

Preliminary
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**RESTRUCTURING AND EFFICIENCY IN THE
U.S. ELECTRIC POWER SECTOR¹**

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Section 1: Introduction

The electricity industry has been undergoing profound reform around the world since around 1990. Led by the disintegration of Central Electricity Generating Board in the UK in 1990 electricity companies have been vertically separated, privatised and actively changed hands on the stock market. Pollitt (1997) documents that some 51 countries were involved in major liberalisation of their electricity markets by the second half of the 1990s. Since then, if anything, the pace of reform has accelerated. In Europe two European Commission Directives in 1996 and 2003 have promoted widespread and ongoing restructuring (Jamash and Pollitt, 2005) among the European Union's 25 member countries. In the US between 1993 and 1998 many states actively promoted deregulation of their electricity sectors, with the process only suffering a setback following the California electricity crisis of 2000-2001 (Joskow, 2003).

Electricity liberalisation around the world has involved some combination of the following. First, *restructuring* involving the partial or complete unbundling of

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vertically integrated companies into separate businesses of generation, transmission, distribution and retailing. This may additionally involve horizontal splitting of businesses to reduce market power. Second, the introduction of *competition*, this may include the creation of wholesale power markets for the trading of bulk electrical energy and the allowing of new entry into generation and retailing, together with third party access rights to transmission and distribution markets. Retail competition is now widespread for industrial and commercial customers and exists in several countries and some US states for residential users. Third, *regulatory reform* involving the introduction of incentive regulation of transmission and distribution networks and the toughening of the oversight of market competition. Finally, the *privatisation* of state owned enterprises in markets not characterised by significant private ownership prior to reform.

The primary focus of the analysis of electricity reform has been on the operation of the generation market. This is because this is the market segment that has seen the most profound reform and which accounts for around 60% of industry value added. This paper will focus on US electricity distribution businesses, which together account for around 35% of industry value added and have a combined contribution to GDP of around 0.5%. These businesses engage in the ownership and operation of lower voltage distribution wires and the billing and customer service of regulated small business and household customers. While the essential regulated monopoly aspect of this business remains unchanged it has been the focus of increasing attention due to the increasingly clear separation of this business from the other segments of the electricity industry supply chain. In addition these businesses have been affected by regulatory reform as noted above. Sappington et al. (2001) note that at least 16 US states have introduced some form of price cap regulation of electricity distribution and retail prices, in place of traditional rate of return based regulation. Sometimes this has involved a simple multi-year rate freeze or some form revenue sharing (known as performance based rate-making or PBR) where cost savings are shared between shareholders and customers. This has increased incentives for utilities to cut costs within their remaining regulated businesses. Often these price caps have been agreed as part of state's the merger approval process.

The restructuring of the US electricity industry unleashed as a result of the move towards competition has resulted in an unprecedented wave of mergers. The Edison Electric Institute records 77 completed mergers between 1994 and 2002 (source www.eei.org). This is in a sector which consists of 305 operating companies. This suggests that more than half of US electricity customers have been served by companies party to a merger or takeover within the space of 8 years. It is the effect of this merger wave that we seek to analyse in this paper.

Mergers may be motivated by several objectives: They may aim to increase productivity growth and improve relative efficiency. They may seek and acquire market power. And some are the result of altogether different case-specific objectives involving particular companies, their executives, and bankers. Individual mergers are evaluated *ex ante* for these purposes by the competition authority in the relevant country, and sometimes *ex post* by interested observers. There are very few large-scale and systematic *ex post* evaluations, however, since comparable data on large numbers of mergers are rarely available. This data problem is resolved in this study by examining a single industry with consistent regulatory reporting obligations throughout the period in which numerous mergers transpired.

We investigate the efficiency and productivity impact of the electricity merger wave on distribution and regulated retailing businesses. We do this by using data envelopment analysis (DEA) to analyse relative efficiency and DEA-based Malmquist indices to analyse productivity growth. In section 2 we discuss the electricity merger wave in more detail before discussing the relevant literature on the efficiency and productivity analysis of mergers in section 3. Section 4 outlines the data sources and issues arising. Section 5 discusses the DEA and Malmquist measures and how we will use regression analysis of these measures to analyse the impact of mergers. Section 6 reports the results of the analysis. Section 7 concludes.

Section 2: The US electricity merger wave

[Insert Table 1 Here]

The late 1990s was characterised by an upsurge in the total value of merger transactions. This was particularly notable in banking, telecoms, oil and defense sectors, but this was also true in the electricity sector. As Table 1 shows there was only one completed merger in 1994 but there were 23 in 2000. The vast majority of the takeovers involved counterparties who were also in the electricity business. This horizontal feature suggests the mergers may have been motivated by potential cost savings from economies of scale and scope, but it is also consistent with the possibility of market power. State Public Utility Commissions (PUCs), charged with overseeing and approving or disapproving such mergers, almost uniformly require merger parties to file evidence detailing the size of cost savings as part of their own evaluation.

One can illustrate the nature of electric utility mergers in the 1990s by a couple of examples. In 1999 Boston Edison, the major utility serving the City of Boston, Massachusetts, completed a merger with Commonwealth Energy System which served customers in neighbouring Cambridge and southern Massachusetts. The new entity known as NSTAR was focussed on electricity distribution and retailing, as the former vertically integrated operating companies had divested themselves of their generating capacity under Massachusetts' electricity reform. The three operating companies: Boston Edison, Cambridge Electric and Commonwealth Electric continue to make separate FERC data filings. The merger filings to the Massachusetts PUC suggest that the the merger would achieve cost reductions of around \$660m over 10 years (DTE, 1999, p.37).

In 2001 the UK's National Grid company completed a take over of Niagara Mohawk, a electricity and gas utility serving upstate New York. This was in addition to their 2000 takeover of the New England Electric System (NEES) which operates in Western Massachusetts, Rhode Island, Maine and New Hampshire. The UK company's main business at the time was the operation of the transmission system in England and Wales, though it has since merged with the UK's gas transmission and distribution system. As part of its negotiation process with state regulators National Grid negotiated a 10 year PBR scheme for Niagara Mohawk and a 20 year PBR scheme from NEES in Massachusetts and Rhode Island. The merger filings to the New York PUC in respect of Niagara Mohawk highlighted the potential for efficiency

savings of \$1.1 bn over 10 years (see National Grid USA and Niagara Mohawk, 2001, p.93).

Utility mergers may involve electricity generation and transmission as well as gas transmission and distribution assets. Our focus will be on just electricity distribution and the associated regulated retail assets. This is because generation data is not as readily available following deregulation (as data filings are not mandatory for competitive generators), transmission business efficiency is notoriously difficult to compare and gas transmission and distribution are not as financially significant as electricity distribution.

Electricity distribution business mergers, in principle, allow several key questions to be investigated. These include the following. First, what are the characteristics of merging and non-merging firms? Second, do mergers actually improve relative performance? Third, do mergers attempt to achieve optimal scale of operation? Fourth, do mergers achieve ex post the savings claimed by the merging parties ex ante? Fifth, do mergers offer the potential for the introduction of tougher incentive based prices as a condition for merger approval? The last of these questions are specific to regulated utility mergers. The fourth question raises an important issue for general anti-trust policy, i.e. can ex ante claims made by companies be believed? The final question raises the issue of how can US utilities be shifted to incentive based regulation in circumstances where they must voluntarily agree to be subjected to such regulation, rather than having it imposed by central governments as in Europe. In this paper we investigate the first of these two questions, while raising the possibility of investigating the last three questions subsequently.

Section 3: Previous Studies of Productivity and Efficiency Analysis

In this section we examine three sets of previous literature relevant to the US electricity merger wave. First, there are a small number of papers specifically on recent US electricity mergers. Second, we discuss the mergers and productivity literature more widely to suggest how this issue might be approached. Finally, we turn to the recent literature specifically on electricity distribution efficiency and productivity measurement.

3.1 US electricity merger literature

Given the amount of data available on the US electricity sector and the scale of recent mergers there have been surprisingly few studies of the sector and mergers. We pick out three strands in the literature: case studies of mergers; event studies of mergers and studies which look at economies of scale in the electricity sector.

Joskow (1998) reviews a proposed merger between Baltimore Gas and Electric (BG&E) and Potomac Electric Power (PEPCO). He examines the regulatory filings in the case. FERC initially rejected the companies request to merge. After further review and rebuttals from the companies FERC accepted their merger request. However it required that they lowered their customer prices after merger. Both companies found the proposed prices too low to offer gains to their stockholders and called off the merger.

In an early paper by Ray and Thompson (1990) examines four case studies of mergers in the 1980s. They look at stock prices to analyse whether these mergers were financially rewarding for bidders and/or target firms. They concluded that regulatory agencies, in these cases, did a good job in limiting the profits of the mergers to firms and transferring some of the synergy gains to consumers. They found that target firm shareholders did make small profits while there was almost no financial benefit to bidding firm shareholders. They concluded that this indicated little financial reason to merge. This paper is in line with two later papers:

Leggio and Lien (2000) analysed 76 electricity mergers over the period 1983-1996 using event study analysis. They compared share prices the day before the announcement to the day after. They found announcement effect gains for target firms of 11.5% if they were unregulated and 8.3% if they were regulated. Bidders suffered small announcement effects of +0.76% if unregulated and -0.5% if regulated. This suggests that overall gains were positive and that regulation does act to transfer some potential gains to consumers.

Berry (2000) used event study analysis to look at 21 electricity/electricity and electricity/gas mergers in competitive markets over the period 1995-1998. He looks at the change in stock prices the day before announcement and two days after. The findings are that for target firms electricity/gas mergers result in 16% gains compared to 8% gain for electricity/electricity. For bidders the gains are -2% for electricity/gas and -1% of electricity/electricity. The author suggests that the scope for economies of scope in electricity/gas mergers is perceived to be significant by the market.

The above studies highlight the effect of regulation in obscuring the potential gains from merger as measured by conventional event study analysis. Profitability studies would suffer from the same problems. They point to the value of productivity analysis to examine whether mergers should be allowed to go ahead and to analyse the extent of their social benefits.

Economies of scale have been highlighted as key sources of efficiency gains from electricity mergers. Stoner (1994) directly addresses the issue of how electricity mergers can bring about efficiency savings. He looks at case studies to see where efficiency savings come from and how much they are likely to be. Mergers which result in companies in the size range of 12-30 TWh are thought to be likely to bring savings, 30-54 TWh could possibly bring savings, while above 54 TWh savings are unlikely. Stoner suggests that substantial merger savings are possible but they are likely to be over-estimated in regulatory review and should be viewed skeptically.

Kwoka (2005) analyses 442 electricity distribution companies using regression analysis of costs. He finds that costs are minimised at 1.47 million customers or 33.6 TWh of electricity distributed, although the cost gradient was quite shallow. The latter fact implies that unit costs varied little over a considerable range, suggesting viable utilities of disparate size. Nonetheless, as there are approximately 95 million customers of the 200 investor-owned utilities in the US (in 2000), there may well be opportunities for mergers to achieve cost savings by growing toward optimal scale. Returning to our two example mergers in section 2. Commonwealth Energy System had only 6.3 TWh units distributed in 1999. According to Kwoka this would imply that they suffered from a 10% higher average cost disadvantage due to being at non-optimal scale.

It should be pointed out that the role of size in mergers is difficult to assess properly. This is because utility data tends to be available separately for electricity and gas operating companies. Operating companies operate within state boundaries and face state level regulation. This gives rise to different types of scale effects: economies of scale and scope operate across electricity and gas operation companies; within state across different holding companies; and inter-state (or internationally) within holding companies. Each of these is likely to be differentiated in its effects and requires careful modelling and reasonably complete datasets which may not be available.

3.2 Mergers and Productivity Literature

There are three broad types of studies evaluating the effects of mergers: event studies, analyses of profitability, and studies of productivity. The first two types are vast, and we make no attempt to summarize them here. We have already noted in the preceding section a few event studies of electricity mergers, and their cautionary conclusions about the benefits of mergers are replicated in event studies in general. The impact of mergers on the profitability of merging companies has been studied intensively by Meeks (1977) and Ravenscraft and Scherer (1987), who find that mergers result in ‘widespread failure, considerable mediocrity, and occasional successes.’²

Event studies and profitability studies dominate the general merger literature, particularly for multi-industry studies. This is because productivity analysis data requires data not usually available in company accounts, national statistics or from stock market data. However there have been a number of productivity studies of specific industries. We begin by examining three of these studies before making some general points about productivity in the restructured electricity supply industry.

McGuckin and Nguyen (1995) examine mergers in a sample of 28,294 US food plants over the period 1977-1987. They look at the labour productivity over this period. The results indicate that ownership change is associated with the more productive plants and that transferred plants do experience improvement in productivity performance.

²Quoted from Scherer and Ross (1990, p. 173).

This paper shows how probit analysis can be used to model the likelihood of a plant being taken over and that simple measures of productivity may be the best that can be done within productivity analysis due to data shortages.

Peristiani (1997) examines around 2,000 US bank mergers over the period 1980-1990. He uses a variant of corrected ordinary least squares efficiency analysis to analyse cost efficiency of each firm in each year. This gives an X-efficiency score for each firm in each year (between 0 and 1). He also finds a scale efficiency measure (between 0 and 1) indicating the extent to which the firm can cut average costs by moving to the optimal scale. He finds that acquirers did not improve X-inefficiency after merger, however they did improve their scale efficiency. The change in return on assets, change in non-interest expenses, change in X-efficiency and change in scale efficiency are then regressed on a set of explanatory variables (such as the physical distance between the target and acquirer). These results suggest that improvements in post-merger performance depend on the ability of the banks to strengthen asset quality.

Cummins, Tennyson and Weiss (1998) examine the impact of mergers in the US life insurance industry. This paper is interesting because it uses the same measures of efficiency and productivity that we will use in this paper. The paper makes use of a sample of around 750 firms per year and 550 firms that are present in a five year block that can be used to analyse productivity change. The analysis calculates DEA efficiency scores for each firm in each year and also Malmquist TFP indices for productivity growth between two years before and two years after a merger. The changes in efficiency scores and the Malmquist TFP indices were then used as dependent variables in regressions which included a merger target dummy and other company characteristic variables. The results suggested that mergers did result in significant improvements in efficiency and productivity for target firms. Probit analysis of the probability of acquisition is then performed using the efficiency measures and company characteristic variables. This shows that in general efficiency is not a significant explainer of the likelihood of being taken over.

What might we expect productivity analysis of US electricity distribution utilities to reveal? Restructuring has had significant effects in other electricity sectors. Domah

and Pollitt (2001) found that costs fell significantly in UK electricity distribution over the period 1990-1998. This fall was particularly marked following 1994-95 when takeovers of the privatised electricity distribution companies were first permitted and when the regulator substantially tightened the regulated prices that the companies could charge. These cost falls were calculated relative to a counter-factual of continuing public ownership. Markiewicz, Rose and Wolfram (2004) examined the impact of US deregulation on electricity generation costs using input equations. They examine large steam and combined cycle gas turbine plants for the period 1981-1999, giving 10645 observations. They find that investor owned utility plants in states that restructured their wholesale electricity industry exhibited larger reductions in non-fuel operating expenses and employment (of about 5%) than those with plants in states that did not restructure their markets over the 1993-1999 period. This analysis does not examine the role of ownership change in achieving these gains.

3.3 Measuring electricity distribution efficiency and productivity

We now turn to the issue of how productivity and efficiency should be measured in electricity distribution. The two important issues are how to specify the inputs and outputs of the production process and which method is most appropriate. Jamasb and Pollitt (2001) review 20 efficiency studies of electricity distribution. These exhibit some consensus about appropriate outputs and inputs but some substantial areas of divergence. Units distributed and customer numbers are the most commonly used outputs, while operation and maintenance costs and measures of capital input such as network length often appear as inputs. Units distributed and customer numbers may further be decomposed into residential and non-residential categories. Network length sometimes appears as an output as a proxy for the size and dispersion of the area which utilities have to serve. Maximum demand also serves as an output, while transformer capacity is a commonly used input. Additionally some studies treat one or more of the variables as fixed or environmental factors. In our analysis we end up using the ratio of residential to total sales as one such environmental variable.

Jamasb and Pollitt (2001) note that three main methods have been used to measure efficiency in academic and regulatory studies. These are the non-parametric data envelopment analysis (DEA) and the parametric approaches of corrected ordinary

least squares (COLS) and stochastic frontier analysis (SFA). COLS fits a regression line to a production or cost function and shifts it to envelope the data, while SFA approaches use maximum likelihood techniques to estimate a frontier while incorporating both an inefficiency and a stochastic error term. Parametric frontiers can incorporate flexible functional forms such as translog or more restrictive forms such as Cobb-Douglas. Jamasb and Pollitt (2003), using data on 63 European distribution utilities calculate efficiency scores using DEA, COLS and SFA methods. They also adopt units delivered, number of customers and network length as outputs and operation expenditure (OPEX) or total expenditure (TOTEX, equals OPEX plus capital expenditure) as inputs. Interestingly, the results from the different methods are highly correlated for the same specifications of inputs and outputs.

Relatively few studies have measured productivity growth in electricity distribution. Productivity growth can be measured straightforwardly using single factor productivity measures. However this is unsatisfactory as output is multi-dimensional in electricity distribution. Alternatively one can use a Tornquist index of TFP which calculates the ratio of weighted outputs to weighted inputs. This is not consistent with efficiency approaches as the calculation of TFP does not depend on relative efficiency measures and hence there can be no decomposition of TFP into technical change and efficiency change. Building on the techniques for efficiency analysis there are two major approaches. One can calculate TFP using DEA based Malmquist indices or make use of SFA-type parametric analysis which incorporates a time trend in the production or cost function.

Hattori, Jamasb and Pollitt (2005) make use of both a DEA-Malmquist and an SFA approach to analyse productivity growth in a sample of 23 Japanese and UK electricity distribution businesses over the period 1986-1998. The basic model specification has units distributed and customer numbers as outputs, OPEX or TOTEX as inputs and measures of density and network length as environmental variables. The time trend in the SFA suggests little productivity growth for a common frontier while the DEA-based TFP measures show significant growth, particularly for the UK firms in the 1994-1998 period following mergers and tougher regulation.

Section 4: Data sources and issues arising

The basic data required for this study consist of outputs, inputs and control (environmental) variables for electric power distribution. While not all are used in every model, this section lists the variables, discusses their sources, and indicates any issues, modifications, or transformations required.

The initial database consisted of 305 major investor owned utilities, including subsidiaries, for the period 1994-2001. For each utility, there are 42 different variables, collectively providing comprehensive information on its finances and operations. The variables include cost, revenue, quantity, sales, customers, assets, and various utility characteristics, as well as geographic extent of utilities' operations and measures of physical capital. Operations and financial data are extracted from Platts Data Disks, which are themselves based on FERC Form 1 filings³. The remainder of the input and output data, including geographic extent of the utilities' operations and measures of physical capital, come from Electrical World Directory of Electric Utilities. Data on the identity and timing of merger targets and buyers is sourced from the Edison Electric Institute website and is listed in Appendix 1. Mergers are dated from the year of completion.

Certain factors reduce the number of observations in the final sample. First, in any given year there are non-responses and unresolvable inconsistencies in the data, resulting in the loss of a considerable number of observations. Furthermore, in order to draw appropriate comparisons across years and models, we employ a balanced panel. The net effect of these considerations is to reduce the maximum number of observations in the database to 546 for productivity analysis and 624 for the efficiency analysis, coming from a total of 78 utilities.

Of these 78 utilities, 28 of them are buying parties, 24 of them are sellers and remaining 26 are non-merging parties over the 1994-2001 period. Although the reduction in the number of utilities seems large, it should be pointed out that significant numbers of utilities that are effectively generators and that the dropped utilities tend to be the smaller ones. Thus the decision making units (DMUs) in our

³ Federal Energy Regulatory Commission Form No. 1 is a comprehensive financial and operating report submitted for Electric Rate regulation and financial audits.

sample cover 59% of the total customers and 53% of the total units distributed for year 2000. These ratios are fairly constant for all years in our sample period.

Following our discussion of previous studies of the measurement of efficiency and productivity in electricity distribution we collected the following inputs and outputs in order to estimate DEA efficiency scores and Malmquist productivity indices:

[Insert Table 2 here]

Sources for all variables, including names of the relevant accounts, can be found in the Appendix 2. Summary statistics for the main variables we actually use are given in Table 3.

[Insert Table 3 here]

While the outputs and physical inputs are common to many previous studies, some discussion of the derived financial costs is warranted. This is because of the integrated nature of many US electric utilities who may be involved in generation and transmission, as well as electricity distribution and retailing. We identify three measures of financial cost which are derived variables:

Non-Capital Costs : Operations and maintenance costs of distribution, which is the sum of distribution costs (D), total service costs due to distribution (Cu) and administration costs (A) due to distribution. Distribution-related administrative cost is estimated as the share of total administrative cost multiplied by the following:

$$S1 = \frac{\text{Wages to Distribution, Customer, and Sales Accounts}}{\text{Total Wages to O\&M}} \quad (4.1)$$

Therefore, Non-Capital Costs (NCC) can be expressed as:

$$NCC = D + Cu + S1 * A \quad (4.2)$$

This measure of cost covers the main, largely controllable, cost facing the electricity distribution part of the utility.

Capital Costs: No single account reports capital costs. We start by defining the implicit revenue of the distribution and retailing part of the utility and then subtract the non-capital cost identified above from this.

The revenue of the utility can be defined by the accounting identity:

$$R = D + C_u + T + G + PP + A + \text{EBITDA} \quad (4.3)$$

Where:

T = Transmission O&M costs

G = Own generation O&M costs

PP = Purchased Power costs

EBITDA = Earnings before interest, tax, dividends and amortisation

The capital cost of distribution is defined as the distribution share of EBITDA. Hence we find EBITDA for the whole company by rearranging (4.3):

$$\text{EBITDA} = R - (D + C_u + T + G + PP + A) \quad (4.4)$$

Capital costs are calculated as $S_2 * \text{EBITDA}$ where:

$$S_2 = \frac{\text{Distribution Assets} + D_1 * \text{Other Assets}}{\text{Total Assets}} \quad (4.5)$$

where $D_1 =$

$$\frac{\text{Distribution Assets}}{(\text{Generation Assets} + \text{Transmission Assets} + \text{Distribution Assets})} \quad (4.6)$$

This implicitly assumes that the return on generation, transmission, distribution and other assets is the same. This is clearly incorrect but it may be a satisfactory first approximation.

Non-Capital Costs and *Capital Costs* sum to give *Total Distribution Cost* (which is equivalent to the implicit revenue of the distribution and retailing business).

Labour Equivalent Non-Capital Costs: O&M costs deflated by labour costs. This measure attempts to provide a crude alternative measure of O&M costs which accounts for regional differences in labour costs (both in actual labour and bought in services). Labour costs are taken to be average utility wages, calculated by dividing total wage expenses by number of total employees. Labour equivalent non-capital costs are then obtained by deflating non-capital costs by average wages. This measure is unsatisfactory to the extent that firms paying overly generous wages may depress the value of this input and improve their measured efficiency, even though the high labour costs are an indication of management inefficiency.

Finally, we note that all cost variables are deflated by GDP Deflator to account for the possible inflationary effects. To account for this possibility, all the cost variables are expressed in terms of year 2000 dollars.

Section 5: Methodology

In this section we discuss our approach to the measurement of efficiency and productivity using the technique of DEA and DEA-based Malmquist indices. We then discuss how these measures can be used to analyse the effects of mergers on efficiency and productivity using appropriate regression techniques.

5.1 Efficiency and Productivity Analysis using Data Envelopment Analysis (DEA)⁴

DEA is a non-parametric method and uses piecewise linear programming to calculate a sample's (rather than estimate) efficient or best-practice frontier and developed in

⁴ This sub-section draws heavily on Hattori, Jamasb and Pollitt (2005).

Farrell (1957), Charnes et al. (1978), Banker, et al. (1984), and Färe et al. (1985). The decision-making units (DMUs) or firms that make up the frontier envelop the less efficient firms. Firm i is compared to a linear combination of firms that produce at least as much of each output as the inefficient firm and minimum possible amount of inputs. Technical efficiency is calculated as a score on a scale of 0 to 1, with the frontier firms receiving a score of 1 (see Cooper et al., 2000 and Coelli et al. 1998).

DEA models can be specified as input or output oriented. The former specification is more appropriate for electricity distribution utilities, as demand for distribution services is a derived demand and beyond the control of utilities.⁵ In this case, technical efficiency measures the ability of a firm to minimize inputs to produce a given level of outputs. DEA does not require specification of a function to represent the underlying technology. However, the efficiency scores can be sensitive to the choice of input and output variables. In addition, as more variables are included in models, the number of firms on the frontier increases. Further, the mean efficiency tends to decline as the size of the sample increases (Zhang and Bartels, 1998). The balance between the number of variables and sample size can, therefore, affect the discriminatory power of the model.

We can incorporate environmental or non-discretionary variables in our DEA models (see Cooper et al, 2000). Such variables are those which are assumed not to be under the control of the firm. The program used here follows the methodology in Banker and Morey (1986). The linear program calculating the efficiency score of the i -th firm in a sample of N firms in variable returns-to-scale (VRS) models takes the form specified in (5.1) where q is a scalar (equal to the efficiency score) and \mathbf{I} represents an $N \times 1$ vector of constants. Assuming that the firms use K inputs and M outputs, X and Y represent $K \times N$ input and $M \times N$ output matrices respectively. The input and output column vectors for the i -th firm are represented by x_i and y_i respectively. Non-discretionary variables can be introduced through additional constraints (see the second and the third constraint in (5.1)) where the subscripts D and ND refer to discretionary (environmental) and non-discretionary variables respectively. When non-discretionary variables are specified in this way in DEA, the methodology

⁵ Output-oriented models maximise output for a given amount of input factors. Conversely, input-oriented models minimise input factors required for a given level of output.

ensures that the efficiency scores of inefficient firms are only calculated on the basis of reductions in their discretionary inputs, while controlling for non-discretionary variables since reductions in these are not feasible. The fourth constraint in (5.1) ensures that the firm is compared against other firms with similar size. In CRS models, this convexity constraint is dropped. The equation is solved once for each firm.

$$\begin{aligned}
 & \min_{q, I} q \\
 & s.t. \\
 & -y_i + YI \geq 0 \\
 & q^{x_{i,D}} - X_D I \geq 0 \\
 & x_{i,ND} - X_{ND} I \geq 0 \\
 & N1' I = 1 \\
 & I \geq 0
 \end{aligned} \tag{5.1}$$

The DEA techniques can be used to calculate Malmquist Index of productivity change over time (see Färe, 1989 and Coelli et al., 1998), assuming the underlying technology is CRS.⁶ We use the Malmquist index as shown in (5.2) and described in Thanassoulis (2001). For example, $C_{EF_{T_0}^{D1}}$ represents the CRS efficiency score for a DMU relative to a technology in year 0 and the unit data for year 1. The left-hand-side ratio in (5.2) measures the efficiency of unit j using data set from period 1, (D1) with technology from year 0, (T0) to the efficiency of the unit with data and technology of year 0, (D0 and T0). The right-hand-side ratio measures the efficiency of unit j using data and technology from year 1, (D1 and T1) to efficiency of the unit with data of year 0, (D0) and technology of year 1, (T1). The Malmquist indices can be broken down into productivity catch-up (the left hand ratio) and frontier shift (the right hand ratio) components as in (5.3). The catch-up factor (EC_j) is a measure of the extent to which a unit has moved close to or away from the frontier while the frontier shift component (TC_j) reflects industry level technological change (see Thanassoulis, 2001, and Coelli et al., 1998).

⁶ See Tulkens and Eeckaut (1995) for some suggested alternative approaches to non-parametric efficiency measurement using panel data.

$$MI_j = \left[\frac{C_{-}EF_{T_0}^{D1} * C_{-}EF_{T_1}^{D1}}{C_{-}EF_{T_0}^{D0} * C_{-}EF_{T_1}^{D0}} \right]^{1/2} \quad (5.2)$$

$$MI_j = \frac{C_{-}EF_{T_1}^{D1}}{C_{-}EF_{T_0}^{D0}} * \left[\frac{C_{-}EF_{T_0}^{D1} * C_{-}EF_{T_0}^{D0}}{C_{-}EF_{T_1}^{D1} * C_{-}EF_{T_1}^{D0}} \right]^{1/2}$$

or (5.3)

$$MI_j = EC_j * TC_j$$

The components of the Malmquist index in (5.2) and (5.3) can be calculated separately with DEA. The two technical efficiency components that are based on data and technology from the same period can be calculated using the basic DEA program described in (5.1). The cross time efficiency based on year-0 technology and year-1 data can be calculated from (5.4) and as in Thanassoulis (2001).

$$\begin{aligned} & \min_{w, I} \mathbf{W} \\ & s.t. \\ & -y_i^1 + Y^0 \mathbf{I} \geq 0 \\ & \mathbf{w} x_{i,D}^1 - X_D^0 \mathbf{I} \geq 0 \\ & x_{i,ND}^1 - X_{ND}^0 \mathbf{I} \geq 0 \\ & \mathbf{I} \geq 0 \end{aligned} \quad (5.4)$$

The superscripts 1 and 0 for inputs x and outputs y of i -th unit indicate the relevant time period for data used for calculating efficiency. The superscripts for input matrix X and output matrix Y indicate the time period for technology used for calculating efficiency. This procedure can be modified to calculate relative efficiency for the remaining component of (5.3) with year-1 technology and year-0 data.

The DEA scores calculated above represent technical efficiency. Ideally we should use data on input prices to further calculate allocative or input price efficiency and also overall productive efficiency which is the combination of allocative and technical efficiency (Farrell, 1957). These measures account for differences in the input prices faced by the firms being analysed. Efficient firms facing lower relative

labour costs should use more labour than efficient firms with higher relative labour costs, if the production function is well-behaved. Many studies of efficiency (such as Jamasb and Pollitt, 2003) make use of technical efficiency measures and use financial measures, such as OPEX, as inputs. This is justifiable if input tradeoffs are weak and financial costs are deflated appropriately such that they represent comparable amounts of real resources. Malmquist DEA cannot incorporate input prices and focusses on technical efficiency.

We make use of CRS DEA in our analysis. CRS is a reasonable assumption in the context of the analysis of mergers since mergers mean that the scale of the holding company can be optimally varied. As common costs and associated savings are allocated back to operating divisions this should be reflected in the costs of individual operating companies. The alternative assumption of VRS would obscure the potential for merger gains through changing scale and substantially reduce measured inefficiency in the sample firms. At this stage we have not incorporated environmental variables due to lack of time in subsequent analysis we will experiment with assigning some of the variables, such as network length, as environmental variables.

We investigate a number of input and output combinations in our analysis. These are outlined in Table 4 below:

[Insert Table 4 here]

DEA scores and Malmquist indices using the above model specifications were estimated using the EMS program provided by Holger Scheel (see Scheel, 2000).

5.2 Regression analysis of productivity and efficiency scores

Following the calculation of the efficiency scores and productivity indices we need to investigate the effects of mergers within the sample. This is done by separate regression analysis of each of the three sets of DEA efficiency scores and the three sets of associated Malmquist TFP, efficiency change and technical change indices.

The crucial part of the regression analysis is the creation of the pre and post merger dummies. Our purpose is to retain all years' data for all DMUs in our data set. Therefore we created a series of dummies for merger timing. We have 7 year-pairs. We label them by their year end i.e., 95 (meaning 1994-95), 96, 97, 98, 99, 00, 01. For any DMU, any year could be as much as 7 years before a merger in the data period, or 6 years before, 5 years before, etc. We then proceed to create dummy variables which allow us to identify the time path of the effects of merger. In order to preserve as much of the merger information in the panel as possible we allow for the maximum number of dummies possible within the timeframe. This suggests a basic set of 'merger timing' dummies:

- m-7: 7 years before a merger
- m-6: 6 years before a merger
- m-5: 5 years before
- etc.
- 0 = year of merger
- m+1: one year post merger
- m+2: 2 years after
- etc.

Our sample includes observations from 6 years before a merger to 4 years after a merger. We don't have any observations that include information about 7 years before merger and 5, 6 or 7 years after the merger. Our dummies can take on a value of 0 or 1 for each year and DMU, which will uniquely identify that DMU's merger experience. (Note that zero values for all implies the DMU was not party to a merger at all.) This allows us to use all of the data to identify pre-merger and post-merger characteristics of the DMUs.

We further wish to distinguish merger effects on buyers and sellers. Due to definitional relationship between the dummies, we could only capture buyer effect by creating interaction dummies for this group. We simply interact each "merger timing dummy" with the buyer dummy and obtain merger timing dummies for buyers in this way. Our base group is non-merging parties. Merger timing dummies capture the additional effect of sellers relative to non-merging parties, while interaction dummies

capture additional effect of buyers relative to non-merging parties. We left out the “year of merger ” dummies for both set of dummies (merger timing dummies for sellers and merger timing dummies for buyers). This implies that comparison is being made to the non-merging parties and parties in the year of merger.

A small number of our firms are involved in two or more mergers. We introduce a further dummy variable which takes the value of 1 in the year after a second merger (and all subsequent years) and 0 otherwise. This is merely to flag whether engaging in multiple mergers yields any differential improvement in performance.

We further create dummy variables for year effects in our regressions. This is to control for general changes in efficiency and productivity.

We run fixed-effects regression for MI scores and technical efficiency and technical change components of MI scores. In this way, we are able to control for time-invariant firm specific effects.

For the DEA efficiency scores we run Tobit regression, as DEA scores are truncated at 1. This regression has the same specification as the others and includes firm and time fixed effects. Interpretation of the coefficients stays same (i.e. that the control group is still non-merging companies and firms in the year of merger). This regression also includes the ratio of residential to total sales (an environmental factor) as a variable to account for the potential significant impact of this ratio on efficiency. We would expect this to be negative as lower amounts of residential sales reflect higher amounts of cheaper to serve industrial and commercial customers.

Section 6: Results

The Tobit regression results for the DEA efficiency scores are given in Table 5. The environmental variable reflecting the ratio of residential in total sales has the expected negative sign. This suggests that less non-residential sales *ceteris paribus* means lower efficiency. These indicate that most of the time dummies are highly significant but so are several of the merger dummies. Look at Model M11. This model focusses on O&M cost efficiency. We can see that firms involved in two mergers have

significantly higher efficiency scores that are 11.4% higher than non-merging firms in the years following second mergers. It also is the case that target firms are significantly more efficient than the control group before merger (4.4% higher two years before merger). Meanwhile buyer firms are significantly less efficient than target firms before merger as shown by the buyer dummy variables. After merger merging parties do relatively poorly compared to non-merging firms (dummies become negative) and, if anything, buyers improve relative to targets (buyer dummies become positive) at least until 3 years after. It is important to note that the presence of firm fixed effects obscures the absolute differences in efficiency between buyers and sellers if these do not vary over time. The results are less significant for the other two models suggesting that the introduction of physical measures of capital as additional inputs (in Model M6) and a financial measure of capital (in Model 1) complicate the picture painted by a focus on O&M costs. However the pattern of the parameter values is generally similar.

[Insert Table 5 here]

[Insert Table 6 here]

In sum, Table 5 seems to indicate that buyers, sellers and non-merging firms do exhibit important pre-merger differences in efficiency and that merger is not beneficial to the merging parties, though buyers may do better than targets.

We now turn to the analysis of productivity in Table 6. Here there is much less evidence of significant parameters than for the efficiency analysis. Few of the time dummies are significant. Looking at the overall Malmquist Index measure of TFP (Change in MI) for Model M11 we can see that firms that engage in a second merger have higher productivity growth in the years following second mergers (productivity growth is 11 percentage points higher). This is in line with the efficiency finding. Looking at the general merger dummies there does not seem to be any significant pattern of productivity growth before merger (none of the dummies are significant). Buyers seem to exhibit negative relative productivity growth between 4 and 5 years before mergers (though this is barely significant) and some evidence of negative

relative performance compared to other firms after merger, particularly four years after.

Model M1 shows firms involved in merger having relatively high productivity growth two years before merger with buyers growing significantly less strongly. Model M6 exhibits some significant negative productivity growth prior to merger. The decomposition of the MI into efficiency change and technical change suggests that the most of the individual model results are driven by efficiency change rather than technical change, as the Change in EFF parameters are broadly significant at the same time as and with relatively similar in magnitude to as the overall TFP index, MI.

[Insert Figure 1 here]

Figure 1 revisits one of our example mergers mentioned in section 2, which also appears in our sample. This focuses on just single factor O&M cost productivity. The NSTAR merger has Boston Edison as the buyer and Commonwealth Electric and Cambridge Electric as sellers. 1999 is the year of merger. Single factor productivity improves in 1999-2001, with if anything the buyer doing better than the sellers. In this respect this simple example is in line with our general finding that mergers may be better for buyers than sellers. However improving productivity following merger is not clearly seen in the sample as a whole. Figure 1 also shows that the buyer less efficient than the two sellers initially: this effect is not identified by our analysis, possibly because it is hidden in the firm fixed effects.

Section 7: Conclusions

This paper has attempted to begin an analysis the efficiency and productivity impact of the significant wave of mergers which has taken place in the US electricity sector. The results are preliminary but they do indicate that further work is justified. We have found some evidence that mergers may involve firms that have enjoyed a period of relatively poor performance taking over firms that have enjoyed a period of relatively good performance. We have also found evidence that mergers do not seem to improve performance but that, if anything, buyers perform better after mergers than sellers.

Given the significance of the US electricity merger wave these findings may have important policy implications. They would be consistent with the view that mergers of electric utilities should not be allowed to proceed unless some guarantee of benefits to customers is obtained. This could be done under a challenging price cap agreement at the time of merger which assumes benefits will be passed to customers via lower prices in the absence of actual performance. Such a regulatory strategy would ensure that utilities cannot merely promise large efficiency savings, most of which may never materialise, but have strong incentives to achieve them to maintain rates of return on capital. The observation that buyers benefit relative to sellers may suggest that closer attention needs to be paid to the allocation of efficiency benefits between the accounts of targets and buyers.

Our next steps are to extend the analysis to include: additional models (with different combinations of inputs and outputs and environmental variables); extension of the dataset to include years post-2001; and more detailed investigation of time path of merger effects. We also need to investigate the role of firm fixed effects as these may be obscuring some of the efficiency and productivity differences between merging and non-merging firms. We would also plan to repeat the analysis using parameter stochastic frontier based techniques.

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*Appendix I: Mergers and Acquisitions in the US electricity industry
1 Jan 1992-31 December 2002*

<i>Buyer</i>	<i>Seller/Acquired/Merged</i>	<i>Status</i>	<i>Date Completed</i>
Indiana-Michigan Power	Michigan Power	Completed	01-Feb-92
Kansas Power & Light	Kansas Gas & Electric	Completed	01-Mar-92
UNITIL Corp.	Fitchburg Gas & Electric	Completed	01-Apr-92
Northeast Utilities	PS New Hampshire	Completed	01-Jun-92
Northeast Utilities	Fletcher Electric Light	Completed	01-Sep-92
Texas Utilities	Southwestern Electric Service	Completed	01-Jan-93
Central & Southwest	El Paso Electric	Withdrawn	01-Apr-93
IPALCO	PSI Resources	Withdrawn	01-Aug-93
Entergy	Gulf States Utilities	Completed	01-Dec-93
Southwestern Public Service	El Paso Electric	Withdrawn	01-May-94
Cincinnati Gas & Electric	PSI Resources	Completed	01-Oct-94
Citizens Utilities	Sierra Pacific Resources	Withdrawn	01-May-95
LG&E Energy	Hadson Corp.	Completed	16-May-95
PECO Energy	PPL Resources	Withdrawn	01-Jun-95
Midwest Resources	Iowa-Illinois G&E	Completed	01-Jul-95
New England Electric System	Nantucket Electric	Completed	01-Mar-96
Washington Water Power	Sierra Pacific Resources	Withdrawn	01-Jun-96
Mid-American Energy	IES Industries	Withdrawn	01-Sep-96
Kansas City Power & Light	Utilicorp United Corp.	Withdrawn	01-Sep-96
Puget Sound Power & Light	Washington Energy	Completed	01-Feb-97
PacifiCorp	TPC Corporation	Completed	01-Apr-97
WPL Holdings Inc.	IES Industries and Interstate Power	Completed	01-Apr-97
Northern States Power	Wisconsin Electric & Power	Withdrawn	01-May-97
Duke Power	PanEnergy	Completed	01-Jun-97
TECO Energy	Lykes Energy	Completed	01-Jun-97
TECO Energy	West Florida Gas	Completed	01-Jun-97
PG&E Corporation	Valero Energy	Completed	01-Jul-97
Enron Corp.	Portland General	Completed	01-Jul-97
CalEnergy	New York State Electric & Gas	Withdrawn	01-Aug-97
Houston Industries, Inc.	NoRam Energy Corp.	Completed	01-Aug-97
Texas Utilities Company	ENSERCH Corp.	Completed	01-Aug-97
Public Service of Colorado	Southwestern Public Service	Completed	01-Aug-97
Ohio Edison	Centerior Energy	Completed	01-Nov-97
Baltimore Gas & Electric	PEPCO	Withdrawn	01-Dec-97
Union Electric Company	CIPSCO	Completed	01-Dec-97
Delmarva Power	Atlantic Energy	Completed	01-Feb-98
LG&E Energy	KU Energy	Completed	01-May-98
Wisconsin Energy	Eselco, Inc.	Completed	01-May-98
Long Island Lighting Company	Brooklyn Union Gas	Completed	01-Jun-98
Enova	Pacific Enterprises	Completed	01-Jul-98
Northern States Power	Black Mountain Gas	Completed	24-Jul-98
PP&L Resources	Penn Fuel Gas	Completed	21-Aug-98
WPS Resources	Upper Peninsula Energy	Completed	29-Sep-98
AEP Resources	Equitable Res. (Mid-stream Gas Opr.)	Completed	01-Dec-98
NIPSCO Industries	Bay State Gas Company	Completed	12-Feb-99
CalEnergy	Mid-American Energy	Completed	12-Mar-99

<i>Buyer</i>	<i>Seller/Acquired/Merged</i>	<i>Status</i>	<i>Date Completed</i>
CMS Energy	Panhandle Eastern/Trunkline Gas	Completed	29-Mar-99
Sempra Energy	KN Energy	Withdrawn	01-Jun-99
OGE Energy	Transok LLC	Completed	01-Jul-99
CP&L	North Carolina Natural Gas Corp.	Completed	01-Jul-99
Consolidated Edison	Orange & Rockland Utilities	Completed	08-Jul-99
Sierra Pacific Resources	Nevada Power	Completed	28-Jul-99
BEC Energy	Commonwealth Energy System	Completed	26-Aug-99
AES Corporation	Cilcorp	Completed	18-Oct-99
Scottish Power	Pacificorp	Completed	29-Nov-99
Allegheny Power	DQE, Inc.	Withdrawn	03-Dec-99
Western Resources	Kansas City Power & Light	Withdrawn	03-Jan-00
Allegheny Energy	West Virginia Power	Completed	04-Jan-00
Dominion Resources	Consolidated Natural Gas Co.	Completed	28-Jan-00
Dynegy	Illinova	Completed	02-Feb-00
Energy East	Connecticut Energy	Completed	09-Feb-00
SCANA Corp	PSC Of North Carolina	Completed	10-Feb-00
Northeast Utilities	Yankee Gas	Completed	01-Mar-00
Berkshire Hathaway	MidAmerican Energy	Completed	14-Mar-00
National Grid Group Plc	New England Electric Systems	Completed	22-Mar-00
Indiana Energy	SigCorp	Completed	31-Mar-00
S.W. Acquisition Corp.	TNP Corporation	Completed	07-Apr-00
National Grid USA/NEES	Eastern Utilities Associates	Completed	19-Apr-00
Wisconsin Energy Corp.	Wicor Inc.	Completed	26-Apr-00
AEP Resources	Central and Southwest Corp.	Completed	15-Jun-00
Northern States Power	New Century Energies	Completed	17-Aug-00
Energy East	Berkshire Energy Resources	Completed	01-Sep-00
Energy East	CTG Resources	Completed	01-Sep-00
Energy East	CMP Group, Inc.	Completed	01-Sep-00
Peco Energy Co.	Unicom Corp.	Completed	23-Oct-00
Nisource Inc.	Columbia Energy	Completed	01-Nov-00
KeySpan	Eastern Enterprises	Completed	09-Nov-00
Carolina Power & Light	Florida Progress	Completed	30-Nov-00
PowerGen plc	LG&E	Completed	11-Dec-00
Utilicorp United	St. Joseph Power & Light Co.	Completed	29-Dec-00
Utilicorp United	Empire District Electric	Withdrawn	03-Jan-01
Consolidated Edison	Northeast Utilities	Withdrawn	15-Mar-01
AES Corporation	IPALCO	Completed	27-Mar-01
FPL Group	Entergy	Withdrawn	2-Apr-01
WPS Resources	Wisconsin Fuel and Light	Completed	2-Apr-01
Sierra Pacific Resources	Portland General	Withdrawn	26-Apr-01
DTE Energy	MCN Energy	Completed	31-May-01
NS Power	Bangor Hydro	Completed	10-Oct-01
Dominion Resources	Louis Dreyfus Natural Gas	Completed	1-Nov-01
First Energy	GPU Inc.	Completed	7-Nov-01
PNM	Western Resources	Withdrawn	8-Jan-02
National Grid Group	Niagara Mohawk	Completed	31-Jan-02
NorthWestern	Montana Power	Completed	15-Feb-02

<i>Buyer</i>	<i>Seller/Acquired/Merged</i>	<i>Status</i>	<i>Date Completed</i>
Duke Energy	Westcoast Energy	Completed	14-Mar-02
Northwest Natural Gas	Portland General	Withdrawn	16-May-02
Energy East	RGS Energy	Completed	28-Jun-02
PEPCO	Conectiv	Completed	1-Aug-02
Aquila Inc	Cogentrix Energy Inc	Withdrawn	2-Aug-02
Black Hills Corp	Mallon Resources Corp	Pending	
Ameren Corp	CILCORP	Pending	

Source: http://www.eei.org/industry_issues/finance_and_accounting/finance/nonav_financial_reports/021231ma.xls

Appendix 2: Variable Sources and Definitions

Variable	Definition	FERC Pages⁷	FERC Account Name / Notes
D	Total Distribution Costs (US\$)	322-126b	TOTAL Distribution Expenses
A	Total Administration Costs (US\$)	322-168b	TOTAL Administration & General Expenses
Cu	Total Customer Service Costs (US\$)	322-134b	TOTAL Customer Accounts Expenses
	“322-134b” + “322-141b” + “322-148b”	322-141b	TOTAL Customer. Service and Information Expenses
		322-148b	TOTAL Sales Expenses
T	Total Transmission Costs (US\$)	321-100b	TOTAL Transmission Expenses
G+PP	Total Power Production Costs (including purchased power) (US\$)	321-80b	TOTAL Production Expenses
S1	Share of Distribution Business in Administration	S1(a) / S1 (b)	
S1 (a)	Numerator (wages of distribution and customer)		
		354-20b	Distribution
	“354-20b”+ “354-21b” + “354-22b” + “354-23b”	354-21b	Customer Accounts
		354-22b	Customer Service and Informational
		354-23b	Sales
S 1 (b)	Denominator (wages) “354-25b”	354-25b	TOTAL Operations and Maintenance
S2	Distribution Share of EBITDA	$(OA * S1 + DA) / TOT$	
DA	Distribution Assets (US\$)	207-69g	TOTAL Distribution Plant
TA	Transmission Assets (US\$)	207-53g	TOTAL Transmission Plant
PA	Production Assets (US\$)	207-42g	TOTAL Production Plant
TOT	Total Assets (US\$)	207-88g	TOTAL Plant in Service
OA	Other Assets (US\$)	$TOT - (DA + TA + PA)$	

⁷The FERC numbers refer to FERC FORM No.1 (REV.12-98).

Variable	Definition	FERC Pages	FERC Account Name / Notes
MSD	Maximum Simultaneous Demand	401-40d	
R	Total Revenue (US\$)	300-12b	TOTAL Sales of Electricity
	Total Units Delivered (MWh)	301-12d	TOTAL Unit Sales (MWH)
	Units Residential	301-2d	Unit Sales to Residential Consumers (MWH)
	Units Non-Residential	"301-12d" - "301-2d"	
Ncu	Total Customers (#)	301-12f	TOTAL Sales to Consumers (#)
	Customers Residential	301-10f	Unit sales to Residential Consumer (#)
	Customers Non-Residential	"301-12f" - "301-2f"	
NL	Distribution Line Length	Platts	TOTAL Network Length (Miles)
EBITDA		$R - D - Cu - T - (G + PP) - A$	Earning Before Interest, Taxes, Depreciation, and Amortization
CC	Capital Costs	$S2 * EBITDA$	
NCC	Non-Capital Costs	$D + Cu + S1 * A$	O&M Costs of Distribution
Dcap	Transformer Capacity	Platts	Distribution Line Transformer Capacity (Mva)
TDC	Total Distribution Costs	$CC + NCC$	
Temp	Total Employees in Distribution	323-4	TOTAL Employees (#)
AvW	Average Wages in Distribution	$("354-25b") / Temp$	
LEQ	Labour Equivalent O&M Costs	NCC / AvW	O&M Costs deflated by Labour Costs

Table 1
Number and Value of US electricity mergers 1994-2002

<u>Year</u>	<u>Number of Completed Mergers</u>	<u>Transaction Value(\$Millions)</u>
1994	1	1500
1995	2	1943
1996	1	4200
1997	13	4897
1998	9	262
1999	10	20800
2000	23	103596
2001	6	21691
2002	5	23100

Source: Edison Electric Institute website.

Table 2 Potential Inputs and Outputs

OUTPUTS	Units Residential (MWH)
	Units Non-Residential (MWH)
	Customer Number Residential (#)
	Customer Number Non- Residential (#)
	Maximum Simultaneous Demand (kW)
	Network Length (miles)
INPUTS	Non-Capital Costs (\$)
	Capital Costs (\$)
	Total Distribution Cost (\$)
	Transformer Capacity (Mva)
	Labour Equivalent O&M Costs (#)
	Network Length (miles)

Table 3: Summary Statistics

Variable	Mean	Std.Dev.	Min	Max
Total Customers (#)	720693	883042.1	6475	4645960
Total Unit Sales (mwh)	23400000	24700000	155077	121000000
Network length (miles)	20960	23730	198	120300
Total Distribution Costs (\$)	344,000,000	435,000,000	2,323,878	2,170,000,000
Labor Equivalent O&M Costs (#)	2625.1	3303.6	21.13	19761.6
Transformer Capacity (Mva)	9577.9	10881.25	82	45152

Table 4: Models Analysed

	Model M1	Model M6	Model M11
Outputs			
Total Sales (MWh)	X	X	X
Total Number of customers	X	X	X
Network Length			X
Inputs			
Total Distribution Cost	X		
Non-Capital Cost			X
Network Length		X	
Transformer Capacity		X	
Labour Equivalent O&M		X	

Table 5
Tobit Efficiency Regression

	M1 DEAscores	M6 DEAscores	M11 DEAscores
RESSales/TOTALSales	-0.201***	-0.556***	-0.312***
	3.84	6.75	3.59
twomergers	-0.019	0.056	0.114**
	0.55	1.37	2.11
7 years before	0.07	0.206***	0.124**
	1.46	2.98	2.31
6 years before	0.011	0.039	0.041
	0.39	1.04	1.33
5 years before	-0.005	0.024	0.068***
	0.21	0.74	2.65
4 years before	-0.004	0.034	0.081***
	0.2	1.16	3.33
3 years before	-0.003	-0.002	0.055**
	0.16	0.09	2.54
2 years before	-0.022	0.011	0.044**
	1.15	0.44	2.02
1 year before	-0.046**	0.034	-0.008
	2.39	1.37	0.36
1 year after	-0.045**	0.009	0.007
	2.16	0.35	0.32
2 years after	-0.04	0.016	-0.029
	1.55	0.48	0.97
3 years after	-0.139***	0.033	-0.097**
	3.85	0.75	2.23
4 years after	-0.095**	0.032	0.019
	2.11	0.58	0.34
d95	0.028*	-0.019	0.092***
	1.65	0.91	5.22
d96	0.035**	-0.022	0.096***
	2.16	1.07	5.69
d97	0.046***	-0.015	0.056***
	2.93	0.77	3.4
d98	0.023	0.008	0.093***
	1.54	0.4	5.82
d99	-0.015	0.014	0.044***
	1.04	0.77	2.87
d00	-0.013	0.035*	-0.014
	0.92	1.94	0.93
d01	-0.015	0.017	0.037***
	1.07	0.97	2.59
buyer * 7 years before	-0.004	-0.161*	-0.087
	0.06	1.72	1.1
buyer * 6 years before	-0.03	-0.056	-0.052
	0.83	1.22	1.23
buyer * 5 years before	-0.019	-0.024	-0.095***
	0.63	0.61	2.61
buyer * 4 years before	0.002	-0.045	-0.121***
	0.06	1.25	3.41
buyer * 3 years before	-0.003	-0.019	-0.084***
	0.11	0.58	2.62
buyer * 2 years before	-0.011	-0.056*	-0.092***
	0.44	1.73	2.87
buyer * 1 year before	-0.006	0.006	-0.007
	0.25	0.17	-0.22
buyer * 1 year after	0.031	-0.009	0.014
	1.12	0.24	0.41
buyer * 2 years after	0.041	0.015	0.025
	1.19	-0.33	0.6
buyer * 3 years after	0.158***	0.008	0.111*
	3.52	0.14	1.94
buyer * 4 years after	0.046	-0.138*	-0.045
	0.77	1.88	0.63
Constant	0.732***	0.960***	0.706***
	34.62	35.68	27.51
Observations	624	584	624
Number of id	78	73	78

Absolute value of t-statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6
Productivity Growth Regressions

	M1	M1	M1	M6	M6	M6	M11	M11	M11
	Change in E	Change in E	Change in TE	Change in E	Change in E	Change in TE	Change in E	Change in E	Change in E
twomergers	0.036	0.051	-0.017	0.028	0.038	-0.007	0.111*	0.115**	-0.002
	0.76	1.16	0.74	0.53	0.72	0.24	1.9	2.03	0.11
6 years before	-0.111	-0.121	0.012	-0.186**	-0.136	-0.053	-0.089	-0.088	-0.006
	1.35	1.56	0.29	2.11	1.54	1.02	0.87	0.89	0.2
5 years before	-0.013	-0.032	0.021	-0.067	-0.042	-0.022	0.03	0.014	0.01
	0.29	0.74	0.94	1.2	0.76	0.67	0.47	0.23	0.53
4 years before	-0.006	-0.012	0.004	-0.04	-0.036	-0.003	0.021	0.022	-0.005
	0.16	0.32	0.23	0.81	0.74	0.11	0.39	0.41	0.32
3 years before	0.016	0.027	-0.01	-0.102**	-0.084*	-0.019	-0.064	-0.056	-0.011
	0.45	0.79	0.6	2.2	1.8	0.69	1.25	1.12	0.74
2 years before	0.081**	0.085***	-0.009	-0.023	-0.015	-0.011	-0.018	-0.026	0.006
	2.52	2.83	0.55	0.55	0.36	0.44	0.39	0.57	0.4
1 year before	-0.012	-0.01	-0.003	-0.071*	-0.080*	0.01	-0.071	-0.064	-0.003
	0.36	0.35	0.18	1.71	1.92	0.4	1.55	1.43	0.21
1 year after	0.052	0.049	0.002	-0.048	-0.035	-0.008	0.055	0.061	-0.001
	1.51	1.51	0.11	1.1	0.79	0.31	1.14	1.3	0.05
2 years after	-0.029	-0.009	-0.015	-0.013	-0.048	0.032	-0.033	-0.025	-0.005
	0.65	0.21	0.68	0.23	0.88	0.98	0.57	0.44	0.27
3 years after	0.032	0.008	0.026	-0.014	-0.006	-0.006	0.006	-0.011	0.026
	0.55	0.14	0.88	0.2	0.08	0.15	0.07	0.15	1.15
4 years after	-0.01	-0.015	0.009	0.06	0.032	0.029	0.300***	0.300***	-0.01
	0.13	0.22	0.25	0.74	0.38	0.6	3.16	3.25	0.35
d95	0.021	0.009	0.014	-0.04	-0.035	-0.006	-0.037	-0.044	0.014
	0.15	0.06	0.2	0.28	0.25	0.07	0.23	0.28	0.29
d96	0.015	-0.007	0.023	-0.014	-0.004	-0.012	-0.054	-0.102	0.059
	0.11	0.05	0.33	0.1	0.03	0.15	0.33	0.64	1.2
d97	0.052	0.023	0.03	-0.046	0.014	-0.061	-0.033	0.009	-0.037
	0.36	0.17	0.43	0.33	0.1	0.73	0.2	0.06	0.76
d98	0.006	-0.021	0.031	-0.024	-0.014	-0.012	-0.072	-0.128	0.066
	0.04	0.16	0.44	0.17	0.1	0.14	0.44	0.8	1.35
d99	-0.01	-0.033	0.023	-0.081	0.023	-0.091	-0.108	-0.141	0.042
	0.07	0.24	0.33	0.57	0.16	1.08	0.65	0.88	0.85
d00	0.007	-0.011	0.019	-0.086	-0.053	-0.033	-0.078	0.016	-0.085*
	0.05	0.08	0.28	0.6	0.37	0.39	0.47	0.1	1.72
d01	0.004	-0.016	0.019	-0.078	-0.059	-0.021	-0.092	-0.129	0.044
	0.02	0.12	0.27	0.54	0.41	0.25	0.55	0.79	0.89
buyer * 6 years before	0.127	0.193	-0.067	0.077	0.033	0.052	-0.102	-0.099	0.001
	1	1.62	1.08	0.6	0.25	0.68	0.67	0.67	0.01
buyer * 5 years before	0.029	0.011	-0.043	0.03	0.02	0.01	-0.115	-0.107	-0.007
	0.48	0.2	1.45	0.42	0.28	0.23	1.42	1.36	0.31
buyer * 4 years before	0.048	-0.02	-0.021	-0.036	-0.038	0.004	-0.116	-0.140**	0.03
	0.95	0.42	0.84	0.57	0.59	0.1	1.64	2.03	1.42
buyer * 3 years before	0.019	-0.008	-0.01	0.02	-0.005	0.025	0.018	0.015	0.004
	0.4	0.18	0.45	0.33	0.08	0.71	0.27	0.23	0.2
buyer * 2 years before	0.094**	-0.092**	-0.002	-0.059	-0.07	0.014	-0.062	-0.057	-0.003
	2.25	2.36	0.1	1.06	1.25	0.41	1	0.95	0.19
buyer * 1 year before	0.043	-0.024	-0.017	0.06	0.044	0.013	0.07	0.052	0.01
	1.04	0.62	0.81	1.07	0.78	0.4	1.12	0.86	0.52
buyer * 1 year after	0.014	-0.004	-0.002	-0.023	0.023	-0.048	-0.055	-0.064	0
	0.32	0.11	0.11	0.39	0.4	1.39	0.86	1.01	0.01
buyer * 2 years after	0.02	0.035	-0.019	-0.003	-0.003	-0.004	-0.01	-0.029	0.014
	0.35	0.66	0.69	0.04	0.05	0.09	0.13	0.39	0.62
buyer * 3 years after	0.082	-0.053	-0.028	-0.004	-0.065	0.059	-0.031	-0.023	-0.02
	1.14	0.79	0.78	0.05	0.73	1.14	0.33	0.25	0.72
buyer * 4 years after	0.042	0.069	-0.024	-0.114	-0.111	0	-0.383***	-0.372***	-0.003
	0.44	0.78	0.52	1.08	1.04	0.01	3.25	3.25	0.08
Constant	0.995***	0.998***	0.997***	1.103***	1.050***	1.055***	1.099***	1.076***	1.019***
	6.98	7.46	14.28	7.76	7.37	12.59	6.65	6.7	20.69
Observations	546	546	546	511	511	511	546	546	546
Number of id	78	78	78	73	73	73	78	78	78
R-squared	0.07	0.07	0.04	0.07	0.09	0.18	0.11	0.25	0.64

Absolute value of t-statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1:
NSTAR Merger companies Productivity Performance (merged 1999)

Productivity equals O&M expenses divided by total customers.

