

There is currently high interest in the emergent reorganization of market and regulatory structure in the United States' electric energy sector. This article focuses attention on external organizational control structures and processes that have become institutionalized in that sector. It specifically addresses the organized environments in which public, quasi-public, and privately owned distributors of electricity have operated in recent history. An approach to analysis of the impact of past policy choices on organizational performance is presented using data envelopment analysis (DEA). It is concluded that DEA provides an interesting starting point for the comparative analysis of organizational performance.

THE IMPACT OF EXTERNAL CONTROL ARRANGEMENTS ON ORGANIZATIONAL PERFORMANCE

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This study focuses on retail distributors of electric energy in the United States and the environmental actors who have historically imposed external management and regulatory control on them. The external actors include the Tennessee Valley Authority (TVA), the United States Federal Power Administrations, the Rural Utilities Service (RUS) (prior to late 1994 known as the Rural Electrification Administration [REA]), and many state Public Service Commissions. The purpose of the research was to examine the hypothesis that the choice and application of different external organizational control structures and processes by these environmental actors result in different levels of organizational performance by the retail distributors. The relationship hypothesized can be written as follows:

Organizational Performance = f (control system employed)

If there is no apparent benign effect of the choice of one control structure or process over the other, then the most rational control system

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choice, by default, would be the least costly. This includes the very real possibility of minimal regulatory controls or even no controls beyond those provided by market competition—a system that can itself be understood as a rationally structured environment for organizational activity.

In the late 1990s, there is accelerating discussion within the electric industry focusing on the question of regulation versus market competition as the most effective medium for control and coordination. However, the issue is not new. As early as September 1987, Charles Stalon, a former commissioner of the Federal Energy Regulatory Commission, testified before the House Subcommittee on Energy and Power:

The debate about the appropriate economic structure and best means of control of the electricity system is intensifying The current system of regulation is broken, that is, it is failing to induce in the electricity industry desirable and attainable levels of economic efficiency. Both the structure and the means of control of the industry probably should be changed The fundamental question . . . is whether that objective can be better furthered by pursuing workably competitive markets in the generating sector of the industry, by reforming and improving the quality of regulation [throughout the industry], or by some combination of the two. (Stalon, 1990, pp. 319-320)

Much uncertainty has emerged with respect to the effect that this lengthy and continuing policy debate portends for the distributors of electric energy in the United States. The analysis reported here directs attention to the impact on electric distributor operations of the various regulatory structures that were in place in 1987, the year of Stalon's testimony. Examination of these structural arrangements and their effects adds richness and historical perspective to the current policy debate (for a review, see Commonwealth of Virginia State Corporation Commission, 1996).

ORGANIZATIONAL UNITS AND THE "ORGANIZED EXTERNAL ENVIRONMENT"

There were 3,241 separate electric utilities in service in the United States in 1987, of which 8 were federally owned and operated (Energy Information Administration [EIA], 1989). The present analysis excluded the federally owned utilities. Data for the utilities included in the study were taken from published reports distributed by EIA and the RUS/REA. Although only 1,565 of the 3,233 nonfederal utilities are included in the database, they account for 99% of the kilowatthours (kWH) sold to

consumers by privately owned utilities, 85% sold to consumers by public utilities, and 94% sold by cooperatives in 1987. Thus, substantially all sales of energy to ultimate consumers in the United States during that year were provided by the utilities included in the database.

External governance structures and processes found to be in place in the study year, 1987, had emerged during the previous 50 to 60 years. And, although the industry is presently in great flux due to the high interest in competition, privatization, deregulation, and the corporate merger of competing private interests, much of the control structure that emerged since the early 1930s remains in place. Supplementing market dynamics, major patterns of control structure and process imposed on retail distributors of electric energy in the United States include

1. control at the state level through Public Service Commission (PSC) regulatory activity,
2. control at the national level by virtue of power contract stipulations negotiated in connection with the purchase of federally generated electric power, and
3. control at the national level due to contractual provisions embedded in federal government financing and loan guarantee arrangements.

In the current government-wide political/economic milieu with attention focused on downsizing, deregulation, and privatization at all levels, these governance structures are under intense scrutiny. A brief summary of each follows.

PUBLIC SERVICE COMMISSION CONTROLS

PSCs have been granted various regulatory powers with which to control and coordinate the activities of electric utilities operating within their boundaries (National Association of Regulatory Utility Commissioners [NARUC], 1989). Some PSCs have substantially more authority to control and coordinate the operations of electric utilities than others (Finder, 1977; Gordon, 1982; NARUC, 1989). These control activities can be dichotomized into (a) activities that relate to rate control and (b) activities that relate to six major service standards. PSCs in different states use various combinations of rate control and service standards in the regulation of the distributors operating within their districts. A typology of PSC control was developed for this study based on these combinations, and PSC control systems were differentiated, forming four levels: (a) Strong Control

(PSC1), (b) Moderate Control (PSC2), (c) Weak Control (PSC3), and (d) No Control.¹ The combination of the elements of control used by each PSC is compiled and reported annually by NARUC. Using this information, each of 1,321 electric distributors included in the study² was coded with respect to the appropriate level of PSC control to which it was subject during the study year.

POWER CONTRACT CONTROLS

A second major pattern of governance to be found in the external environment of electric distributors results from provisions in contracts for the purchase of electric energy by retail distributors from entities that operate electric generators or electric transmission systems and sell energy at the wholesale level to the distributors. For purposes of the study, these distributor/buyers were divided into three mutually exclusive groups with respect to power contracts:

1. distributors who contract with the TVA for the purchase of substantial amounts of power,
2. distributors who contract with the Department of Energy through one of the power marketing administrations for the purchase of substantial amounts of power, and
3. distributors who do not purchase substantial amounts of power from the federal government.

Retail distributors in the third category are not subject to significant organizational controls imposed by TVA or the Federal Power Marketers (FPMs) by virtue of the fact that they either generate their own power or obtain it from another source that, in general, is either privately or cooperatively owned. However, the elements of control structure and process imposed on retail distributors who do purchase power from TVA or the FPMs are evident; they are significant; and they can be specified. A brief description of these governance structures follows.

The Tennessee Valley Authority Power Contract

The Tennessee Valley Authority Act of 1933 authorizes TVA to sell electric energy to states, counties, municipalities, corporations, and others for the primary purpose of benefiting the people of the Tennessee Valley geographic section as a whole and, particularly, for the benefit of domestic

and rural consumers in the TVA area. The stated goal is to make power available to these consumers at the lowest possible cost.

A review of standard contractual provisions that have been included in the contract for the sale of electric energy by TVA reveals that, in the process of carrying out its mandate, TVA structures its contractual relations with retail distributors in such manner that it (TVA) actually controls the resale price range within which the distributor sells power to its customers. The power contract has also provided that the distributor will be subject to stringent financial and general management controls administered by TVA.

The Federal Power Marketer Power Contract

Although control structures and processes are consciously and explicitly emphasized in the organizational arrangements between TVA and its customer/distributors, the degree of this control effort does not seem to be nearly so great in the case of the FPMs who also sell electric energy to retail distributors. These federal agencies do not understand operating control of distributors, per se, as being a significant responsibility. Thus, the organized environment of those retail distributors who purchase power from FPMs rather than from TVA is structured considerably differently with respect to the governance of distributor operations. FPMs seem to view themselves as primarily sales and marketing elements in the distribution channel for federally generated electric power. This contrasts sharply with the TVA approach that, although including a concern for sales and marketing, also clearly includes a substantial emphasis on TVA involvement in distributor engineering, accounting, and general management functions.

Conversely, it must be recognized that energy transactions with Federal Power Marketers do not occur in a totally unfettered private market. Annual reports and documents published by these government agencies indicate the presence of certain control arrangements in power contracts that are different from those one would expect in mere market transactions (i.e., arms-length transactions among investor-owned utilities where the federal government is not one party to the transaction). Perhaps the most important influence on distributors by the FPMs results from the fact that the latter operate under the auspices of Congressionally delegated authority with the general mandate to transmit and dispose of federally generated surplus electric energy in such a manner as to encourage the

widespread use of electric power at the lowest possible cost to ultimate consumers consistent with sound business principles. Thus, a legislated bias favoring the general public interest enters contractual arrangements with the Federal Power Marketers. This contrasts significantly with contractual arrangements that would be expected to result from economic self-interest governed solely by competitive market forces, particularly if marketpower asymmetries are factored into the analysis.

RURAL ELECTRIFICATION ADMINISTRATION CONTROLS

The financing of electric utility operations by RUS/REA creates a relationship that involves far more than that found in the mere debtor-creditor relationship typical of market-governed transactions. The depth of RUS/REA involvement in control of the daily operations of RUS/REA-financed distributors is significant and, compared to the other governance structures discussed here, has been highly bureaucratic in that there is substantially greater emphasis on process controls. The RUS/REA control system is operative by virtue of the conditions imposed in the financing arrangements between the agency and the distributor, and one stated purpose of these controls is to accomplish the objectives of RUS/REA. The federal entity has involved itself in the daily operational aspects of borrower distributors to the point that "There are established procedures and practices in printed [RUS/REA] bulletins on practically every aspect of rural electrification" (REA, 1963, p. 7). The extent of involvement in distributor operations and the detail involved in the system of process control that emerges from these organizational arrangements is attested to by a 20-page list of RUS/REA publications issued in 1981 (Zolle, 1981) that presents RUS/REA regulatory bulletins, standard contract forms, and highly detailed construction specifications. Many of these prescribed forms, specifications, and regulatory procedures continue in use in the late 1990s and are maintained by RUS on an interactive Web site available to be downloaded by borrower distributors. Neither TVA nor the FPMs rival RUS/REA with respect to the imposition of detailed process controls on distributors.

For purposes of the study, electric distributors were identified as either subject to RUS/REA control (designated REA) or not, depending on whether they used financing arrangements involving loans or loan guarantees from RUS/REA.

MEASURING ORGANIZATIONAL PERFORMANCE

Data Envelopment Analysis (DEA) (Charnes, Cooper, & Rhodes, 1978), a method useful for measuring the relative managerial efficiency of decision-making units (DMUs), was used to measure organizational performance of distributors. This procedure is comprised of a mathematical programming technique that can be used to compare the relative efficiencies of individual DMUs—in this case, the relative performance of individual distributors of electric energy.

The method has been previously used to measure relative efficiencies in a wide range of fields: the court system (Lewin, Morey, & Cook, 1981), railroad property valuation (Adolphson, Cornia, & Walters, 1989), electric cooperatives (Thomas, 1986), public education (Charnes & Cooper, 1980; Charnes, Cooper, & Rhodes, 1981), health care organizations (Sherman, 1986), and the national park service (Rhodes, 1986), among many others. Seiford (1994) lists some 470 DEA-related studies.

DEA provides a measure of relative efficiency that is especially applicable to situations where there are multiple inputs or outputs that cannot otherwise be easily combined into a meaningful, unified measure of production efficiency. Charnes, Cooper, Lewin, and Seiford (1994) note that calculations undertaken with this methodology

produce a single aggregate measure of each DMU in terms of its utilization of input factors (independent variables) to produce desired outputs (dependent variables); [and] . . . can simultaneously utilize multiple outputs and multiple inputs with each being stated in different units of measurement. (p. 10)

Ganley and Cubbin (1992, p. 2) suggest DEA is especially appropriate for the comparison of the relative efficiency of organizations that may have multiple activities that would lead to accomplishment of multiple goals. And, DEA seems particularly useful when comparing the relative efficiency of organizations that are similar in overall mission and technology but that may have adopted somewhat differing activities and/or intermediate goals to accomplish that mission.

For purposes of DEA, the relative efficiency of a DMU can be defined as the ratio of the organization's total weighted output to its total weighted input (Sexton, 1986). In concept, this model can be written as follows:

$$\text{Efficiency of DMU } k = \frac{\sum_{r=1}^s U_{rk} Y_{rk}}{\sum_{i=1}^m V_{ik} X_{ik}}$$

where k = the DMU under analysis;

s = number of outputs;

m = number of inputs;

Y_{rk} = amount of output r produced by DMU k with $r = 1, \dots, s$;

X_{ik} = amount of input i used by DMU k with $i = 1, \dots, m$;

U_{rk} = the unit weight placed on output r by DMU k with $r = 1, \dots, s$; and

V_{ik} = the unit weight placed on input i by DMU k with $i = 1, \dots, m$.

The computational process applying this conceptual model is described in the appendix. The results of the analysis are discussed below.

DEA RESULTS

Table 1 presents the mean relative efficiency scores, standard deviations, and minimum and maximum scores for the population and subpopulations of distributors included in the study. Also shown (in parentheses) is the number of distributors in each group who attained the maximum DEA relative efficiency score of 1.0.

In this table, the ALL category includes the total population of distributors in the study regardless of the control system to which the distributor was subject. The separate control system subpopulations are designated TVA, FPM, PSC1, PSC2, PSC3, and REA, with the control systems relating to these designations being the same as defined earlier. The group designated NONE includes those distributors not subject to any of the control systems specified in the study.

Table 2 ranks the distributor subpopulations according to mean performance scores, from best to worst, and displays their positions relative to the mean score for all distributors in the study population. Clearly, TVA administrators should be pleased with the position of TVA distributors relative to the mean scores for all other subpopulations.

TVA distributor performance suggests that TVA controls are effective. On the contrary, distributors subject to REA and FPM control systems did not perform as well. Those distributors subject to moderate PSC control (PSC2) performed above average, whereas those distributors subject to PSC1 (strong) and PSC3 (weak) control levels fell below the average performance level for all distributors. It is interesting that the average score for those distributors not subject to either of the three control systems defined in the study was not only above the mean for all distributors but also only 6% below that of the highest scoring subpopulation, TVA.

TABLE 1
Data Envelopment Analysis Relative Efficiency
Subpopulation Scores

<i>Control System</i>	<i>Mean Efficiency Score</i>	<i>Standard Deviation</i>	<i>Minimum Efficiency Score</i>	<i>Maximum Efficiency Score^a</i>	<i>n</i>
ALL	.34	.17	.103072	1.0 (19)	1,321
TVA	.55	.17	.232692	1.0 (3)	134
FPM	.25	.12	.130343	.7 (0)	60
PSC1	.32	.13	.113485	1.0 (3)	475
PSC2	.52	.22	.201629	1.0 (2)	20
PSC3	.29	.14	.116901	1.0 (2)	235
REA	.26	.08	.103072	1.0 (1)	862
NONE	.49	.21	.170764	1.0 (9)	141

a. Numbers in parentheses indicate the number of decision-making units attaining the maximum efficiency score of 1.0 in each group.

TABLE 2
Subpopulation Ranks on Data Envelopment Analysis
Relative Efficiency Scores

<i>Rank</i>	<i>Subpopulation</i>	<i>Score</i>
1	TVA	.55
2	PSC2	.52
3	NONE	.49
Mean	(all distributors)	.34
4	PSC1	.32
5	PSC3	.29
6	REA	.26
7	FPM	.25

However, the analysis is not complete at this stage, and other factors must be considered.

CONTROL SYSTEM INTERACTION

Electric distributors may be subject to control exercised by one of the three systems described (i.e., PSC control, power contract control, or REA control) or to none of these controls. It is also possible that a distributor

will be subject to control from more than one of the governance structures. For example, it is common for certain distributors who purchase power from TVA to also be financed by RUS/REA. Thus, in this case, the performance of the distributor may be influenced not only by the TVA power contract control system but also by the RUS/REA control system. Furthermore, the interaction of the two systems of control operating together may produce an additional effect on performance. Similar interactions are possible across all combinations of the three control systems defined in this study.

With the exception of the performance scores for those distributors who were not subject to any of the control systems specified in the study, analysis that examines only the population and subpopulation mean scores, as in Tables 1 and 2, does not allow for the effect of multiple combinations and possible interactions of the control systems. As such, the inferences taken from these mean scores may be flawed. Recognizing this complexity in the interpretation of the results of the DEA scores, an attempt was made to enhance the analysis using an ordinary least squares (OLS) regression model as a descriptive tool.

The basic theoretical relationship between the various organizational control systems that might be found to be influential in the environment of a selected organization and the impact of those systems on the performance of the organization is hypothesized above as

$$\text{Organizational Performance} = f(\text{control system employed})$$

Based on this relational notion, a regression model was developed to analyze the performance scores for the distributors. Relative performance scores produced by the DEA procedure formed the dependent variable vector, and the control structures and processes defined in the study were treated as independent dummy variables.

In the full specification of the model, it was important to control for the fact that there may exist various interactions among the control systems as described above. To accomplish this, it is helpful to conceptualize the control variables and the levels of control as a $4 \times 3 \times 2$ factorial design or factorial experiment (Mendenhall, 1968). That is, the control variable, Public Service Controls, is composed of four levels of control: strong, moderate, weak, and no control. The control variable, Power Contract Controls, is comprised of three levels: TVA, federal power marketer, and independent (or none). In addition, the REA control variable, REA Controls, is comprised of two levels: REA control and no control. The regression model, using dummy variables for these qualitative variables, captured this design (Armour & Teece, 1986; Kaplan, 1982; Searle & Udell, 1970).

EXTRANEOUS PHYSICAL AND SOCIOECONOMIC FACTORS

Weather conditions and other factors found in the physical environments of the distributors of electric energy may affect the performance scores of the various distributors. Likewise, socioeconomic factors extraneous to rationalized control systems may have an impact. The effect of such factors confound the interpretation of mean DEA distributor performance scores because these effects may be present regardless of the organizational control structure or process to which the distributor is subject. Intuitive examples of such important environmental factors include variances across distributors in the number of consumers served and in the prosperity level of the community of users served as well as differences in average daily temperature, in the usage of electric heating versus the usage of gas heating by distributor customers, and finally, in the relative need for, and existence of, redundant plants and equipment.

Based on a review of literature dealing with the operating efficiency of electric distributors (Foley 1985; Smith, 1975, 1976; Thomas, 1986), 14 environmental factors³ that seemed most likely to provide statistical control for the effect of environmental influences were included in the regression model.

REGRESSION RESULTS

The regression coefficients for the dummy variables representing the presence of the designated control systems and their interactions are displayed in Table 3.

In this analysis, the intercept can be understood as a benchmark from which distributor average performance varies according to the presence or absence of the various control systems. Following Mohr's (1988) line of reasoning, each reported coefficient represents the average effect on distributor performance of the particular control system to which that variable relates. This effect is stated in terms of the mean change in distributor performance scores from the constant term (i.e., intercept) in the model. For example, with all other control systems, system interactions, and environmental controls held constant, the TVA control system produces an average relative efficiency score 5.13% higher than would be the case if

the TVA control system were not in place. In Mohr's terms, this is the "treatment effect" of the TVA control system. It can be understood to be the average effect (in terms of increased relative efficiency) of the TVA control system on distributor performance.

Similarly, coefficients for each of the control system variables included in the model and displayed in Table 3 can be interpreted as estimates of the average effect of that particular control system on the performance score of distributors when other control systems, interactions, and environmental variables are held constant.

A comparison of the regression model coefficients with the mean performance scores displayed in Table 2 is of interest. As displayed in that table, the TVA subpopulation average performance score was .55, which was the highest mean DEA score for any distributor subpopulation. This result is consistent with the coefficient of .0513 for TVA control systems determined in the regression analysis. In both analyses, TVA has the highest positive effect on distributor performance when compared to the other defined control systems.

Note that, in Table 3, the subpopulation group, PSC3, which is the weak form of PSC control, reversed its position relative to the other levels of PSC control reported in Table 2. However, if one considers all levels of PSC control as a group, then in both analyses, PSC controls have a less positive impact on distributor performance than do TVA controls, but they have a more positive impact than either RUS/REA or FPM controls. PSCs hold the middle ground.

RUS/REA and FPM distributors were consistent across both the mean score analysis (Table 2) and the regression analysis (Table 3) in that neither control system performed as well as the TVA or PSC systems. However, when system interactions and environmental variables are controlled for, as in the regression model, on average, RUS/REA has a much greater negative impact on distributor efficiency scores than does FPM; the FPM coefficient is $-.095$, compared to $-.273$ for RUS/REA.

Generally, the analysis of the DEA relative efficiency scores based on the OLS regression model lends support to the subpopulation ranks of control systems based on the more simplistic analysis of mean efficiency scores displayed in Table 2. Distributors of electricity subject only to TVA and PSC control systems rank higher in relative efficiency than those subject only to FPM and RUS/REA systems.

TABLE 3
Ordinary Least Squares Regression Results

<i>Variable</i>	<i>Variable Coefficient</i>	<i>Standard Error</i>	<i>t Ratio</i> ^a
Control system variables			
TVA	.05130	.02143	2.394**
FPM	-.09543	.03337	-2.860***
PSC1	-.02892	.01358	-2.130**
PSC2	.02951	.02617	1.128
PSC3	.04588	.03302	1.389
REA	-.27346	.01541	-17.748***
Intercept	.66173	.27902	2.372**
Interaction control variables			
PSC1REA	.04203	.01668	2.520**
PSC3TVA	.05342	.05601	0.954
PSC3FPM	.07928	.06570	1.207
PSC3REA	-.05604	.03441	-1.629
PSC1TVAREA	-.08075	.04754	-1.699*
PSC3TVAREA	-.10730	.06616	-1.622
PSC1FPMREA	-.01704	.10001	-0.170
PSC3FPMREA	-.08098	.07286	-1.112
TVAREA	.12269	.02626	4.672***
FPMREA	.14496	.03762	3.853***

NOTE: $R^2 = .61633$. $N = 1,211$.

a. See Note 6.

* significant at the .10 level, two-tailed test. ** significant at the .05 level, two-tailed test.

*** significant at the .01 level, two-tailed test.

SUBJECTIVE NATURE OF DEA INPUT AND OUTPUT CHOICES

DEA is not without limitations. Just as with any technique useful for the evaluation of organizational efficiency, DEA results are significantly, and sometimes dramatically, affected by the choice of inputs and outputs specified in the performance measurement model. In this regard, Ganley and Cubbin (1992) note,

the existing literature has perhaps been over-enthusiastic in its reception of DEA. The fundamental output measurement and variable selection problems are rarely recognized in applied studies. (p. vii)

Variable selection for the DEA model remains essentially a subjective exercise, which at best is based on expert opinion. It would clearly be appropriate to develop more formal, less disputable, selection criteria. This should increase the credibility of the DEA model and make it more difficult for DMUs to manipulate their efficiency score. (p. 6)

It is important that the significance of the choice of inputs and outputs be recognized in a study such as the present one. A number of authors have addressed the issue (see, for example, Adolphson, Cornia, & Walters, 1989; Charnes, Cooper, & Rhodes, 1981; Golany & Roll, 1989; Lewin et al., 1981; Sexton, Silkman, & Hogan, 1986). A particularly relevant discussion of the factors that should be considered when selecting inputs and outputs for DEA analysis is found in Golany and Roll (1989). These authors suggest that the initial pool of measures from which the final set of inputs and outputs is selected be as wide as possible. The pool so created may include variables that fall in any of the following categories: (a) variables that are fully or partially controllable by the DMU, (b) environmental factors that are not controllable by the DMU at all, or (c) either quantitative variables or qualitative variables that have been assigned numerical values in some logical fashion. "All the factors which may possibly have any bearing on the performance of the DMUs to be analyzed should be listed" (p. 240). It is interesting that Golany and Roll cite the work by Dennis Thomas (1986) as exemplary in this regard. In the Thomas study (which also addressed electric distribution, but on a much smaller scale), 92 data elements were taken from electric industry rating systems and initially considered for inclusion in the analysis as inputs and outputs. Significantly for the present discussion, the Thomas work, modified somewhat to fit data available on a national basis, provided the grounding for the choice of inputs and outputs used in this analysis. Thomas's study is directly applicable here because it deals specifically with DEA inputs and outputs for electric distributors, and, as the Chairman of the Public Utility Commission of Texas at the time, he was in the position to generate a very practical, yet comprehensive, analysis of these inputs and outputs using panels of seasoned staff experts comprised of active practitioners regulating the operations of Texas electric distributors. The panel experts were drawn from the functional areas of accounting, financial analysis, engineering, and administration. For a detailed description of the process and the theory underlying the choices of inputs and outputs by this group, see Thomas, (1986, specifically, pp. 163-178, 255-259).

A MINIMALIST, COMMON SENSE INTERPRETATION OF THE DEA MEASURE

Ludwin and Guthrie (1989) make a rather profound observation that seems helpful with respect to the impact of the choice of inputs and outputs on the interpretation of the DEA measure. In presenting the results of a study that included an application of DEA to the measurement of the relative efficiency of community schools in Fort Wayne, Indiana, these writers say,

We do not argue that we know which [input and output] variables are most important. Our argument is minimalist: we have found general agreement that those used in this analysis are not unimportant. This is sufficient for examining the efficiency of the FWCS elementary schools *based on the inputs and outputs chosen* [italics added]. (p. 367)

The minimalist position taken by these writers makes eminently good sense, particularly when it is recognized that applications by different analysts of DEA to the measure of relative technical efficiency of electric distributors reflect varying choices of inputs and outputs (see, for example, Thomas, Greffe, & Grant, 1986; Pollitt, 1995, pp. 168-174; Tankersley & Tankersley, 1996).

These variances in choices of inputs and outputs, of course, produce differing results in the efficiency measure. But this seemingly problematic result is also true with other methodologies such as regression analysis and ratio analysis, the two most prevalent techniques presently used to measure efficiencies of organizational performance. There, too, the choice of variables for the regression models and the choice of factors included in performance ratios affect the efficiency measurements produced. Just so with DEA; each set of inputs and outputs produces a specific result, reflects a particular perspective, and perhaps even serves an unspecified purpose. To mitigate this apparent dilemma, Thomas (1986) framed the final choice of DEA inputs and outputs for his analysis of electric cooperatives as follows:

For the outputs, the final selection concentrated in the broadest sense on the question, "What does an electric cooperative produce?" . . . For the inputs the final selection focused on the question, "what factors determine how many units of output a cooperative produces?" (pp. 175-176)

Adopting the minimalist perspective described by Ludwin and Guthrie (1989) and using the Thomas (1986) work as guidance, the inputs selected for the present application of DEA included (a) administration expense, (b) distribution expense, (c) consumer expense, and (d) net plant investment. The outputs chosen were (a) retail sales in megawatthours (MWH), (b) net revenue, (c) adjusted net margin,⁴ and (d) loss factor.⁵ Following Thomas, the goal was to relate those inputs that are thought to determine how many units of output a retail distributor of electricity produces to those outputs that, in fact, an electric distributor actually produces. At the very least, these are important inputs and outputs relevant to the measure of efficient operations of distributors of electric energy; thus, they satisfy the Ludwin and Guthrie minimalist criterion for use in examination of efficiency of the distributors.

SUGGESTED CONTINUING RESEARCH

A first concern relates to the definition and differentiation of the control systems identified in the study. Much of the categorical assignment of the control systems is based on a formalistic analysis of statutory language, contract provisions, process control documents, and other existing legalistic material. One reviewer of this article has noted, "the sociology of law and institutional theory (old and new) teach us, the relationship between the law on the books (e.g. contractual provisions) and the law in action is an open question requiring empirical investigation." Perhaps PSC control systems are dominated by individuals trained in the law, whereas the REA control system is dominated by the accounting/auditing perspective. Perhaps TVA is dominated by technically oriented engineers trained in the physical sciences. Are political appointees more influential in one system than the other? An examination of the underlying values and assumptions of those enacting the control process has the potential to yield insights that are not obvious from a formalistic review of documents and other artifacts that comprise the control technology. Such an investigation of the law in action might provide an improved typology for differentiating and categorizing organizational control systems.

A quite different, yet related, issue suggested for future study is the missing explanation for the performance scores of those distributors of electricity who were not subject to the control systems defined in the

study. This seems particularly important due to the current and continuing high level of interest on the part of U.S. policy analysts in competitive market controls as a substitute for regulation in electric distribution. The control system category, NONE, in Table 1 indicates that 141 distributors who were not subject to either of the control systems defined here had a mean efficiency score only 6% lower than the TVA distributors. What accounts for the relatively good performance of those distributors who are not subject to the management controls discussed? What is the nature of the external control environment within which these 141 entities operate? Has the study failed to identify a definitive control system that impacts these cases? Are there implications for the efficacy of competitive market controls here, or do other factors that have not been properly accounted for in the study explain this good result?

Finally, have the DEA inputs and outputs selected for this analysis introduced a bias in the results? Ganley and Cubbin (1992) note that there is presently no formal variable selection criteria available in the DEA process. They argue, "This is clearly unsatisfactory in introducing an undesirable subjective factor into the analysis. . . . DMUs can argue for alternative input-output sets which maximise their efficiency score" (p. 158). Although the present research suggests that organizational performance is to some degree a function of the governance structure and process found in the external control environment of organizations, to properly rationalize the structure of organizational environments, one needs to know much more about this governance function. The tentativeness and pre-diagnostic nature of this analysis is implied by Charnes et al. (1994) in *Data Envelopment Analysis: Theory, Methodology and Applications*, wherein it is said

the DEA approach provides an analytical tool for determining effective and ineffective performance as the *starting point* [italics added] for inducing theories about best-practice behavior. The resulting explanations could be in the form of central tendency models or in the form of comparative ethnographic research whose aim is to induce grounded theory. (p. 10)

APPENDIX

For computational purposes, the data envelopment analysis (DEA) process can be written in the form of a fractional linear program that can then be transformed into an ordinary linear program and solved using the simplex method (Sexton, 1986). The computational model used in this analysis is as follows:

$$\text{Maximize } H_k = \sum_{r=1}^s U_{rk} Y_{rk},$$

subject to

$$\sum_{r=1}^s U_{rk} Y_{rj} - \sum_{i=1}^m V_{ik} X_{ij} \leq 0,$$

$$\sum_{i=1}^m V_{ik} X_{ik} = 1,$$

$$U_{rk} \geq 0, \text{ and}$$

$$V_{ik} \geq 0,$$

where k = the decision-making unit under analysis;

n = number of DMUs to be analyzed;

m = number of inputs;

s = number of outputs;

X_{ij} = amount of input i used by DMU j with $i = 1, \dots, m$ and $j = 1, \dots, n$;

Y_{rj} = amount of output r produced by DMU j with $r = 1, \dots, s$ and $j = 1, \dots, n$;

V_{ik} = unit weight placed on input i by DMU k with $i = 1, \dots, m$; and

U_{rk} = unit weight placed on output r by DMU k with $r = 1, \dots, s$.

The significant problem addressed in the operationalization of this ratio as a measure of efficiency is the determination of the weights to be assigned to each output and each input included in the formulation. It is here that DEA is most useful as a technique for measuring relative efficiency because the DEA process produces these weights automatically by virtue of the formulation of the mathematical algorithm. With the specification of certain minimal conditions, DEA (using a linear programming process) selects that set of weights that will present the relative efficiency of each DMU in the best possible light. The specified conditions for the algorithm are (a) no weight can be negative, (b) each DMU must be allowed to use the same set of weights to evaluate its efficiency, and (c) the ratios resulting from each of these separate evaluations must not exceed one (Charnes, Cooper, & Rhodes, 1981; Sexton, 1986). Thus, the DMU under analysis maximizes its efficiency ratio subject to the named conditions, and in the process, the efficiency ratio for that DMU is, in effect, forced into comparison with the efficiency ratio for each other DMU using the optimal input and output weights for the DMU under analysis.

The DEA results reported here were obtained using commercially available linear programming software. For an interesting and important discussion of

limitations associated with standard linear programming software in DEA applications and a description of specialized DEA software packages that overcome certain of these limitations, see Agha Iqbal Ali (1994a, 1994b). Also included in that work are a number of suggestions for improving future DEA practice as it emerges to become a standard and generally accepted technique for management analysis.

NOTES

1. The different levels of Public Service Commission control were defined as follows:

1. Strong Control (PSC1): the combination of authority over retail rates and the authority to invoke three or more of the six important service standards;
2. Moderate Control (PSC2): authority over retail rates, but with the authority to invoke less than three of the six important service standards;
3. Weak Control (PSC3): no authority over retail rates, but with the authority to invoke three or more of the six important service standards; and
4. No Control: no authority over retail rates, and the authority to invoke less than three of the six important service standards.

2. Data envelopment analysis (DEA) was used to measure the relative efficiency of the electric distributors in this study. Data used for the DEA process were taken from publications produced by the United States Energy Information Agency and the Rural Electrification Administration. These are compiled from self-reported annual reports filed by electric distributors in accordance with statutory requirements. As discussed in Sexton, Silkman, and Hogan (1986), DEA is extremely sensitive to data errors. Therefore, where there were missing data or patently obvious errors, the distributor was eliminated. After editing, the database used in the DEA process was comprised of 1,321 distributors.

3. The fourteen environmental variables in the analysis are:

NORESCON: number of residential consumers for each system

NOCOMMCON: number of small commercial consumers for each system

NOINDCON: number of industrial consumers for each system

AVRESUSE: average annual megawatthour (MWH) usage for residential consumers for the year 1987

AVBUSUSE: average annual MWH usage for small commercial consumers and industrial consumers for the year 1987

RTERESCO: eleven year average annual growth rate in percent for number of residential consumers

RTEBUSCO: eleven year average annual growth rate in percent for number of small commercial and industrial consumers

RTEAVRES: eleven year average annual growth rate in percent for average annual kWh usage for residential consumers

RTEAVBUS: eleven year average annual growth rate in percent for average annual kWh usage for small commercial consumers and industrial consumers

EBI: average household income for the service area

CONEQNDX: price index for electrical equipment for the region in which the system is located

LABORNDX: price index for construction labor costs for the region in which the system is located

MWHCOST: cost to the decision-making unit of power sold in \$/MWH

GENERATO: binary dummy variable indicating if each system operates at least one power generating plant

4. Adjusted Net Margin is, in general, net income after adding back the cost of purchased power and transmission expenses incurred by the distributor DMU. Following the Thomas (1986) DEA analysis of electric distributor inputs and outputs, power and transmission expenses were added back to distributor net income "to eliminate their impact on measuring operational efficiency" (Thomas, 1986, p. 255).

The comparable output, Net Margin before power and transmission expense, as used in the Thomas (1986) study, was further modified in the present study to add back cost of produced power for those DMUs that generate power. This modification is a prerequisite to comparability across DMUs that purchase power and those that generate power. This was not an issue in the Thomas study because only one of the DMUs in that study generated power, and it was handled as a special case.

A modification was also made to include operating margins (operating income) rather than net income, as in the Thomas (1986) model. The difference between net income and operating income under distributor accounting rules is that net income is calculated after deducting interest expense and nonoperating income and expense that by definition, do not reflect managerial efficiency. Managerial efficiency is the subject of interest in this study, thus, the modification.

5. Loss Factor: Losses of energy in the distribution of electric power occur due to properties of physical plant as well as to properties of administrative processes. The total measure of power sold by a distributor will not equal the total power available for sale due to these losses. The general definition for *Line Loss* is $((\text{total MWH generated} + \text{total MWH purchased}) - (\text{MWH sold or used})) / (\text{total MWH generated} + \text{total MWH purchased})$. *Line Loss* is a statement, in percentages, of unaccounted-for electric power. *Line Loss* thus provides a measure of the quality of the distributor system resulting from not only physical power losses due to the technical quality of the system but also unaccounted-for electric power losses due to administrative error. Both are functions of managerial efficacy. Because DEA maximizes outputs, it is convenient to use the reciprocal value of *Line Loss* as the output measure.

6. Studies using ordinary least squares regression modeling commonly display standard errors and the related *t* ratio required to determine the statistical significance of the related *b* coefficients calculated in the regression process. There is, however, disagreement as to the utility of these values in studies such as the present one, where essentially the entire population is included in the data set (see Agresti & Finlay, 1997; Bainbridge, 1992; and Studenmund & Cassidy, 1987). Following Bainbridge, *t* tests are displayed here for those who consider them useful in such studies; however, the following caveat seems appropriate.

Mohr (1988) notes, "When we . . . turn our attention to [expost-designs] it [is] clear that a constructive role for significance testing there simply does not, in principle exist" (pp. 94-96). Morrison and Henkel (1969) further suggest, "Significance tests . . . are not legitimately used for any purpose other than that of assessing the sampling error of a statistic designed to describe a particular population on the basis of a probability sample" (pp. 131-133). Studenmund and Cassidy (1987) offer the following observation:

The t-test helps make inferences about the true value of a parameter from an estimate calculated from a sample of the population. . . . As the size of the sample approaches the size of the population, an unbiased estimated coefficient approaches the true population value; if a coefficient is calculated from the entire population, then an unbiased estimate already measures the population value and a significant t-test adds nothing to this knowledge. . . . many [samples] are quite large; and others, even though fairly small, are not really samples of a population but contain the entire population in one data set. (pp. 108-109)

There is no probability sample in this study. Rather, all electric distributors operating in the United States during 1987 for which data were available were included in the study. Neither testing for the statistical significance of the coefficients nor the resulting statistical inferences to be drawn from such tests is considered useful by the author.

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