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Frontier Analysis of UK Distribution Networks and the Question of Mergers: A Critique of Ofgem

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ABSTRACT

Since privatization, the 14 UK electricity distribution network operators (DNOs), being natural monopolies, have been subject to RPI-X regulation by the UK regulator (Ofgem). Mergers between the 14 DNOs have formed 7 identifiable ownerships (management teams). It is argued in this research that Ofgem has not used a sufficiently robust approach to benchmarking, and has therefore failed to accurately assess network efficiency gains. Furthermore, Ofgem has used invalid arguments against further mergers. By using more informative panel datasets, as well as a more robust estimation technique (Stochastic Frontier Analysis), this research reveals two crucial facts. Firstly, there is almost no more room for the DNOs in question to become more cost efficient, as the industry is operating close to minimum efficient scale. This suggests that Ofgem needs to widen its scope of benchmarking and regulation (e.g. quality-incorporated benchmarking). Secondly, there seems to be no increasing returns to scale in the industry, a more appropriate reason why further mergers should not take place.

JEL Classification: L51, L52

Key Words: Ofgem, Frontier Analysis, Mergers.

FRONTIER ANALYSIS OF UK ELECTRICITY DISTRIBUTION NETWORKS AND THE QUESTION OF MERGERS: A CRITIQUE OF OFGEM

Ziver Olmez[1]

1. Introduction

Electricity distribution networks are characteristically natural monopolies and require some form of price and/or incentive regulation. This is so that distribution companies do not abuse monopoly power through rent-seeking and inefficient operation. If the regulatory regime is efficacious, then both producers and consumers become better off. Some countries (including some states in the USA) have adopted different approaches to deal with this problem. These include penalty/reward schemes in meeting/exceeding/failing to meet quality standards, absolute fines (requiring firms to pay a pre-determined amount if quality drops below a certain threshold), and quality incorporated benchmarking.[2]

The purpose of this research is two fold.

1. To provide a preliminary investigation of scale efficiency, prior to any quality incorporated benchmarking taking place. This preliminary investigation is necessary because, if there are any economies of scale to be reaped, and distribution companies cannot significantly increase their respective outputs, mergers need to take place between most efficient and least efficient distribution companies (henceforth known as distribution network operators, or DNOs).[3]

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[2] The only country that currently has a fully functioning quality incorporated benchmarking system (quality dependant revenue caps) is Norway, which introduced the scheme in 2001.

[3] 'Is there a case for mergers between DNOs in the UK?' is the fundamental question this research will be answering by providing valuable findings to that end. Although mergers may reduce the number of comparators for benchmarking (a detriment of mergers voiced by the Office of Gas and Electricity Markets (Ofgem)), it would also mean that the post-merger benchmarking could address more efficient (newly merged) firms, and therefore a higher scope for efficiency and quality improvements.

2. The second key purpose of this research is to critically analyze the way in which the regulator, Ofgem[4], undertakes cost-function estimation and benchmarking that would answer this question of mergers. Pollitt (2005) has argued that Ofgem's technical methodology and approach is not sufficiently robust for benchmarking.[5] The fourteen DNOs are, as at 2007, owned by seven different firms, which implies that any cost analysis and benchmarking method should reflect this. It is argued here that when compared to a method of benchmarking that treats the seven firms as 14 separate entities (Ofgem's method), grouping the DNOs with respect to ownership in cost analysis reveals critical and more accurate information on DNOs efficiencies. Consequently, this research will aim to improve on Ofgem's benchmarking methodology.

The costs and benefits of potential mergers need to be correctly considered and measured, so as to circumvent the possibility of Ofgem keeping an artificially large number of DNOs in the market, solely for the purposes of benchmarking. After all, if the results from this research imply further mergers, this could create two importantly positive outcomes. Firstly it would mean that those DNOs would be operating closer to minimum efficient scale (and therefore lower average costs), and this creates more scope for lowering prices. Secondly, it would result in more efficient comparators, which not only makes the regulator's job easier (by reducing inefficient outliers), but also increases overall system quality. On the other hand, if the results of this research imply that mergers should no longer take place, then this would suggest that Ofgem should incorporate a more robust methodology in their benchmarking efforts (such as the one used here). Furthermore, it would suggest that DNOs are becoming significantly more efficient over time, hence requiring Ofgem to deepen its analysis of those DNOs, in order to capture other areas of possible improvement on overall distribution system quality.

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[4] Office of Gas and Electricity Markets (Ofgem) was previously OFFER (regulator for electricity) but combined with OFGAS (regulator for gas) to form Ofgem in 1999 (Bower, 2003).
[5] Due to, *inter alia*, insufficient data points in regression analysis, choice of regression estimation technique, and the treatment of the fourteen DNOs as fourteen separate entities, rather than grouping them with respect to ownership.

2. The Need for Regulation

Before focusing on the UK, it is appropriate initially to review and discuss the notion of incentive and price regulation and the necessity of regulation.

The necessity of regulation stems from the concern that natural monopolies may raise their price above marginal cost and therefore cause a 'deadweight' loss, since output is restricted. If perfect information exists between customers and the monopolist, then a first-best outcome can be reached through bargaining. However, since this is not the case in reality, a regulatory body may be necessary. In any case, any bargaining that could occur, even in the presence of perfect information, would entail high transaction and bargaining costs and would probably prove inefficient (Cowan, 2006). Ideally, regulation is present to protect and promote the welfare of both consumer and producer. The varying approaches to achieving a well-functioning (or fitting) regulatory scheme are however subject to debate, and are governed by changing paradigms in the industrial environment.

The regulatory scheme of choice in the UK is the RPI-X price cap regulatory scheme, and its basic structure is as follows. First an index of prices for the regulated firm is derived. Then, the restriction that the annual growth rate of this index can be no more than the rate of general retail price inflation (RPI), less a predetermined figure (X), is imposed. Known as the 'X' factor, this predetermined figure is set for a period of five years, by the end of which a new 'X' value is introduced (dependant upon the degrees of change in industry and market conditions) for the upcoming five year period (Cowan, 2006). In this period of price control, the regulated firm retains all profits that it realizes from outperforming against regulated prices (Pollitt, 2004).

3. Ofgem Critique

Ofgem is the UK regulator for gas and electricity networks, and is overseen by the Department of Business, Enterprise and Regulatory Reform (BERR)[6] (as a result of the Utilities Act in 2000). In broad terms Ofgem's roles is to make sure competitive markets work successfully, regulate the natural monopoly segments of gas and electricity networks, ensure secure and safe supplies of electricity and gas, and more recently, address environment and fuel poverty issues (Bower, 2003).

The distribution segments of electricity and gas (as well as the transmission segments) essentially have natural monopoly characteristics. This is because minimum efficient scale is large enough that even if competition were present, competing firms would reap these scale economies by merging and eventually forming a monopoly anyway (Bower, 2003). Put simply, with respect to feasibility and logistics, it makes no sense to have competing wires and pipes providing energy/heat to buildings. Regulation therefore exists to ensure that distribution firms do not set prices at the monopoly level, so as to protect consumer welfare. However, it should be noted that Ofgem has no authority on overseas distribution networks, and as the UK becomes increasingly dependent on imported energy (via interconnectors from the EU, for example), there is the danger of a growing grey area in the regulatory framework that must be addressed. This is perhaps a fitting role for BERR, especially since Ofgem's authority has diminished since the Utilities Act (2000).

However, a crucial part of this research is a critical discussion on Ofgem's approach to benchmarking. There seem to be several set backs in Ofgem's regulatory framework, vis-à-vis benchmarking methodology.[7] Pollitt (2005) provides an assessment of Ofgem's approach, and the points below explore the author's main findings.

[6] Known as Department of Trade and Industry prior to May 2007.

[7] Initially, a consultation document is issued about 18 months before the end of the ongoing five year price control period, which addresses the timetable, and other issues for the next price review. Then, a final proposal document is issued about six months before the beginning of the next price review, detailing the X factors in the RPI-X framework, and proposing them to each DNO. Efficiency analysis is carried out to provide a single efficiency score for the benchmarked portion of costs in the year of analysis. Interestingly,

- The main benchmarking method that Ofgem uses is based on a regression analysis of operating costs (opex). Specifically, they use Corrected Ordinary Least Squares (COLS), a relatively simple estimation technique that lacks robustness. It cannot capture time-varying efficiency gains that panel data can for instance. It also cannot distinguish between inefficiency and noise in the error term.[8]

- After an OLS regression is run (opex against a composite variable of output), the estimated line of best fit (frontier) is 'manually' shifted downwards to intersect the lowest data point. This in effect provides a frontier line against which inefficient DNOs are then compared. This assumes a linear cost function, rather than a quadratic, which may not be realistic in practice. Furthermore, 'manually shifting' is rather crude, and inferior to alternative techniques such as stochastic frontier analysis (SFA)[9] or data envelopment analysis (DEA).

- Ofgem uses only one explanatory variable in its specification, which is a composite measure of output (composite scale variable, or CSV). In the 1999 review, this was calculated as[10]

  $$\text{CSV} = (\text{Customer numbers})^{0.5} \times (\text{Units distributed})^{0.25} \times (\text{Network length})^{0.25}$$

  Using a composite measure such as the one above does not make it feasible to use square and interaction terms, which could prove useful in frontier analysis. However, the composite measure does have an important advantage in that it avoids potential multicollinearity issues that could arise, since these output

exploring the way in which Ofgem does this reveals that benchmarking is only one of many different stages in setting X factors (Pollitt, 2005).

[8] It should be noted, however, that with respect to practical application, transparency, verifiability, and low regulatory burden, the COLS methodology proves appropriate.

[9] CEPA (2003) found that SFA could not be implemented due to lack of sufficient data available to Ofgem. The rejection of such a robust parametric method solely due to a 'lack of sufficient data size' seems like a curious (and poor) excuse, since a fitting panel dataset is readily available for this purpose, and is in fact used in this research.

[10] It was acknowledged that customer numbers are not relevant to DNOs whose customers are supply/retail companies. This led to Ofgem imposing a higher weight on network length (^0.5) and a lower weight on customer numbers (^0.25) for the 2004 price review (Pollitt, 2005).

variables in fact move in the same direction at once (Pollitt, 2005). Ofgem does not explore other cost drivers that may be crucial for cost function estimation. It could be that factors such as climate, topography, customer density (and other drivers that are not necessarily output variables) may affect costs significantly.

- Mergers, one of the main focuses of this research, happens to be a crucial issue for the implementation of Ofgem's methodology. There are fourteen distinct DNOs with fourteen respective areas covering England, Wales and Scotland. However, these fourteen DNOs are owned by seven independent companies, as mergers and buy-outs already took place during the 1995-2002 period. This implies that separate benchmarking of the fourteen DNOs may in actual fact no longer be valid. This potential invalidity arises from the possibility that these seven companies can manipulatively (mis)represent higher overall efficiency by moving costs around between the DNOs that they own (Pollitt, 2005)[11].

- Both the 1999 and 2004 price reviews used data from the previous (single) year alone, 1997-1998 and 2002-2003 respectively. Panel data could increase the robustness of estimates by providing more data points, allowing for time-varying effects, and allowing for the use of more versatile/powerful statistical techniques (DEA and/or SFA). It would also allow the inclusion of additional variables directly into the cost function specification. It is not at all clear why Ofgem have not chosen to take this path, given that the data is readily available for such analysis.[12]

- Ofgem have not sufficiently explored the possibility of using international data for benchmarking. It has been noted that they argue against mergers mainly due to the loss of comparators in benchmarking (Ofgem, 2002). However, as the UK

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[11] CEPA (2003) explore how aggregating available data into the seven groups and using the resulting 'grouped' dataset for estimation and frontier analysis may alter efficiency estimates of DNOs. Their results showed that efficiency scores for all DNOs increase. Although, the number of data points becomes even lower by using seven firms and the robustness of statistical estimates is questionable under such a setup. The use of panel data, however, can improve these estimates.

[12] Electricity Industry Review series, Electrica Service Ltd.

becomes more import dependant with respect to energy/fuel source, and as the European grid becomes more integrated, it could prove useful to incorporate DNOs across Europe, faced with similar cost driving characteristics, into the estimation process. This also would take care of the sample size issue.[13]

4. The 'Merger Effect'

Ofgem (2002) has argued that mergers amongst DNOs could be detrimental to benchmarking, since it implies losing comparators. A counter-argument is that this loss would be compensated, as any post-merger benchmarking would include only the resulting most efficient DNOs, which gives scope for higher standards. These higher standards, as well as the improvements accruing from the mergers, would then translate into welfare gains to customers.[14]

There seems to be an exaggerated fear of loss of comparators. Mergers are likely to take place between an efficient and inefficient firm, or two inefficient firms, in order to a) increase output to minimize the gap between current long run average cost levels and minimum efficient scale, and b) in order to increase overall system efficiency. Even if there were many comparators, benchmarking methods and comparisons between DNOs become less helpful in the long run, as regulation means DNOs become increasingly cost efficient with time.

Furthermore, the method used for quantifying the detriment of mergers is arguably fundamentally flawed and the controversy surrounding this calculation is noted in the Ofgem (2002) proposal. The method assumes that all mergers result in an equal detriment, and fails to take into account the fact that Ofgem still is able to make comparisons across fourteen DNOs, regardless. If any anti-merger arguments are to be made, they should ideally be done so on the basis that DNOs have achieved such levels

[13] This suggestion is very plausible, since nine of the fourteen DNOs are in fact foreign owned (Pollitt, 2005).

[14] A guide to Ofgem's views regarding mergers can be acquired from the associated Ofgem consultation documents (2001), and their policy statement (2002) – www.ofgem.gov.uk

of efficiency, that they are operating close to minimum efficient scale, and, if the DNOs exhibit any undesirable characteristics thereafter, a more appropriate regulatory method should be employed.

5. Stochastic Frontier Analysis (SFA)

SFA is a parametric method that uses a maximum likelihood (ML) estimation framework to calculate parameter estimates for regressors in a model. There are a number of assumptions that can be made about the distribution of the error terms in SFA. Choosing which distribution to use in the estimation process is governed by factors such as computational convenience, or theoretical preference. This depends on the beliefs of the researcher. Generally, these distributions can be divided into half-normal, truncated normal and exponential (with different means) (Coelli et al, 2005).

The basic SFA model used in this research is structured as follows,

(1) $\boldsymbol{C}_{it} = \boldsymbol{X}_{it}\mathrm{b} + (\boldsymbol{V}_{it} + \boldsymbol{U}_{it})$; $i = 1,\ldots,N$, $t = 1,\ldots,T$

where,

$\boldsymbol{C}_{it}$ is the natural log of the operating expenditure (cost) o f the i-th DNO/firm in the t-th time period.

$\boldsymbol{X}_{it}$ is a (k x 1) vector of input quantities (or cost drivers) of the i-th firm in the t-th time period.

b is a vector of unknown parameters (coefficients).

$\boldsymbol{V}_{it}$ is statistical noise in the data (random error terms). It consists of random variables. We assume that they are independently and identically distributed [iid $N(0, \sigma v^2)$]. We also assume they are independent of $\boldsymbol{U}_{it}$ (the inefficiency term),

where, $\boldsymbol{U}_{it} = (U_i \exp(-\eta(t - T)))$

$(U_i \exp(-\eta(t - T)))$ are non-negative random variables. We assume that they account for the cost of inefficiency in production. We also assume that the are iid N(μ , σu^2), where η is a parameter that needs to be estimated.

Therefore if $v_{it} \neq 0$ but $u_{it} = 0$, then the model collapses to OLS, since this implies that there is no inefficiency.

SFA is a much more robust method than COLS because it divides up the error term into two parts, one to measure (in)efficiency, and the other part to measure noise. The first of these, u_{it} (a one-sided non-negative error term), captures the effect of costs, and the second, v_{it}, captures the effect of noise.

The fact that SFA takes into account heterogeneity between comparators (which may be due to geological differences between areas, among other things) makes it a more appropriate technique than alternatives. Furthermore, ML estimators have many desirable large sample properties (asymptotic properties) that are asymptotically more efficient than the COLS estimator (Coelli et al, 2005). However, this does suggest that the sample needs to be sufficiently large for ML estimators to outperform COLS estimators. One of Ofgem's justifications for using COLS was the lack of sufficient data. However, in this research, a sufficiently large sample of data on DNOs is used, and therefore allows for the use of SFA. Conventional hypothesis tests can be carried out as well, which can tell us a lot about the significance of cost drivers.

One disadvantage of SFA is that a functional form needs to be specified for the cost (production) function that is to be estimated, and furthermore, a distribution of the error term needs to be specified as well. However, with realistic assumptions, and a good understanding of the particular industry, these functional and distributional forms can be defined appropriately. Regarding Ofgem's concern for mergers and losing comparators, removing a comparator in an SFA framework would have an effect, in so far as resulting in a shift of the estimated frontier and a difference in confidence intervals associated with the parameters. However how this occurs and to what extent depends on the comparator being removed (Europe Economics, 2001).

Generally, the costs of operating a distribution system are those that are incurred in building and maintaining the system (lines, mains, transformers and measuring and billing electricity) (Filippini et al. 2004). Operating expenditure data is used to proxy costs, as opposed to capital expenditure (or total expenditure), since any costs savings that can be realized by a DNO (within the five year review) are those on the operating side. The major costs drivers are commonly total number of customers, customer density in the area, size of the serviced area, total kWh sold, length of the distribution line and maximum demand. For better comparability (with the regulator's findings), as well as availability of data, the three cost drivers used in this specification are circuit length (in kms), number of distribution customers, and units of electricity distributed (gWh). These are the three variables in forming the composite variable that Ofgem uses in cost function estimation. Effectively, the DNOs' operating costs for distributing electricity can be represented by the function,

(2) $C = C\,(Y, NC, CL)$

where,

C = Operating Expenditure (opex)

Y = Output (gWh)

CL = Circuit Length (both overhead and underground)

NC = Number of Customers

6. The Cost Function (three models)

6.1 The Three Models

The estimation of this cost function requires some functional form specification. A log-log (Cobb-Douglas) functional form is commonly used (as is the translog specification) and would be appropriate in this case, since the function is non-decreasing and linearly homogenous (Coelli et al, 2005).[15] It would have been useful to include input prices as additional regressors, however lack of data availability did not permit this. The models are assumed to be distributed as truncated normal random variables, with time-varying inefficiency effects. This is so that technical efficiency changes over time can be assessed.

(3) $$\ln C = \beta_0 + \beta_y \ln Y_{it} + \beta_{CL} \ln CL_{it} + \beta_{NC} \ln NC_{it} + v_{it} + u_{it}$$ **(Model 1)**

where u_{it} is a non-negative variable representing inefficiency, and v_{it} represents errors of approximation and other sources of statistical noise. As previously mentioned, these three regressors above can give rise to meaningless and/or insignificant coefficient estimates due to multicollinearity. However, since these three variables are important cost drivers, a composite scale variable (CSV) identical to the one used by the regulator (Ofgem) will be used.

(4) $$\text{CSV} = (\text{Customer numbers})^{0.25} \times (\text{Units distributed})^{0.25} \times (\text{Network length})^{0.5}$$

Note that in this setup, network length has the higher weight of the three regressors. Ofgem used this setup in their 2004 benchmarking analysis.[16] Using the composite variable in this analysis enables better comparability of the results here with Ofgem's results in the past.

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[15] Cobb-Douglas forms are first-order flexible, in that they have sufficient parameters to provide a first-order differential approximation to a random function at a single point. Although translog forms are second-order flexible, a Cobb-Douglas form is more appropriate here since there is only one parameter to estimate (CSV). Furthermore, this avoids multicollinearity issues.

[16] It has been observed that units distributed and customer numbers are almost perfectly correlated (CEPA, 2003). Furthermore, connected customers as such are irrelevant to DNOs whose customers are made up of supply companies (implying that customer numbers could even be dropped from the CSV measure altogether, resulting in the assignment of a 50-50 weight on the remaining two variables). Also, it is argued that network length can act as a proxy for geographical (topological) differences in DNOs' respective regions. These findings led to Ofgem assigning a higher weight on network length.

Thus, the composite model (2) becomes,

(5) $$\ln C = \beta_0 + \beta_{CSV} \ln CSV_{it} + v_{it} + u_{it} \qquad \textbf{(Model 2)}$$

where,[17] $\ln CSV = [(\ln NC)^{0.25} \times (\ln Y)^{0.25} \times (\ln CL)^{0.5}]$

It is also worth taking into account a neutral approach to the weighting of these variables to form the composite scale variable (CSV). That is, we can assume that all three variables have equal weight in affecting costs. Therefore, a third model can be formed as follows.

(6) $$\ln C = \beta_0 + \beta_{CSV} \ln CSV_{it} + v_{it} + u_{it} \qquad \textbf{(Model 3)}$$

where, $\ln CSV = [(\ln NC)^{0.33} \times (\ln Y)^{0.33} \times (\ln CL)^{0.33}]$

In this Model (3), in assuming that all variables have equal weight, what is being sought is to uncover (if any) significant differences in estimated parameters as a result of Ofgem's choice of weighting. If the differences in estimation are minimal, and conclusions the same, then the Ofgem's choice of weights (Model 2) can be used with more confidence and authority.

6.2 Efficiency Predictions

Within this framework, Coelli (1996) defines cost efficiency relative to the cost frontier as,

(7) $$EFF_i = E(C_i \mid U_i, X_i) / E(C_i^* \mid U_i, =0, X_i) \qquad ; 1 \leq EFF_i \leq \propto$$

where, C_i^* is the cost of the i-th DNO/firm, which would be equal to C_i when the dependent (opex) variable is in original units, and equal to $\exp(C_i)$ when it is in natural logs.

Expression **(7)** can be interpreted as 'the ratio of actual costs to the efficient level of costs' (Filippini et al, 2004). EFF_i can take values between 1 and infinity. The closer the EFF_i value is to one, the more efficient the DNO/firm, and vice versa. For example,

[17] Note that, in this case, CSV is a logged (natural log) regressor.

if EFF_i=1.25, then that DNO/firm's cost inefficiency is 25%. Alternatively, the DNO/firm's cost is 25% higher than the cost of an equivalent firm that is efficient.

Form the results, the predictions of cost efficiency are calculated as follows,

(8) $EFF_i = \frac{X_{it}\beta + U_i}{X_{it}\beta} \geq 1$ - For dependent variables in original units

(9) $EFF_i = \exp(U_i) \geq 1$ - For dependent variables in natural logs

7. Data

The panel dataset used here holds much more information then that used by Ofgem. For all fourteen DNOs, data on circuit length (in Kms), number of distribution customers, and units of electricity distributed (GWh) was collected from the electricity industry reviews 5 through 10. This covers a period from 1999/00 to 2004/05. The data on operating expenditure (opex), the dependent variable in the analysis, was collected from Ofgem's Electricity Industry Price Control Review Publications (2003, 2004, and 2005). Ofgem has used different measurements of opex for different years and hence some of the data had to be adjusted for standardization purposes. For this reason, some of the opex figures may not be the exact ones reported in the reviews. Ultimately, this data consists of a panel of fourteen DNOs across six periods. Each period equals one year, and therefore the data covers six years. This yields a total of 84 data points, solving the problem of insufficient data points, which Ofgem faced. This is called DATASET – 1.

It may indeed be the case that previously obtained estimates and efficiency scores by Ofgem are inaccurate, since the fourteen DNOs are owned by seven different entities. Therefore, a second dataset is formed by grouping the DNOs in DATASET – 1 into their respective ownerships (over the exact same period, using the same variables). This is called DATASET – 2. The grouping was done by summing the figures (of variables) of each of the DNOs owned by the same firm. Figure 1.1 illustrates this setup.[18]

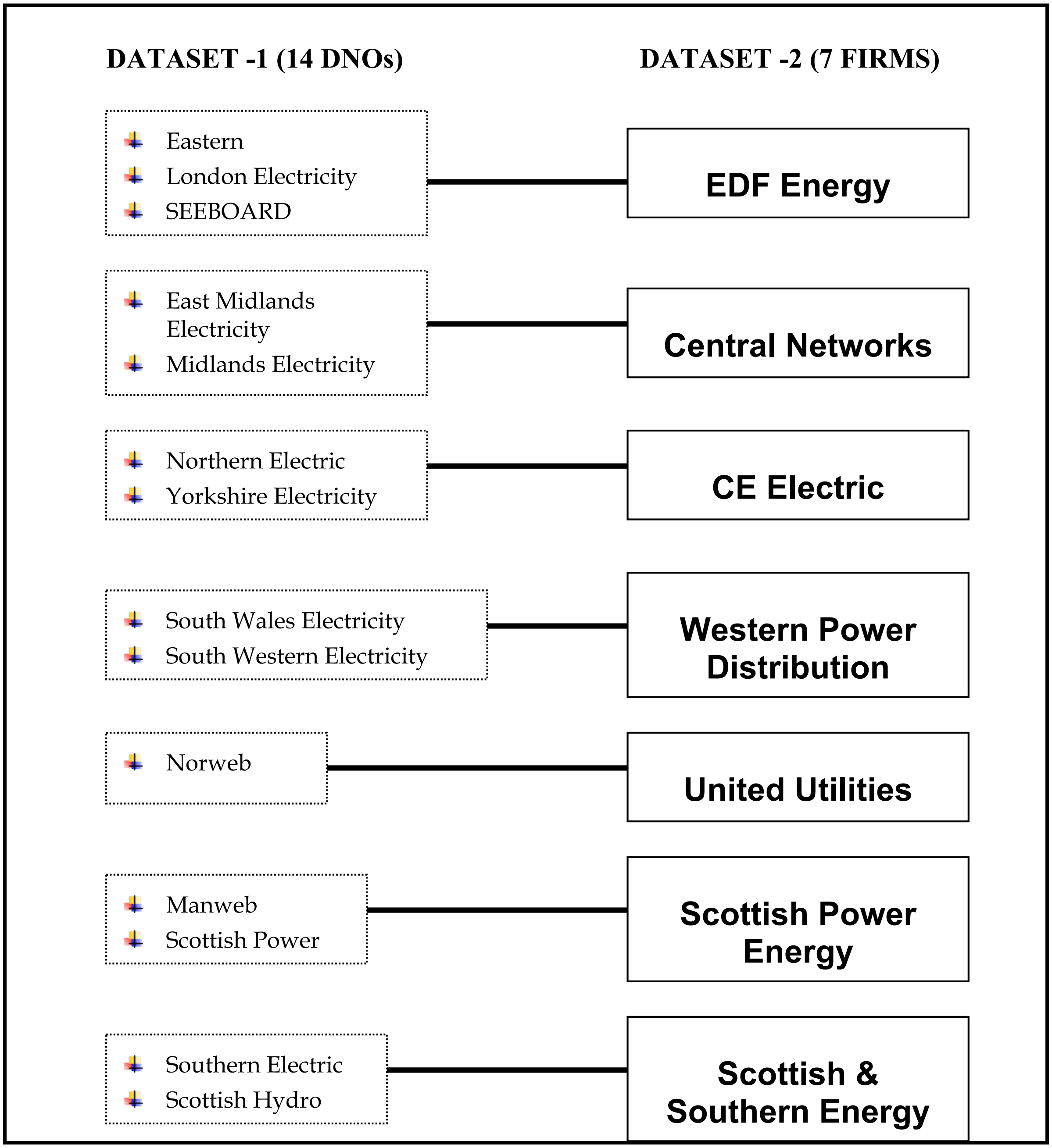

Figure 1.1 – DATASET -1 : DATASET -2

[18] Most of the DNOs transferred ownership (or merged) between the years 1998 and 2002, with the exception of Manweb, which was sold to Scottish Power Energy in 1995. The advantage of this dataset is that it captures this period of mergers, and subsequent years thereafter. This further justifies the use of DATASET-2, to explore the differences in efficiency scores, when compared to DATASET-1.

8. Results

The results from Model 2 and Model 3 regressions are shown in table 1.1 below.[19]

Model 2 - Ofgem Weights **Model 3 - Neutral Weights** Dependent Variable – lnC	**Dataset - 1 - 14 DNOs** **Dataset - 2 - 7 Ownerships** **Constant**	**Coefficient (lnCSV)**	**σ²**	**Log-Likelihood**
Model 2 (Dataset - 1) **N = 14, T = 6**	**-3.337***** (-3.35)	**0.663***** (7.384)	0.064	6.497
Model 2 (Dataset - 2) **N = 7, T = 6**	**-8.847***** (-8.882)	**1.134***** (13.804)	0.064***	5.358
Model 3 (Dataset - 1) **N = 14, T = 6**	**-3.282***** (-3.295)	**0.669***** (7.182)	0.412	14.694
Model 3 (Dataset - 2) **N = 7, T = 6**	**-10.022***** (-9.914)	**1.240***** (14.634)	0.034***	11.464 *****,**,*: at 0.1%, 1%, 5% respectively**

Table 1.1 – Frontier Analysis Results

Both Model 2 and 3 were acceptable (as parameters were significant), and therefore Model 2 (Ofgem Weights) results will be used hereafter to enable better comparability with Ofgem's method.[20] Economies of scale prevail if the average costs of an electricity distribution utility fall as the output (volume of electricity sold) in a network area rise (Filippini et al, 2004). In the model, this can be calculated as follows,

(10) $$\frac{1}{\delta \ln C / \delta \ln CSV}$$

[19] Preliminary research revealed that Model 1 produces insignificant parameter estimates and therefore is omitted altogether.

[20] Model 3 parameters were not significantly different from Model 2, meaning that both Models led to similar conclusions. The motivation for proceeding with Model 2 therefore is to enable better comparability with Ofgem's model.

Economies of Scale estimates (Model 2 Only)	Note: economies of scale exist if statement (13) > 1
Dataset - 1	**1.51**
Dataset - 2	**0.88**

Table 1.2 – Economies of Scale estimates

The mean efficiencies of DNOs in Dataset – 1 versus those of firms (ownerships) in Dataset – 2 are as follows

MEAN EFFICIENCY MODEL- 2			
PERIOD	DATASET-1	DATASET-2	DIFFERENCE
1	1.478	1.711	-0.233
2	1.303	1.203	0.100
3	1.199	1.068	0.131
4	1.133	1.024	0.109
5	1.090	1.009	0.081
6	1.061	1.003	0.058

Table 1.3 – Mean Efficiency

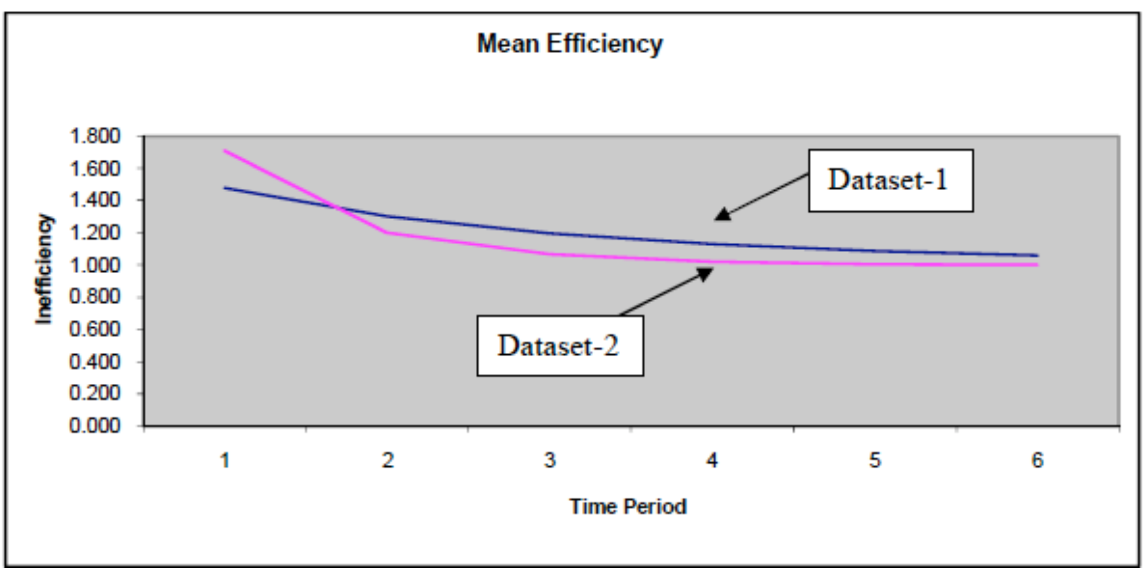

Figure 1.2 - Mean Efficiency[21]

[21] Period 1 = 1999/2000, Period 6 = 2004/2005

9. Evaluation

These results warrant the critique of Ofgem's benchmarking technique and attitude towards mergers. Furthermore, they justify the criticisms made therein. The key points below discuss what exactly these results point towards, and what may have to be altered in the regulator's approach in order incorporate a more robust and wholesome approach to regulation.

- Regarding mean efficiencies, the results indicate **lower inefficiency** when using Dataset - 2, rather than Dataset - 1. Figure 1.1 above illustrates this. This means that if one estimates the parameters in the model according to their seven ownership categories (as one should), then we see that the DNOs have been realizing greater efficiency gains between 1999/00 and 2004/05 than would otherwise have been estimated. Although Dataset-2 yields greater inefficiency in period 1, from period 2 onwards it yields greater efficiency. This suggests that the takeover/mergers that took place were still in their infancy in period 1, but through time, as the benefits of mergers were realized (better management, investment in new technology, and so on), these mergers resulted in greater efficiency gains for the 14 DNOs in question.

- The mean efficiencies, which can also be interpreted as industry efficiency, whether it is for Dataset-1 or Dataset-2, were extremely close to 1 in 2004/05. The closer this value is to 1, the more efficient the industry is, ceteris paribus. This suggests that firms have been rapidly becoming cost efficient, and that Ofgem's regulatory authority has been effective. However, it also suggests that further efficiency gains, if sought after, will have to originate from non-cost related areas such as quality of service (such as number/duration of outages and customer service). This does imply that a quality-incorporated benchmarking approach should be implemented, as was suggested by Pollitt (2005). The danger with Ofgem continuing with its current benchmarking approach is that the any further efficiency gains realized by the 14 DNOs (7 firms) will most likely not outweigh the costs of further Ofgem price reviews, and can lead Ofgem to over-regulate on the cost front.

- The output elasticities, and consequently returns to scale, reveal the most important point accruing from this analysis, that being, Dataset-2 results suggest that no more mergers should take place. When using the output elasticity from Dataset-1 to calculate economies of scale, it is seen that there are increasing returns to scale in the industry and output should be increased further to reap these returns. Ceteris paribus, and perceiving mergers as a way to increase output, this suggests that more mergers can take place. However, these results are misleading as they do not take into account the seven ownerships, possible management improvements, technology investments and cost shifting that can arise from these ownerships. Therefore, for more insight, one can turn to the Dataset-2 results. These show that in fact there are decreasing returns to scale in the industry (although not by much, as the 0.88 value is close to 1, indicating constant returns to scale). One can conclude from this, that no more mergers ought to take place in the UK electricity distribution sector.

- Ofgem can use these findings as a stronger argument for avoiding further mergers in the industry. This is particularly important as Ofgem's current argument of losing comparators is invalid. Furthermore, incorporating European DNOs into the benchmarking framework has not been yet considered, and possibly should be.

The results obtained in this research point out the inappropriate stance Ofgem has taken against mergers, specifically, that mergers would hinder the integrity of benchmarking, by compromising the available number of comparators in the industry. Furthermore, it has shed light on the future direction of benchmarking, regulation, and merger behaviour in the utility sectors.

10. Conclusion

A panel dataset can be used to employ a more robust frontier analysis technique and Ofgem should more seriously consider in its next price control review, to use the 7 ownerships (management teams) in its benchmarking framework. This would ensure that the data paint a more accurate picture of industry efficiency. Furthermore, since the results here suggest that most cost efficiency gains have been realized, further mergers are not warranted in the industry. Therefore a more wholesome and non-cost focused benchmarking framework needs to be employed in order to improve electricity network performance. As suggested earlier, quality incorporated benchmarking is one option already employed in some countries such as Norway, and should be considered for the Ofgem regulatory framework.

As we see the dawn of a more integrated European electricity distribution network, it seems appropriate that similar European DNOs are incorporated into the benchmarking process, which can be a step in facilitating a more standardized, efficient, and eventually pan-European electricity distribution network.

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