= .0206	1.3486	6	.0217	4	
9	.1822	.0061	.0200	.9800	B_1	= -.0250	1.5075	3	.0224	2	
10	.1018	.0043	.0000	1.0000	B_2	= -.0161	1.4042	5	.0204	6/7	$\lambda = \frac{8 - 4}{12 - 4} = .50$
11	.6312	.0101	.2600	.0300			1.3071	7	.0181	10	
12	2.9341	.0317	.0000	.0000			2.9341	1	.0317	1	

--1967--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results		Standardized Variables and Rankings Staff/kw		Standardized Variables and Rankings Opcost/kw		Contingency Table and λ
1	.4245	.0095	.1400	.1500			.9950	10	.0159	11	
2	.3604	.0135	.0200	.0100	Dep. Var.	= Staff/kw	.4276	12	.0142	12	
3	.5440	.0100	.3800	.0700	Cons.	= 1.3087	1.6695	2	.0220	4	
4	.3384	.0117	.0600	.2200	B_1	=-2.7298	.7792	11	.0169	10	3 1
5	.1333	.0050	.0000	.8800	B_2	=-1.2590	1.2412	6	.0191	8	1 2 1
6	1.0983	.0192	.0000	.0000			1.0983	9	.0192	7	1 3
7	.5395	.0166	.2300	.0300	Dep. Var.	=Opcost/kw	1.2051	8	.0237	2	
8	.0469	.0054	.0000	1.0000	Cons.	= .0203	1.3059	5	.0214	5	
9	.1772	.0060	.0200	.9800	B_1	= -.0286	1.4649	3	.0223	3	
10	.1119	.0038	.0000	1.0000	B_2	= -.0160	1.3709	4	.0198	6	$\lambda = \frac{8 - 4}{12 - 4} = .50$
11	.4598	.0102	.2600	.0400			1.2199	7	.0183	9	
12	2.9263	.0309	.0000	.0000			2.9263	1	.0309	1	

--1968--

Utility	Raw Data: Dependent Variable Staff/kw	Opcost/kw	Independent Variables Ind %	Resale %	Regression Results	Standardized Variables and Rankings Staff/kw		Opcost/kw		Contingency Table and λ
1	.4159	.0083	.1400	.1400		.9263	10	.0149	11	
2	.3546	.0130	.0200	.0100	Dep. Var. = Staff/kw	.4156	12	.0137	12	
3	.5903	.0104	.3800	.0600	Cons. = 1.2501	1.5930	2	.0219	3	
4	.3110	.0111	.0600	.2400	B_1 =-2.4497	.7451	11	.0165	10	
5	.1411	.0050	.0000	.8700	B_2 =-1.1962	1.1848	7	.0184	8	3 1
6	1.0015	.0199	.0000	.0000		1.0015	9	.0199	6	1 2 1
7	.5607	.0158	.2300	.0000	Dep.Var.=Opcost/kw	1.1241	8	.0222	2	1 3
8	.0448	.0054	.0000	1.0000	Cons. = .0197	1.2410	5	.0208	5	
9	.1915	.0061	.0200	.9800	B_1 = -.0279	1.4128	3	.0218	4	
10	.1161	.0035	.0000	1.0000	B_2 = -.0154	1.3123	4	.0189	7	
11	.5303	.0100	.2600	.0300		1.2031	6	.0177	9	$\lambda = \frac{8-4}{12-4} = .50$
12	2.8419	.0292	.0000	.0000		2.8419	1	.0292	1	

--1969--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results	Standardized Variables and Rankings: Staff/kw		Standardized Variables and Rankings: Opcost/kw		Contingency Table and λ
1	.4520	.0095	.1400	.1300		.8268	10	.0148	11	
2	.3246	.0133	.0100	.0100	Dep. Var. = Staff/kw	.3521	12	.0137	12	
3	.6129	.0108	.3800	.0600	Cons. = 1.0525	1.3416	2	.0208	3	
4	.2840	.0113	.0700	.2500	B_1 = -1.7617	.6539	11	.0166	9	
5	.1868	.0058	.0000	.8600	B_2 = -.9862	1.0046	6	.0178	8	3 - 1
6	.9382	.0192	.0000	.0000		.9382	8	.0192	6	1 3
7	.8430	.0155	.2200	.0000	Dep. Var. =Opcost/kw	.9306	9	.0210	2	1 3
8	.0538	.0055	.0000	1.0000	Cons. = .0187	1.0400	5	.0195	5	
9	.1816	.0060	.0200	.9800	B_1 = -.0250	1.1833	3	.0202	4	
10	.1129	.0045	.0000	1.0000	B_2 = -.0140	1.0991	4	.0185	7	$\lambda = \frac{9-4}{12-4} = .63$
11	.5061	.0098	.2500	.0300		.9761	7	.0165	10	
12	2.2841	.0264	.0000	.0000		2.2841	1	.0264	1	

--1970--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results	Standardized Variables and Rankings: Staff/kw		Standardized Variables and Rankings: Opcost/kw		Contingency Table and λ
1	.4847	.0107	.1400	.1500		.9250	9	.0168	11	
2	.3135	.0136	.0100	.0100	Dep. Var. = Staff/kw	.3442	12	.0140	12	
3	.6299	.0111	.3400	.0600	Cons. = 1.1048	1.3852	2	.0215	2	2 2
4	.2888	.0119	.0700	.2600	B_1 =-2.0392	.6999	11	.0176	10	2 1 1
5	.1782	.0073	.0000	.8900	B_2 =-1.0323	1.0969	5	.0201	6	1 3
6	.8885	.0188	.0000	.0000		.8885	10	.0188	7	
7	.5521	.0153	.2100	.0000	Dep. Var.=Opcost/kw	.9803	8	.0212	3	
8	.0557	.0066	.0000	1.0000	Cons. = .0197	1.0880	6	.0210	4	
9	.1846	.0057	.0100	.9900	B_1 = -.0280	1.2270	3	.0202	5	
10	.1998	.0041	.0000	1.0000	B_2 = -.0144	1.1322	4	.0185	8	$\lambda = \frac{6-4}{12-4} = .25$
11	.5353	.0111	.2400	.0400		1.0660	7	.0184	9	
12	2.4242	.0283	.0000	.0000		2.4242	1	.0283	1	

--1971--

Utility	Raw Data: Dependent Variable Staff/kw	Opcost/kw	Independent Variables Ind %	Resale %	Regression Results	Standardized Variables and Rankings Staff/kw		Opcost/kw		Contingency Table and λ
1	.5648	.0137	.1400	.1500		1.0093	8	.0195	9	
2	.3367	.0158	.0300	.0100	Dep. Var. = Staff/kw	.4090	12	.0167	12	
3	.6450	.0134	.3400	.0600	Cons. = 1.1156	1.4093	2	.0232	2	2 2
4	.3209	.0143	.0600	.2900	B_1 =-2.0640	.7469	11	.0200	7	1 - 3
5	.1740	.0088	.0000	.9000	B_2 =-1.0421	1.1119	5	.0215	4	1 2 1
6	1.0001	.0196	.0000	.0000		1.0001	9	.0196	8	
7	.5375	.0155	.2000	.0000	Dep. Var.=Opcost/kw	.9503	10	.0208	5	
8	.0539	.0090	.0000	1.0000	Cons. = .0206	1.0960	6	.0231	3	
9	.1990	.0063	.0100	.9900	B_1 = -.0263	1.2513	3	.0205	6	
10	.0757	.0036	.0000	1.0000	B_2 = -.0141	1.1178	4	.0177	11	$\lambda = \frac{3-4}{12-4} = -.13$
11	.5369	.0113	.2400	.0400		1.0739	7	.0182	10	
12	2.2105	.0266	.0000	.0000		2.2106	1	.0266	1	

--1972--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results	Standardized Variables and Rankings Staff/kw		Standardized Variables and Rankings Opcost/kw		Contingency Table and λ
1	.5558	.0142	.1400	.1300		.9385	8	.0183	10	
2	.3256	.0159	.0300	.0100	Dep. Var. = Staff/kw	.3905	12	.0166	12	
3	.6619	.0148	.3300	.0700	Cons. = 1.0559	1.3379	2	.0218	2	2 - 2
4	.3275	.0144	.0500	.2900	B_1 =-1.8458	.6972	11	.0187	9	2 2
5	.1633	.0093	.0000	.8900	B_2 =- .9561	1.0142	6	.0195	7	2 2
6	.9302	.0216	.0000	.0000		.9302	10	.0216	4	
7	.4518	.0180	.2000	.0000	Dep. Var.=Opcost/kw	.9310	7	.0217	3	
8	.0590	.0092	.0000	1.0000	Cons. = .0198	1.0151	5	.0207	5	
9	.2148	.0074	.0000	.9900	B_1 =-.0187	1.1613	3	.0188	8	
10	.1822	.0092	.0000	1.0000	B_2 =-.0115	1.1383	4	.0207	6	
11	.5335	.0122	.2300	.0400		.9963	7	.0170	11	$\lambda = \frac{6-4}{12-4} = .25$
12	2.1209	.0225	.0000	.0000		2.1209	1	.0225	1	

--1974--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results	Standardized Variables and Rankings: Staff/kw	Rank	Standardized Variables and Rankings: Opcost/kw	Rank	Contingency Table and λ
1	.5675	.0256	.1500	.1600		1.1811	9	.0332	9	
2	.3053	.0305	.0500	.1400	Dep. Var. = Staff/kw	.6180	12	.0346	8	
3	.7524	.0252	.3100	.0800	Cons. = 1.3065	1.7074	2	.0365	5	1 1 2
4	.6203	.0329	.1100	.0600	B_1 =-2.7587	.9986	11	.0375	3	1 2 1
5	.1425	.0197	.0000	.9000	B_2 =-1.2481	1.2658	8	.0357	7	2 1 1
6	1.3397	.0365	.0000	.0000		1.3397	5	.0365	4	
7	.3865	.0303	.2300	.0000	Dep. Var.=Opcost/kw	1.0210	10	.0376	2	
8	.0762	.0240	.0000	1.0000	Cons. = .0348	1.3243	7	.0418	1	
9	.1319	.0184	.0100	.9900	B_1 = -.0317	1.3951	4	.0363	6	
10	.0879	.0081	.0000	1.0000	B_2 = -.0178	1.3360	6	.0259	12	
11	.6771	.0215	.2500	.0400		1.4167	3	.0301	11	$\lambda = \frac{4 - 4}{12 - 4} = .00$
12	2.0739	.0325	.0000	.0000		2.0739	1	.0325	10	

--1975--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results		Standardized Variables and Rankings: Staff/kw		Standardized Variables and Rankings: Opcost/kw		Contingency Table and λ
1	.6224	.0268	.1400	.1300			1.2149	8	.0334	10	
2	.3840	.0318	.0600	.0600	Dep. Var.	= Staff/kw	.6431	12	.0347	9	
3	.5239	.0287	.3200	.0700	Cons.	= 1.2886	1.6035	2	.0394	5	0 2 2
4	.6947	.0345	.1000	.0300	B_1	=-3.1092	1.0419	11	.0380	6	3 - 1
5	.1798	.0229	.0000	.9100	B_2	=-1.2096	1.2805	6	.0404	3	1 2 1
6	1.0996	.0405	.0000	.0000			1.0996	9	.0405	2	
7	.3684	.0331	.2200	.0000	Dep. Var.	=Opcost/kw	1.0524	10	.0395	4	
8	.0971	.0233	.0000	1.0000	Cons.	= .0366	1.3067	5	.0425	1	
9	.1430	.0192	.0000	.9800	B_1	= -.0291	1.3284	4	.0380	7	
10	.0578	.0071	.0000	1.0000	B_2	= -.0192	1.2674	7	.0263	12	
11	.7056	.0243	.2100	.0400			1.4069	3	.0312	11	$\lambda = \frac{1 - 4}{12 - 4} = -.38$
12	2.2170	.0350	.0000	.0000			2.2170	1	.0350	8	

--1976--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results	Standardized Variables and Rankings: Staff/kw	Rank	Standardized Variables and Rankings: Opcost/kw	Rank	Contingency Table and λ
1	.6661	.0277	.1500	.1400		1.1926	5	.0355	10	
2	.4211	.0337	.0600	.0000	Dep. Var. = Staff/kw	.5749	12	.0357	9	
3	.5027	.0278	.3300	.0700	Cons. = 1.1934	1.4194	3	.0401	5	1 1 2
4	.6595	.0349	.1000	.0000	B_1 =-2.5627	.9158	11	.0382	7	2 1 1
5	.2679	.0215	.1000	.8900	B_2 =-1.0147	1.4273	2	.0428	1	1 2 1
6	.9726	.0421	.0000	.0000		.9726	9	.0421	3	
7	.3870	.0351	.2200	.0000	Dep. Var.=Opcost/kw	.9508	10	.0424	2	
8	.1096	.0220	.0000	.9800	Cons. = .0377	1.1040	7	.0418	4	
9	.1504	.0185	.0100	.9800	B_1 = -.0331	1.1704	6	.0386	6	
10	.0622	.0082	.0000	1.0000	B_2 = -.0202	1.0769	8	.0284	11	
11	.7230	.0206	.2100	.0300		1.2916	4	.0282	12	$\lambda = \frac{3-4}{12-4} = -.13$
12	2.2247	.0380	.0000	.0000		2.2247	1	.0380	8	

--1977--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results		Standardized Variables and Rankings Staff/kw		Opcost/kw		Contingency Table and λ		
1	.7351	.0293	.1500	.1300			1.2856	5	.0377	10			
2	.4852	.0382	.0600	.0000	Dep. Var. = Staff/kw		.6573	12	.0405	9			
3	.5385	.0310	.3400	.0700	Cons.	= 1.2848	1.5352	2	.0453	5	1	1	2
4	.7562	.0382	.1100	.0000	B_1	=-2.7015	1.0534	9	.0423	6	2	1	1
5	.2003	.0236	.0900	.9000	B_2	=-1.1177	1.4499	3	.0457	4	1	2	1
6	.9052	.0459	.0000	.0000			.9052	11	.0459	3			
7	.3881	.0390	.2200	.0000	Dep. Var.=Opcost/kw		.9824	10	.0473	1			
8	.1045	.0257	.0000	.9800	Cons.	= .0418	1.1999	8	.0461	2			
9	.1709	.0218	.0000	.9800	B_1	= -.0377	1.2662	6	.0422	7			
10	.0995	.0118	.0000	1.0000	B_2	= -.0208	1.2172	9	.0326	11			
11	.7664	.0207	.2100	.0300			1.3672	4	.0292	12	$\lambda = \frac{3-4}{12-4} = -.13$		
12	2.4703	.0411	.0100	.0000			2.4973	1	.0411	8			

--1978--

Utility	Raw Data: Dependent Variable Staff/kw	Raw Data: Dependent Variable Opcost/kw	Raw Data: Independent Variables Ind %	Raw Data: Independent Variables Resale %	Regression Results	Standardized Variables and Rankings: Staff/kw		Standardized Variables and Rankings: Opcost/kw		Contingency Table and λ
1	.7639	.0277	.1400	.1300		1.1149	5	.0365	10	
2	.5249	.0351	.0700	.0000	Dep. Var. = Staff/kw	.6404	12	.0380	9	
3	.6413	.0306	.3300	.0700	Cons. = 1.2137	1.2506	3	.0458	4	1 - 3
4	.7900	.0359	.1400	.0000	B_1 = -.6506	1.0211	8	.0417	8	2 2
5	.8417	.0162	.2400	.7400	B_2 = -.9226	1.9206	2	.0436	6	1 2 1
6	.9590	.0467	.0000	.0000		.9590	10	.0467	2	
7	.3757	.0375	.2300	.0000	Dep. Var.=Opcost/kw	.7555	11	.0470	1	
8	.0944	.0226	.0000	.9800	Cons. = .0417	.9985	9	.0457	3	
9	.1623	.0200	.0000	.9800	B_1 = -.0412	1.0664	6	.0431	7	
10	.1346	.0121	.0000	1.0000	B_2 = -.0236	1.0572	7	.0357	11	
11	.7798	.0226	.2200	.0300		1.1706	4	.0324	12	$\lambda = \frac{4 - 4}{12 - 4} = .00$
12	2.5928	.0439	.0100	.0000		2.6093	1	.0439	5	