Cost and Service Reliability Performance Evaluation for Electric Distribution Utilities

Thesis in fulfillment of the requirements for a Master's of Science degree in the Agricultural and Applied Economics Department of the University of Wisconsin-Madison

Authored by Steve Fenrick

Executive Summary

The research in this thesis presents a scientific methodology for ascertaining cost and reliability performance for power distribution utilities. Performance analysis has traditionally relied on the following methods for defining efficiency: 1) Econometric benchmarking 2) Data envelopment analysis, 3) Peer group cost benchmarking, and 4) Productivity trend analysis. A synopsis of these four performance assessment approaches is provided in Chapter Two. North American precedents using the varying approaches are also presented in Chapter Two.

Cost and reliability econometric models for the U.S. power distribution industry are estimated in Chapters Three and Four, respectively. Utility performance in these two key areas is judged through the comparison of actual data values to econometric benchmark predictions using an array of variables reflecting the operating and business conditions of the sampled utilities. A key finding is that there are multiple external service territory characteristics that do significantly impact cost and reliability data, and should, therefore, be incorporated in a performance evaluation.

Productivity trend theory is presented in Chapter Five. Productivity trends measure the direction of cost efficiency as opposed to the relative level of cost efficiency. Using this approach, first the recent productivity trend of a utility is calculated. This calculated trend is then compared to an expected trend. The expected productivity trend is calculated using the econometric cost function developed in Chapter Three. Model estimates for the annual technological advancement of the industry and the availability of scale economies are used to fashion the benchmark productivity growth trend.

This thesis offers the reader an overview and calculation methods for assessing cost and reliability performance levels and trends of power distributors. The context and uses of benchmarking and productivity trend analysis are offered. Example results and case studies are supplied for each of these tools. Suggestions on further research are included throughout the text and also in the concluding chapter.

[Chapters 1 thru 5 are not provided; please contact Steve Fenrick (fenricks@powersystem.org) for a complete copy of the thesis]

Chapter Six: Conclusions

The research in this thesis presents a scientific methodology for ascertaining performance for power distribution utilities. Cost and reliability econometric models have been estimated. Utility performance in these two key areas is judged through the comparison of actual data values to econometric benchmark predictions. This method explicitly normalizes for the external circumstantial factors influencing attainable cost and reliability levels. Productivity trends were calculated, along with a method to critique these trends relative to an econometrically-formed expectation.

There are four commonly used benchmarking performance evaluation techniques in energy utility regulation.

1) Econometric benchmarking,
2) Data Envelope Analysis,
3) Peer group cost benchmarking, and
4) Productivity trend analysis.

Chapter Two contains a synopsis of these four performance assessment approaches and discusses precedents in North America. Chapters Three, Four, and Five contain my research efforts in properly designing and conducting econometric benchmarking and productivity trend analysis.

My first analysis, found in Chapter Three, is to estimate a cost function of the U.S. power distribution industry using a translog cost functional form. The dependent variable is total distribution costs, inclusive of both the capital and O&M costs of each sampled utility. This model was used to compare actual data values to model predictions. The econometric benchmarking method is especially germane for the utility distribution industry where assets are spread and maintained across dissimilar service territories. My model contains a number of external factor variables. The econometric results of the cost function were good: all coefficients were logically-signed and most were statistically significant.

The presence of reasonable and significant external factor parameter estimates exemplifies the flexibility of the econometric benchmarking approach relative to techniques which are unable to explicitly adjust for these relevant variables.

Benchmarking approaches which do not incorporate these variables will be omitting relevant information. This omission could be the cause of perceived good or poor performance rather than the actual performance of the studied utility.

Variables found to significantly impact cost include: number of retail customers, retail deliveries, distribution peak demand, input prices, percentage of overhead plant, number of gas customers served, percent of service territory that is forested, twenty year customer growth percentage, percent of deliveries that are residential and commercial, and customer density per line mile. Data values for these variables have been collected and their impacts on total cost estimated through the econometric benchmarking approach presented in this thesis.

The estimated cost function provided coefficient estimates of the three identified outputs of the industry. Outputs were defined as: number of retail customers, amount of sales volume, and peak demand. These coefficient estimates can be used to determine if the industry is characterized by constant returns to scale, or increasing or decreasing returns to scale. My research indicates that for a sample mean U.S. power distributor, scale economies have been exhausted and firms display constant returns to scale.

This first analysis required the implementation of the perpetual inventory capital cost method. This method uses a series of capital addition data starting in 1964 to estimate the cost of capital for each utility. This method allows utilities with differing plant depreciation practices and unique capital addition histories to be compared. It uses a geometric decay approach to calculating depreciation.

My second analysis, found in Chapter Four, was to estimate four models with varying definitions for service reliability as the dependent variable. I used SAIDI and SAIFI as measures of reliability. Each measure was calculated in two distinct ways: all outages included in the index, or with major event day outages excluded from the index. A double log functional form and a Box-Cox transformation were estimated. Comparisons were then made of actual data values to model predicted data values for a utility serving the state of Maryland.

Similar to the first analysis, external factor variables were found to significantly influence reported reliability data. Variables found to significantly impact reliability statistics include: number of retail customers, percentage of overhead plant, percent of service territory that is forested, and the number of line miles. Data values for these variables have been collected and their impacts on reliability estimated through the econometric benchmarking approach presented in this thesis.

A key result of this research is the robust reliability influence of underground power lines. Underground power lines were estimated to reduce both the frequency and duration of outages. This result held for all four models and was particularly prevalent in reliability definitions that were inclusive of all outages. This implies that placing power lines underground helps to prevent outages during severe weather.

A third analysis was conducted and found in Chapter Five. In this analysis I turned my attention towards examining performance *trends* rather than the performance *levels* examined in the previous two chapters. A productivity trend analysis examines the trajectory of the cost efficiency of the utility. The calculations necessary, along with a case study, were presented in this thesis. These calculations included the techniques used to combine multiple outputs and inputs into index measurements. This enabled total factor productivity trends to be constructed.

A comparison approach to judging a utility's given productivity was based on the econometric model parameter estimates found in Chapter Three. This decomposes productivity into its three main components: technology advancement, realization of scale economies, and relative efficiency change. A prediction of a given utility's productivity trend was constructed and compared to its actual trend. This evaluation was used to determine if the historic productivity gains of a utility were on par with the industry given the possibilities for realization of scale economies and technological advancements.

My research provides a range of analyses to evaluate the performance of electric distribution utilities. A couple of problematic themes were discovered that hampered the research development. One constraint of the research was the definitional inconsistency and unavailability of reliability data for the full sample. U.S. electric utilities are required to file expense and output (customer, retail sales) data with the Federal Energy Regulation Commission. No such requirement is placed on the reporting of reliability statistics. This fact limited the reliability econometric research to fewer observations. Varying definitions of reliability statistics across utilities made analysis more difficult and challenging to interpret.

Theory would suggest that higher levels of reliability would be accompanied by a higher level of cost. The research presented separate models for cost and reliability. Several attempts were made to combine cost and reliability data into one model. However, no sensible model was forthcoming. If and when reliability data becomes more common and consistent, a comprehensive model could be developed in future research which incorporates cost or reliability as a function of the other. These estimates would be useful in a performance assessment framework and in determining the marginal impacts of costs and reliability.

Another future research avenue of combining reliability and cost into one model is by quantifying the economic costs resulting from outages (see Appendix). By monetizing the impacts of reliability, the reliability and cost level models can be combined into a comprehensive measure. Evaluating the overall social costs of the power distributor would be a more complete measure of performance as opposed to constraining the benchmark analysis at expense levels incurred by the utility. Utilities found to be incurring lower than expected total social costs are enhancing the overall welfare of their service territory through a combination of low rates and fewer outages.

Along these same lines, further research could develop a comprehensive productivity trend incorporating reliability data as an output into the analysis. End-use consumer economic losses due to outages would form the basis for combining reliability metric data with input and output factors. By weighting an index in this way, the costs of outages and the costs of employing input factors would be weighted in proportion to the costs borne by ratepayers, either through rates or loss of service. Comprehensive productivity trends would provide a more complete evaluation of the historic and current operational path of the utility.

Chapter Five discussed the theoretical decomposition of productivity trends. One of the elements is the impact on productivity from relative efficiency changes across a given time period. An investigation of the interplay between beginning period cost efficiency benchmarking estimates and observed productivity trends may be of interest. The construction of incentive regulation rate plans typically involves both a productivity estimate and cost efficiency analysis to determine allowed rate escalation. The hypothesis that strong cost efficiency will negatively influence subsequent productivity growth should be examined.

Further research on expanding the included external variables in both the cost and reliability models could prove fruitful. An example would be a variable controlling for the severity of storms within a service territory for each sampled year. This would further eliminate possible reasons for actual data values and predicted values to deviate from each other. Possible exploration could include climate, storm, and geographic variables.