Relative Efficiency of Electric Cooperatives in South Carolina: An Application and Test of Data Envelopment Analysis

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Abstract
This article presents the results of a prediagnostic review of the operating performance of South Carolina cooperative electric distributors using data envelopment analysis (DEA), a technique useful for analyzing the relative efficiency of decision making units across the not-for-profit, for-profit and public sectors. DEA is not without limitations, but it is suggested that the technique has the potential to add richness to the discussion of performance evaluation for quasi-public organizations.

Introduction

Data Envelopment Analysis (DEA) has been characterized as a technique that is as useful as any yet developed for measuring the technical efficiency of public sector and not-for-profit organizations.

The private sector long has had "bottom line" measurements available to it, specifically the profit margin. But the nonprofit sector does not, and researchers in the field of program evaluation slowly are developing measurement techniques that enable them to determine their level of efficiency....Data Envelopment Analysis may be as close to any of the program evaluation methodologies that we have in deriving measures of technical efficiency for the public sector. (Henry, 1995, pp. 192-193)

Even a cursory review of public management literature indicates that studies of organizational efficiency utilizing DEA have become commonplace. Since the development of the technique in the late 1970s by Charnes, Cooper and Rhodes (1978), DEA has been applied to the evaluation of technical efficiency in such wide ranging activities as the national park service, health care organizations, public education, electric cooperatives, railroad property evaluations, and the court systems, among many others (Tankersley, 1990). Recent interesting applications of DEA have addressed the relative efficiency of State Boards of Accountancy in their enforcement and disciplinary processes (Turner and Depree, 1991), the relative efficiency of agricultural production units (Haag and Semple, 1992) and even the evaluation of segments of the marketing channel, e.g., customer-supplier relationships (Kleinsorge, Schary and Tanner, 1992). DEA does not require a market price for the evaluation of inputs and outputs in a production or transformation process, but rather, it has the capability to deal with units of inputs and outputs in physical terms (e.g. pounds, tons, gallons, etc.) as well as those stated in monetary terms (e.g. dollars). Because of this useful property, the technique can be applied across for-profit and not-for-profit organizations. Consequently, DEA may provide the long-awaited measure useful for comparing the technical efficiency of private sector organizations with public sector organizations.

Ratio Analysis and Regression Models

Typically, two approaches are used to measure organizational efficiency. These are ratio analysis and regression modeling. Both approaches, however, have significant limitations. Ratio analysis suffers the very practical constraint that while an organization may score very high on one ratio, or one set of ratios, it may simultaneously score relatively low on another set. This result requires that subjective judgements be made by the analyst as to which individual ratio, or combination of ratios, should be considered most important in the evaluation. Couple this with the fact that the number of possible performance ratios to be reported for an organization is large, and the condition quickly becomes intractable. [One recent report included some fifty operating ratios for the organization under analysis. (CFC, 1993)]

On the other hand, given a specified level of the various inputs consumed in a production process, regression modeling can be used to compare the expected output level to the actual for a given organization. But, to do so requires that a production function, or mathematical model, reflecting how inputs are combined in the production process, be accurately specified. And even then, regression analysis relates the organization's relative efficiency to the average level of efficiency for the group, not the optimal efficiency theoretically, or even historically, possible. In this case, those organizations exceeding expected (average) production levels are considered efficient. Those below the average are considered inefficient. Clearly, this measure is limited in those cases where inefficient organizations dominate the group thus producing lower expected output levels. It would seem to be much better to compare actual performance to a theorized (or actual) optimal performance. This would, at least, provide management with important targets for improvement.

The DEA Method

Data Envelopment Analysis provides this possibility. It is a linear-programming based methodology that allows management analysts to measure the relative productive efficiency of each member of a set of comparable producing units based on a theoretical optimal performance for each organization. For this purpose, the organizational units under analysis are designated as decision making units (DMUs), and, "These decision-making units can be separate institutions or firms, such as police departments or hospitals, or they can be separate sites or branches of a single program or agency, such as classrooms or schools within a city school district or local Head Start programs." (Sexton, 1986, p. 7.)

The method was "designed specifically to measure relative efficiency in situations in which there are multiple inputs and outputs and there is no obvious objective way of aggregating either inputs or outputs into a meaningful index of productive efficiency." (Sexton, 1986, p. 10) In the case of DEA, the relative efficiency of an organization is defined as the ratio of its total weighted output to its total weighted input. Using a linear programming maximization process (e.g. the simplex method) DEA selects the best weights for each input and output for the particular DMU under analysis so as to maximize the ratio while satisfying certain minimal conditions. APPENDIX A provides details of the conceptual model as well as an operational explanation of DEA.

Application of DEA to South Carolina Electric Cooperatives

South Carolina electric cooperatives were chosen for this application of DEA. The *1992 Statistical Report, Rural Electric Borrowers*, published by the United States Department of Agriculture, Rural Electrification Administration (REA)[1] indicates that as of December 31, 1992, there were 20 electric cooperatives operating within the State of South Carolina that had REA approved loans or loan guarantees. These cooperatives are the decision making units (DMUs) included in the present study. Operating input and output data for the cooperatives were taken directly from the *1992 Statistical Report.*

Inputs and Outputs Used to Calculate Relative Efficiency

In order to calculate relative efficiencies using DEA, it is necessary to choose a pool of inputs and outputs considered germane to the productive efficiency of the DMUs (i.e. the electric distributors). In any given case, however, the variables that should be selected are not self-evident. Generally, such choices are made on the basis of the judgement of experts and other stakeholders relevant to the particular industry under study. (Adolphson, Cornia and Walters, 1989; Charnes, Cooper and Rhodes, 1981; Golany and Roll, 1989; Lewin et al, 1981; and Sexton, Silkman and Hogan, 1986, provide information useful in making the appropriate choices of inputs and outputs for use in DEA analysis.) For the present study, the general approach was taken from these works, but guidance for specific decisions was taken from an earlier application of DEA to Texas electric cooperatives by Thomas (1986) and a nationwide study of electric distributors by Tankersley (1990).

Several practical guidelines for structuring the DEA model are offered by Thomas, Greffe and Grant (1986). They suggest:

> *As for the number of inputs and outputs to be included in a DEA model, the number of inputs usually exceeds the number of outputs in order to aid in the interpretation of the results. Additionally, a general rule of thumb is that the total number of DMUs in the data set should be at least twice the number of inputs and outputs specified in the model. By keeping the number of inputs and outputs low relative to the number of DMUs, fewer DMUs will appear on the efficient frontier, resulting in more meaningful measures of relative efficiency. (p.820)*

Along this same line, it is important to note that one unintended outcome of the DEA process is that the choice of a relatively high number of performance measures will tend to cause relatively more organizations to receive higher efficiency ratings than would otherwise be the case (Adolphson et al., 1989). Consequently, all other things being equal, and if the indicators chosen measure performance along important dimensions, the fewer measures chosen, the better the analysis. The important consideration here is to choose those indicators which measure performance along useful dimensions (as defined by the relevant evaluators) while, at the same time, reflecting meaningful causal relationships.[2] Following these guidelines, the variables included in Run One of this analysis were:

INPUTS	OUTPUTS
1.Administration Expense	1.Retail Sales (MWH)
2. Distribution Expense	2. Net Revenue
3. Consumer Expense	3. Loss Factor
4. Plant In Service	

TABLE 1
DEA Relative Efficiency Scores and Ranks

	Run One		Run Two	
Name	**Score**	**Rank**	**Score**	**Rank**
Fairfield Electric Cooperative, Inc	1.0000	1	.9528	2
Marlboro Electric Cooperative, Inc.	1.0000	1	.7336	17
Horry Electric Cooperatve, Inc.	1.0000	1	1.0000	1
Palmetto Electric Cooperative, Inc.	1.0000	1	.8592	9
Black River Electric Cooperative, Inc.	.9617	2	.9311	3
York Electric Cooperative, Inc.	.9408	3	.8362	12
Santee Electric Cooperative, Inc.	.9318	4	1.0000	1
Mid-Carolina Electric Cooperative, Inc.	.9070	5	.8977	7
Pee Dee Electric Cooperative, Inc.	.9000	6	.8352	13
Little River Electric Cooperative, Inc.	.8384	7	1.0000	1
Blue Ridge Electric Cooperative, Inc.	.8277	8	.8625	8
Laurens Electric Cooperative, Inc.	.8202	9	.8097	15
Newberry Electric Cooperative, Inc.	.7923	10	.8542	11
Berkeley Electric Cooperative, Inc.	.7846	11	.8103	14
Broad River Electric Cooperative, Inc.	.7671	12	.8543	10
Tri-County Electric Cooperative, Inc.	.7635	13	.9040	6
Aiken Electric Cooperative, Inc.	.7621	14	.7747	16
Edisto Electric Cooperative, Inc.	.7399	15	1.0000	1
Lynches River Electric Cooperative, Inc.	.7155	16	.9051	5
Coastal Electric Cooperative, Inc.	.6372	17	.9061	4

Descriptive definitions as well as the sources of the values for each of these variables for the South Carolina cooperatives can be found in APPENDIX B.

DEA Results (Run One)

The relative efficiency scores and the performance ranks resulting from Run One for the South Carolina cooperatives are shown in Table One. (Run Two results are also displayed in Table One; these are discussed below). The Run One average (mean) efficiency score is 0.85 with a standard deviation of 0.11. Twelve of the 20 cooperatives in Run One rank within one standard deviation of this average. Five cooperatives attained an efficiency score more than one standard deviation above the mean, while three ranked more than one standard deviation below the mean. The median score was 0.83.

It is important to realize that these DEA relative efficiency scores must be considered *prediagnostic* in nature. And, they must be interpreted in the broader context of the specific characteristics of each distributor's operations as well as the environmental constraints which may be affecting the distributors. Nonetheless, on their face, the results clearly suggest where operational review and performance auditing should be focused. The three distributors who ranked more than one standard deviation below the mean for the group would provide a good starting point in the overall effort to improve the efficiency of service to customers. It would be interesting to compare the management and operating practices, environmental constraints and performance outcomes of these three distributors to the operations of the five cooperatives that scored more than one standard deviation above the mean. It is possible that certain very effective, yet transferable, management policies and operating techniques might become obvious if distributors were examined in the light of this analysis.

The Validity of DEA as A Measure of Relative Efficiency

If DEA is to provide guidance in the effort to locate management inefficiencies and move toward improvement of distributor operations, it is clear that there must be solid acceptance of DEA as a performance measurement technique. Not only must the calculated relative efficiency scores actually measure what they have been designed to measure, they must be perceived to do so as well. Due to lack of familiarity with the technique on the part of distributor management, as well as the relative complexity of DEA, it seems reasonable that managers of those electric cooperatives receiving low DEA scores might simply challenge, or even reject outright, the outcome of Run One of the study. Thomas, Greffe and Grant (1986) address this possibility, and suggest,

A key question which remains to be answered is the extent to which DEA is accepted as a valid performance measurement tool. As with any new quantitative technique, the first obstacle which must be overcome is the perception that DEA is a black box into which data is entered and results obtained. (p. 1,813)

In a more general, administrative context, discussing what they describe as *operational validity* of a measure, O'Sullivan and Rassel (1995), suggest, "A measure that appears to be operationally valid is said to be *face valid*." (p. 99) To accomplish face validity, investigators may simply assume that their measure is operationally valid or in the alternative, "...investigators may [simply] consult the literature to find [proper] measures and discussion of their appropriateness. In practice, face validity is probably the most common form of validation." (p. 99) Because of its prevalent use, as well as the praise it has received in the literature, DEA appears to have acquired *face validity* as a comparative measure of performance for not-for-profit, for-profit and government organizations. O'Sullivan and Rassel caution, however:

A more sophisticated form of operational validity [than face validity] is *content validity*. Content validity involves systematic identification of the elements that constitute a measure. This entails identifying the elements integral to the concept of interest....The researcher must...demonstrate that the measure involved includes all the identified elements and assigns to each the proper relative weight. (p. 99)

Thomas (1986) discusses this issue relative to the application of DEA to electric distributors, concluding:

Failure to include a valid input or output [in the DEA analysis] will bias the results against efficient users of the input or efficient producers of the output. Inclusion of an invalid input or output causes some DMUs to be rated as more efficient than they really are. (p. 28)

Sensitivity of DEA to Changes in Inputs and Outputs

To test the *content validity* of DEA as applied to the South Carolina cooperative electric distributors in Run One, a second DEA model was structured and the analysis performed. While the first analysis was guided by the previous work of Thomas (1986) and Tankersley (1990), the second run was based on the logic of Thomas, Greffe and Grant (1986), who made significant changes in the variables utilized in their DEA model from the original Thomas work. Modifying this later model for availability of data, the following inputs and outputs were incorporated into the second DEA analysis of the South Carolina cooperatives (see APPENDIX B for definitions):

INPUTS:	OUTPUTS:
1. Administration Expense	1. Number of Customers
2. Distribution Expense	2. Distribution Line Miles
3. Consumer Expense	
4. Plant in Service	

DEA RESULTS (Run Two)

As noted above, the relative efficiency scores along with the related ranks for the South Carolina cooperatives resulting from the second analysis (i.e. Run Two) also are displayed in Table One. The Run Two average (mean) score is 0.89 with a standard deviation of 0.08. In this second run, 13 cooperatives rank within one standard deviation of the mean while four attained a score greater than one standard deviation above the mean. Again, as in Run One, three distributors ranked more than one standard deviation below the mean. The median score was 0.88.

DEA Content Validity: Comparison of Run One Results with Run Two Results

While the overall range and distribution of the relative efficiency scores reported in Table One for Run One and Run Two are similar, an examination of the individual scores and their relative positions is illuminating. A simple comparison of the best performing distributors in Run One (those with an efficiency score of 1.000) to the scores for the same distributors in Run Two suggests problems of *content validity* for DEA as a measure of efficiency. While Fairfield Electric Cooperative, Inc. and Horry Electric Cooperative, Inc. maintained their positions as being among the top scorers in both runs, Palmetto Electric Cooperative, Inc. moved from a rank of first place in Run One to ninth place in Run Two, and, even more interestingly, Marlboro Electric Cooperative, Inc. moved from first place in Run One to last place (ranked 17) in Run Two. How does one reconcile these results while maintaining the *content validity* of DEA as a measure of relative operating efficiency? Consider the following.

DEA Exonerated as a Useful Analytical Technique?

Classical public administrationists were well aware of the problem of specifying what constitutes good organizational performance. Luther Gulick addressed the issue and suggested the following:

In the science of administration, whether public or private, the basic "good" is efficiency....Efficiency is axiom number one in the value scale of administration. (Gulick and Urwick, 1937, p. 192) On the other hand however, Dwight Waldo, writing in the late 1940s, offered the following mitigating advice:

... the "pure concept of efficiency" proposed by Gulick as the basic "good" of administrative study, is a mirage....I hold that efficiency cannot itself be a value....Things are not simply "efficient" or "inefficient." They are efficient or inefficient for given purposes, and efficiency for one purpose may mean inefficiency for another. (Waldo, 1984, p. 193)

DEA as a measure of relative efficiency must be considered in this light. While, as demonstrated above, it is clear that changing from one set of inputs and outputs to another will change the relative efficiency scores of the decision making units included in the analysis, the saving grace for DEA is that, relative to other measures of organizational efficiency, DEA performs rather admirably.

Consider the alternatives: ratio analysis and regression modeling of the production function discussed above. Both the Rural Electrification Administration as well as the National Rural Utilities Cooperative Finance Corporation have provided extensive analyses of electric cooperative operations based on one or both of these approaches. These analyses can be found in 1) the Rural Electrification Administration (REA) Regression Models, 2) the REA Borrowers Statistical Profile, and 3) the Cooperative Finance Corporation Key Ratio Trend Analysis. (Thomas, 1986)

If the objective is to measure absolute efficiency, not efficiency as a relational concept, these approaches suffer the same *content validity* problem as DEA, i.e. if an important operating ratio is not considered, or if an important variable is omitted from the production function required for regression analysis, the analysis and conclusion are no better than that afforded by an inappropriately structured DEA model. Likewise, they also share the problems associated with arriving at agreement as to which ratio(s) or regression model(s) will be considered most important in the evaluation of distributors. This seems best addressed by recognizing that "efficiency" is a relational concept. One must refuse to accept a simplistic interpretation of any analytical result that does not allow for this. At least implicitly, efficiency measures must answer the question, "efficient for what", or perhaps, even better, "efficient in light of what". Here, each analytical method suffers its own complexities and offers its own advantages. However, if one accepts that efficiency is a relational concept, not an absolute concept, one important strength of DEA is that it provides for the integration of multiple inputs and outputs into one measure, a feature not provided by the other approaches. If a group of stakeholders can agree on a set of important inputs and outputs that relate to a particular dimension, goal, or even constraint on distributor operations, then the DEA approach can be used to calculate and report the relative efficiencies of all the decision making units included in the group *with respect to that set of inputs and outputs*.

A fairly obvious extension would be to develop DEA models that include several sets of inputs and outputs designed to reflect different aspects, or dimensions, of distributor operations. For example, one might utilize three models in an analysis: a financial efficiency DEA model, a quality of service DEA model and an environmental constraint DEA model. The financial model would be designed to reflect relative performance with respect to important financial inputs and outputs, the quality of service model would relate quality of customer service measures to inputs, while the environmental constraint model would indicate the effect on distributor performance of uncontrollable elements in the organizational environment. Table Two suggests inputs and outputs that might be used in such a three-pronged analysis. Distributors could then be compared on the basis of their relative efficiency scores relative to these three dimensions. Perhaps the mean score of each distributor on all three measures would be a useful point of departure for the analysis.

The Hypothetically Efficient Target

In addition to the above, however, DEA provides a benefit not yet mentioned. In the process of calculating the relative efficiency scores of the decision making units included in the DEA analysis (by utilizing the "dual" of the linear program) a subset of perfectly efficient electric distributors is identified for each inefficient distributor. These relatively efficient distributors make up the "efficient reference set" for the specified inefficient distributor, and they can be thought of as those to which it was compared to obtain the efficiency score. These are also the distributors which, hypothetically, the inefficient distributor should emulate to move toward more efficient operations. Based on the reference set of distributors, hypothetical multipliers for both inputs and outputs are obtained from the DEA process that can be used to formulate managerial strategies for operational improvement of

TABLE TWO
Suggested Input/Output Sets for Electric Distributors

The Financial DEA Model

INPUTS:	OUTPUTS:
1. Administration Expense	1. Operating Margins
2. Distribution Expense	2. Return on Investment
3. Consumer Expense	3. Equity
4. Plant in Service	

The Quality of Service DEA Model

INPUTS:	OUTPUTS:
1. Administration Expense	1. Customer Satisfaction
2. Distribution Expense	2. Customer Outages
3. Consumer Expense	3. Measure of System Losses
4. Plant in Service	

The Environmental Constraint DEA Model

INPUTS:	OUTPUTS:
1. Administration Expense	1. Number of Customers
2. Distribution Expense	2. Distribution Line Miles
3. Consumer Expense	
4. Plant in Service	

the inefficient distributor. A hypothetical perfectly efficient DMU can be constructed for each inefficient distributor reflecting the adjustments required to its inputs and outputs to develop a combination whose efficiency would be relatively perfect when compared to the other distributors included in the analysis. (See Sexton, 1986, for details of this process.) Thus, DEA not only provides measures of relative efficiency with respect to specified subsets of inputs and outputs, it suggests paths for improvement to operations of inefficient decision making units.

Conclusion

While it is obvious that data envelopment analysis as applied in this study has not solved the problems associated with *content validity* in the measurement of relative efficiency of the South Carolina cooperative electric distributors, it also is clear that the methodology adds richness to the discussion of performance measurement for these decision-making units. By providing for analysis of relative efficiency on the basis of various select combinations of inputs and outputs, the method provides for expanded discussion and the possibility of new insight with respect to improved management technique and effectiveness of electric distributors. Of particular interest will be the continued development of sets of inputs and outputs that most directly reflect financial efficiency, the provision of quality customer service and the effect of environmental factors upon distributor efficiency.

Likewise, the potential that DEA offers for developing hypothetically efficient target operations for single, specified electric cooperatives based on existing, real operations of a comparative reference set of distributors is intriguing. Given the current emphasis (particularly in the electric energy industry) on the benign effects of market competition and the efficacy of the "bottom line" for directing efficient operations in both the public and private sectors, it would appear that managers of cooperative electric distributors, operating as quasi-public organizations, would welcome the further development and application of a measure such as DEA.

APPENDIX A

The relative efficiency of a decision making unit (DMU) is defined in DEA analysis as the ratio of the organization's total weighted output to its total weighted input. Mathematically, this formulation is:

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

where:
k = the DMU under analysis;
s = number of outputs;
m = number of inputs;
Y_{rk} = amount of output r produced by DMU k, $r = 1,...,s$;
X_{ik} = amount of input i used by DMU k; $i = 1,...,m$;
U_{rk} = the unit weight placed on output r by DMU k, $r = 1,...,s$; and,
V_{ik} = the unit weight placed on input i by DMU k, $i = 1,...,m$.

A major function of the DEA process is the proper determination of the weights to be assigned to each output and each input for the several DMUs included in the analysis. DEA provides that each DMU will be fitted with that set of weights which presents its highest possible efficiency score subject to certain minimal conditions. These specified conditions are, 1) no weight can be negative, 2) each DMU must be allowed to use the same set of weights to evaluate its efficiency and 3) the ratios resulting from each of these separate evaluations must not exceed one (Charnes, Cooper and Rhodes, 1981; Sexton, 1986). Thus, the efficiency ratio for each DMU is forced into comparison with the efficiency ratio for every other DMU in the group using the chosen input and output weights.

The DEA process (above) can be transformed into an ordinary linear program and solved using the simplex method (Sexton, 1986). The transformed linear program appears as follows:

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

subject to:

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

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

$$U_{rk} \geq 0;$$
$$V_{ik} \geq 0;$$

where,
k = the DMU 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; $i = 1,..., m$; $j = 1,...n$;
Y_{rj} = amount of output r produced by DMU j; $r = 1,...,s$; $j = 1,...n$;
V_{ik} = unit weight placed on input i by DMU k, $i = 1,...,m$;
U_{rk} = unit weight placed on output r by DMU k; $r = 1,...,s$.

Commercial linear programming software packages are available for use on personal computers that make this analysis reasonably straightforward for management personnel having moderate exposure to operations research techniques.

APPENDIX B
INPUTS AND OUTPUTS

Values for the input and output variables for Runs One and Two were taken from the list of Active Borrowers—Loan, Operating and Financial Statistics found in the *1992 Statistical Report, Rural Electric*

Borrowers (United States Department of Agriculture, Rural Electrification Administration, Informational Publication 201-1, July, 1993). A broad definition of the various inputs and outputs follows.

Inputs (Run One and Run Two)

1. Administration Expense—generally includes among others, officer, executive manager and unallocated salaries, office supplies and expenses, outside services, property insurance, employee pensions and benefits, regulatory commission expense, advertising and miscellaneous (Line 40, Administration and General Expense).

2. Distribution Expense—generally includes operation supervision and engineering, load dispatching, station expenses, overhead and underground line expenses, meter expenses, customer installation expense, miscellaneous expenses and distribution system rentals as well as maintenance supervision and engineering, maintenance of structures, station equipment, overhead and underground lines, line transformers and meters (Line 36, Distribution Expense, Operation and Line 37, Distribution Expense, Maintenance).

3. Consumer Expense—generally includes supervision, meter reading, customer records and collection expense and uncollectible accounts (Line 38, Consumer Accounts, and Line 39, Customer Service and Information Expense).

4. Plant In Service—generally includes distribution plant, transmission plant, general plant and other plant, at cost (Line 12, Utility Plant in Service).

Outputs (Run One)

1. Retail Sales (MWH)—generally, sales measured in units of energy sold; not dollars sales (Line 67, MWH Sales Total, and Line 66, MWH Sales to Others for Resale).

2. Net Revenue - any revenue received from energy sales. Does not include other sources of revenue (Line 75, Total Sales of Electric Energy).

3. Loss Factor - "Line loss" is a statement, in percent, of unaccounted for electric power. "Line loss", thus, provides a measure of the quality of the distributor system resulting from physical power losses due to the technical quality of the system as well as losses due to unaccounted for electric power due to administrative error. Since DEA maximizes outputs, it is necessary to use the reciprocal value of "Line Loss", the "Loss Factor", as the output measure (Line 86, MWH Purchased 1992, Line 85, MWH Generated 1992 and Line 67, Total MWH Sales).

Outputs (Run Two)

1. Number of Customers - average number of customers served by the DMU during the year including residential service, small commercial and industrial service, large commercial and industrial service, irrigation service, and other service (Line 59, Average Number Consumers Served—Total).

2. Number of Distribution Line Miles - miles of distribution line served including overhead distribution miles and underground distribution miles (Line 81 plus Line 82).

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Endnotes

1 Presently known as United States Department of Agriculture, Rural Utilities Service.

2 The literature of electric utility performance measurement suggests the existence of a reasonably stable consensus as to which measures should be considered in the measurement of distributor performance. There is however, little consensus in the literature as to the appropriate methodology for the assessment (i.e., weighting) of these factors in comparing the performance of distributors (De Alessi, 1974; Axelrod, 1975; Kendrick, 1975; Mann and Seifried, 1972; Foley, 1985; Smith, 1975; 1976; Stevenson, 1975; Tenenbaum and Wald, 1975; Thomas, 1986; Utley, 1971). This condition, of course, renders oblique support for the use of DEA in assessing the performance of these organizational units since the DEA approach does not require consensus as to the weight given specific inputs and outputs; rather, it requires consensus with respect to the overall group of measures which are considered important. (Tankersley, 1990, pp. 77-78)