CEPA's report on benchmarking

Ofgem appointed consultants Cambridge Economics Policy Associates (CEPA) to produce a report examining the important considerations for Ofgem in using benchmarking in the distribution price control review (DPCR 4). The work comprised three areas:

A. **Ofgem's approach in DPCR 3 –** This focussed on the regression technique (COLS) used to benchmark DNO's on (normalised) controllable operating costs. CEPA were asked to review the approach in DPCR3 identifying its strengths and weaknesses. In addition they were asked to identify significant developments that would require alternative approaches e.g. mergers, the use of the frontier firm as the benchmark etc;

B. **Alternative benchmarking techniques and methodologies –** Given the available data and other restrictions CEPA were asked to advise on the strength and weakness of alternative techniques to those used in DPCR 3. In addition CEPA were asked to advise on the approach to selecting appropriate cost drivers; and

C. **Re-run of DPCR 3 approach using 2001/02** – The DNOs were benchmarked on standard controllable (operating) costs by applying the DPCR 3 approach to 2001/02 data. The purpose of this exercise was to highlight further issues Ofgem should consider in developing its approach to benchmarking..

The purpose of the report is to inform Ofgem in developing its approach on benchmarking and to provide a basis for Ofgem to begin consultation on these matters. Comments in the report reflect CEPA's views and should not be regarded as Ofgem policy.

Key issues for consideration

Ofgem welcomes views on any of the issues discussed in CEPA's report, in particular on the following

<u>Input data</u>

What costs should be benchmarked? E.g. controllable operating costs, total controllable costs, capital expenditure etc
How should controllable costs be defined for the purposed of benchmarking?
What adjustments are required to enable comparisons between the DNOs?
How should measures of total cost be calculated?
What adjustments are required to for firm specific factors?
Should international data be used? If so from what sources?
Should panel data be used?

<u>Benchmarking techniques and methodology</u>

Which techniques should Ofgem use?
Which cost drivers should be included and how should they be selected?
How should the weighting of cost drivers be determined?
What assumptions should be made if using regression e.g. functional form, the intercept (fixed costs)
If using DEA what combination of inputs and outputs should be used? Should the models be input or out put orientated or both
What assumptions should be made about returns to scale and economies of scale?

Use of benchmarking in the final cost assessment

What is an appropriate benchmark for the DNOs, the frontier firm? the average firm? or something else?
How should benchmarking be combined with other analysis particularly the bottom up modelling and TFP analysis?

Other issues

How should merged firms be treated for the purpose of benchmarking? should DNO groups be benchmarked as well as the 14 DNOs?
Should measures of quality or other outputs be incorporated into the benchmarking process?

Responding to this document

If you wish to comment on any of the issues raised in CEPA's report and/or those outlined above please include them with your response to the DPCR Update Document intended for publication on 17 October 2003, responses should be sent to:

Nienke Hendriks
Ofgem
9 Millbank
London
SW1P 3GE
nienke.hendriks@ofgem.gov.uk

The deadline for responses is **19 November 2003**

Any questions on CEPA's report should be addressed in the first instance to Haren Thillainathan (haren.thillainathan@ofgem.gov.uk, 0207 901 7055)

Background to Work on Assessing Efficiency for the 2005 Distribution Price Control Review

Scoping Study

Final report

Prepared for Ofgem

By

CAMBRIDGE ECONOMIC POLICY ASSOCIATES

September 2003

CONTENTS

GLOSSARY

BPQ	Business plan questionnaire
BT	British Telecom
CES	Constant elasticity of substitution
COC	Cost of capital
COLS	Corrected ordinary least squares.
CRS	Constant returns to scale
DEA	Data envelopment analysis
DMS	Data management services
DNO	Distribution network operator
DPCR	Distribution price control review
DSA	Deterministic statistical approach
DTe	*Dienst uitvoering en toezicht Energie* (the Dutch energy regulator)
EEA	Engineering economic analysis
EHV	Extra high voltage
HG	High voltage
IIP	Information and Incentives Programme
IRS	Increasing returns to scale
LP	Linear programming
LV	Low voltage
MLE	Maximum likelihood estimation
MV	Medium voltage
NTR	Non-trading rechargeable
Offer	UK Electricity regulator prior to merger with gas regulator to form Ofgem
Ofgas	UK gas regulator prior to merger with electricity regulator to form Ofgas
Oftel	Office of Telecommunications
Ofwat	Office of Water Services
OLS	Ordinary least squares

opex	Operating costs
PES	Public Electricity Supplier
PFP	Partial factor productivity
PPA	Parametric programming approach
RAB	Regulatory asset base
SFA	Stochastic frontier analysis
TFP	Total factor productivity
totex	Total costs
USO	Universal service obligation
VRS	Variable returns to scale

EXECUTIVE SUMMARY

Introduction

This report has been prepared by Cambridge Economic Policy Associates (CEPA) for Ofgem as an initial contribution to its thinking on benchmarking the efficiency of electricity distribution businesses in the 2005 distribution price control review. We were asked to review the methodology used in 1999, review alternative methodologies, to assess the appropriateness of cost drivers, and to analyse data provided by Ofgem on distribution network operators and use it to inform our views.

The 1999 distribution price control review

In 1999, Ofgem used regression analysis – regressing operating costs on a composite scale variable - to inform its judgement of the efficiency frontier. The final assessment of the frontier was based on a combination of frontier analysis, expert industry judgement about fixed costs and a decision that the most efficient firm would not be used to determine appropriate levels of efficiency for other firms. Given the uncertainties surrounding benchmarking techniques and the drawbacks of relying solely on a single methodology, such a pragmatic approach appears robust. A number of detailed concerns about the regression methodology are set out in the body of the report (section 3).

Applying the 1999 methodology to 2001/02 data

At Ofgem's request, due to the preliminary nature of the 2001/02 data, the underlying data have not been reproduced here. However, the data suggest that all companies have shown some movement towards the frontier since 1997/98. Indeed, on average the distribution companies have outperformed the expected reduction in opex between 1997/98 and 2001/02 (20% reduction versus targeted 16%, unweighted average). However, three other observations are striking: one of the most efficient firms in 1999, has improved its efficiency the most; one of the least efficient firms has made very little improvement in efficiency despite strong incentives to do so; and there is greater dispersion in the efficiency scores based on 2001/02 data than there was in 1999. This raises the question as to whether the frontier set in 1999 was in fact the true frontier and / or whether there is something distinctive about the outlier firms.

Alternative methodologies

Our analysis of the implications of using alternative benchmarking methodologies suggests that the most appropriate approach to determining the efficiency frontier for the DNOs given the data currently available is likely to be a combination of data envelopment analysis (DEA) and corrected ordinary least squares (COLS). In particular, emphasis could be placed on the DEA scores with COLS being used to assess the validity of the DEA scores.

The statistically superior approach, stochastic frontier analysis (SFA), could not be successfully applied, as the sample size was insufficient to be able to distinguish between the efficiency of companies and noise in the estimate of the frontier. It is unlikely that this approach could be applied in the price control review on a single years' data, although it might be possible with the use of panel data. We rejected the use of parametric programming analysis on theoretical grounds.

Analysis of a total factor productivity (TFP) index showed wide disparity in the performance of firms, showing that it is premature to use these directly to set X factors. However, TFP can be a useful tool for assessing frontier shift.

The composite scale variable

In 1999, Ofgem used a composite scale variable consisting of a weighted average of customer numbers, units distributed, and network length as the sole independent variable for the regression analysis. Customer numbers and units distributed are highly correlated, and the use of both in the composite variable therefore seems unnecessary. We recommend that Ofgem considers simplifying the composite variable, to include only units distributed and network length.

Cost drivers

In order to assess whether the use of a single independent variable in the frontier analysis is appropriate, we assessed the implications of including a number of other cost drivers. We selected a number of representative cost drivers and used correlation analysis to ensure that they were measuring different characteristics of distribution network operators. Cost drivers selected included customer density, the percentage of customers at high voltage, the percentage of customers at the lowest voltage level, and the percentage of losses. A second stage regression analysis of efficiency scores on cost drivers and scale variable showed that for the UK DNO sample, none of these were significant. While they may in practice affect costs, there does not appear to be merit in including them in a statistical benchmarking exercise.

The benchmark variable

Ofgem used operating expenditure as its benchmark variable in 1999. We analysed the impact of using a measure of total expenditure instead. While the most efficient firm remained the same under the two measures, some of the least efficient firms did improve their scores significantly; indicating that using opex as the measure of efficiency may miss out important factors that are relevant to customers. The appropriate definition of total expenditure is not, however, clear cut and would merit further investigation.

Quality

There is clearly a trade off between improving quality and reducing costs. The 1999 benchmarking analysis did not include a measure of quality directly, with quality improvements being incentivised separately instead. Our analysis suggests that, based on available data, this approach is appropriate. Although DEA analysis did show that some inefficient firms appear more efficient when quality is included in the analysis, a second stage regression analysis of efficiency scores against quality was not significant. Quality does not therefore help to explain the observed dispersion in operating cost efficiency among UK DNOs.

Key issues

Benchmarking is an important tool that can inform judgements about efficiency. However, it is only a tool and cannot substitute for judgements based on a wider range of evidence. With respect to the benchmarking process, the analysis indicates that there are a number of issues that Ofgem needs to consider prior to the review. In particular:

- The significant reduction in operating costs achieved by one of the most efficient firms in 1999 may raise questions about the true position of the efficiency frontier.
- Further investigation is needed to understand why some inefficient firms did not improve substantially, despite strong incentives to do so. Analysis of total expenditure and total factor productivity may help to explain the reason for this.
- In the context of recent mergers and the increasingly international nature of the industry, scale could be considered a choice variable. If Ofgem considers this to be an appropriate assumption, the approach to assessing efficiency would need to change accordingly.
- The use of a single year's data for the 14 DNOs restricts the choice of benchmarking methodology. The use of panel data and / or international data within the formal benchmarking exercise would widen the range of available methodologies and could improve the quality of these techniques.

1. INTRODUCTION

1.1 Aim of study

This report has been prepared by Cambridge Economic Policy Associates (CEPA) for Ofgem as an initial contribution to its thinking on approaches to benchmarking the efficiency performance of electricity distribution businesses under the 2005 distribution price control review (DPCR). In particular, we were asked to review the 1999 methodology for benchmarking operating costs, assess alternative benchmarking techniques, and analyse the appropriateness of the cost drivers used with a view to providing recommendations on approaches to benchmarking that Ofgem could use in the forthcoming DPCR.

Our study is informed by analysis of data provided by Ofgem on Distribution Network Operators (DNOs). It should, however, be noted that the aim of the analysis is not at this stage to form judgements on the efficiency scores of individual firms per se but rather to assess the appropriateness of different approaches to benchmarking going forward.

The full terms of reference are provided in annex 1.

1.2 Benchmarking and price regulation

Under the 'RPI-X' style of regulation used by Ofgem and other UK utility regulators, an assessment is made of the revenues that companies need to cover costs and to provide investors with an appropriate rate of return, while fulfilling their statutory duties. A crucial element in the assessment of an appropriate level of revenue to allow companies is a judgement about the extent to which they are able to become more efficient.

The use of external benchmarking[1] – the comparison of a firm's actual costs to an exogenous reference level (for example the most efficient firm in the sector) – can improve the quality of this assessment. In addition, it can be used to strengthen the incentives facing regulated firms by rewarding them financially for closing the gap between their actual and potential efficiency. It may also reduce the cost to regulators of making judgements about efficiency compared to other methods.

Benchmarking has been widely used by utility regulators in a range of sectors, including electricity distribution. In some countries, such as the Netherlands, Norway and the UK, benchmarking has been adopted as an explicit part of the process for determining allowed revenues, whilst in other countries, such as Finland, benchmarking studies are used to support rather than to determine regulatory decisions.

Although widely used, benchmarking is not universally accepted as part of the regulatory process. For example, some commentators have argued that the results of benchmarking are

[1] *A benchmark is deemed to be 'external' if a company cannot influence the benchmark against which it is assessed via its own actions.*

the result of arbitrary choices about details of the techniques, and therefore inappropriate for the determination of price controls. Particular forms of benchmarking approaches can also distort decisions by utilities[2]. If benchmarking is to be used in the regulatory process, the approach must be chosen with care. Drawing in part on the work of Bauer et al 1997, Figure 1 sets out some principles that can be used to assess benchmarking approaches.

Figure 1: Principles for assessing benchmarking techniques

In assessing the most appropriate benchmarking methodology, we have used the following principles to inform our view:

- ***Practical application***: It should be straightforward to implement the technique in practice, given the available data. Some of the more sophisticated techniques based on econometric methods may be inappropriate when there is only a relatively small sample of firms.
- ***Robustness***: One of the major criticisms levelled at the use of benchmarking techniques is that the choice of model and data is subjective, and so benchmarking is inappropriate for use in regulatory price controls. Consequently, the model selected must be robust to changes in assumptions and methodologies. In particular, the ranking of firms, especially with respect to the 'best' and 'worst' performers, and the results over time should demonstrate reasonable stability; and the different approaches should have comparable means, standard deviations and distributional properties.
- ***Transparency and verifiability***: In order to ensure accountability and confidence in the price control it is important that the benchmarking process is both fully transparent and verifiable.
- ***Ability to capture business conditions adequately***: The approach taken should be able to capture the particular characteristics of the industry concerned. For example, some allowance should be made for topology of the network (e.g. via the inclusion of network length).
- ***Restrictions***: The restrictions placed on the relationship between the chosen performance measure and variables should be minimised.
- ***Consistency with economic theory***: The approach taken should ideally conform to economic theory.
- ***Consistency with non-frontier approaches:*** Results from benchmarking exercises should be broadly consistent with financial analysis and investor perceptions about relative firm performance.
- ***Regulatory burden***: The burden placed on both the regulator and regulated companies in terms of data collection and analysis should not be overly burdensome.

[2] *For example, if a frontier firm mergers with a non-frontier firm such that the combined firm is less efficient, this may have the effect of increasing the efficiency scores of all the other firms, Jamasb, Nillesen & Pollitt (2003).*

1.3 Measuring efficiency

Determining an efficiency frontier involves decisions about numerous issues including:

- The variables that are to be benchmarked, and factors that are used to explain differences;
- The organisations against which performance is to be compared; and
- The techniques used for making comparisons between organisations.

1.3.1 Variables used in benchmarking

A very simple example of benchmarking involves assessment of the unit costs of production of a single output. Benchmarking techniques can also be used to: assess the efficiency with which physical inputs are converted into physical outputs, without reference to costs; production efficiency using several inputs and outputs; and cost analysis using several cost categories. Performance can also be assessed at a single point in time or over time.

The appropriate approach with respect to benchmarking for electricity distribution is to focus on costs rather than production. This is because, given the universal service obligations and defined territories of the DNOs, the level and mix of output is basically determined exogenously for each company.

Different levels of performance may not always be due to inefficiency, but as a result of other factors, and the variables used to explain differences in performance are an important component of benchmarking in practice. Scale is usually the most important factor, but other factors such as quality may also be significant.

Further discussion of choice of variables is set out in sections 6 and 7.

1.3.2 The comparator group

The choice of comparator group will largely be determined by the structure of the industry concerned. Options that have been used for comparing performance include:

- Company-level data from other firms in the same industry (UK based), probably operating under the same regulator (comparative or yardstick competition approach);
- Sub-company-level data (i.e. multiple observations within the same company, e.g. regions);
- Data from international operators in the same or other relevant industry(ies);
- Comparisons with other UK privatised industries;
- Nature of work comparisons: comparisons with other UK industries carrying out similar activities to the relevant regulated firm or firms;

- Comparisons with the practices of other UK regulators; and
- Comparison against the public sector entity (pre-privatisation).

Despite the existence of some important differences between the operating environments of the 14 UK electricity distribution businesses, there are few industries that are constituted by so homogenous a set of companies. The 14 DNOs therefore provide a natural comparator group for benchmarking analysis. However, there may be a rationale for adding international comparators.

1.3.3 Benchmarking technique

There are a wide range of methods that can be used to determine the efficiency frontier. These include linear programming methods and statistical techniques. The choice of technique can have an impact on the determination of efficiency scores and depends at least partly on the data available and the aims of the benchmarking exercise. Different benchmarking techniques are discussed in section 2.2.

1.4 Structure of document

This report seeks to assess the available benchmarking methodologies with respect to the UK electricity distribution sector and provide preliminary conclusions on the types of analysis that Ofgem should investigate for the 2005 DPCR.

Section 2 summarises some general theory on benchmarking and assesses a range of techniques, highlighting their pros and cons and discussing their use to date by electricity regulators. Section 3 reviews the methodology to benchmark operating costs used by Ofgem in the 1999 DPCR; and section 4 examines the implications of applying this methodlogy to the preliminary 2001/02 data. Sections 5 to 7 then consider the impact of making a variety of changes to the 1999 methodology, in particular:

- The choice of methodology to determining the efficiency frontier (section 5);
- The weights placed on the composite scale variable (section 6); and
- The inclusion of additional cost drivers (section 7)

Section 8 then considers whether it may be appropriate to benchmark total rather than operating costs, include quality in the benchmark or account for merger activity between DNOs. Finally, in section 9, we assess the implications for Ofgem with respect to benchmarking for the forthcoming DPCR.

Recent developments in the UK electricity distribution industry and details of the data and analysis used are set out in the annexes.

2. REVIEW OF BENCHMARKING TECHNIQUES

2.1 The efficiency frontier

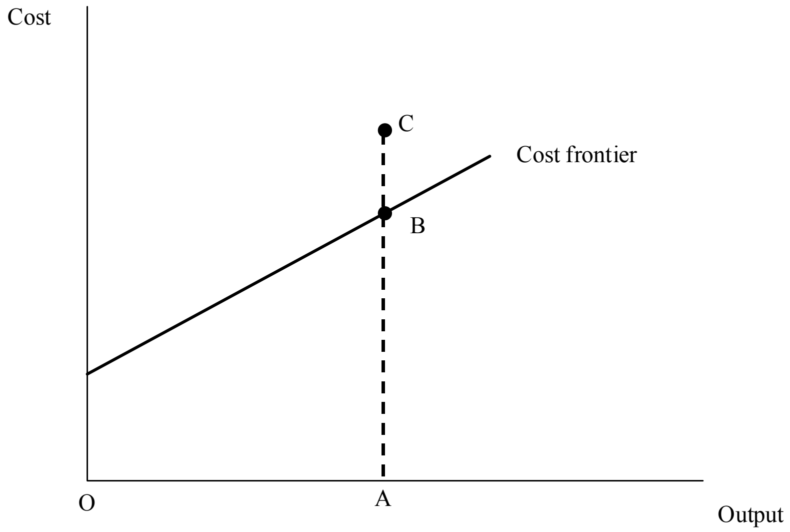
The object of benchmarking is to compare the efficiency of carrying out a particular business activity or group of activities either at a point in time or over time. The theoretical literature defines the efficiency of a firm in terms of two separate concepts: technical and allocative efficiency. Technical efficiency reflects the ability of a firm to produce the maximum level of output from a given set of inputs; whilst allocative efficiency reflects the extent to which firms use the inputs (for example capital and labour) in optimal proportions to minimise the costs of outputs for a given set of input prices and a given technology. These two measures of efficiency can be combined into a measure of total economic efficiency, also referred to as cost efficiency.

In each case, the relevant efficiency measure is defined relative to an assessment of best practice at a particular point in time. This is referred to as the 'efficiency frontier'. If a firm is operating on the frontier it is defined as efficient; if it is operating away from the frontier it is defined as inefficient, and the level of inefficiency is measured relative to the frontier (in the case of a cost frontier, inefficient firms are those operating above the frontier). The extent to which a firm is inefficient is reflected in an 'efficiency score'.

Figure 2 illustrates this with a simple example of a cost frontier, where (minimum) total costs are shown as a function of a single output variable. Firm B is operating on the efficiency frontier and is therefore considered to be 100% efficient and is given an efficiency score of unity. By contrast, firm C is above the cost frontier, and it is therefore inefficient. Firm C's efficiency is measured relative to the cost frontier by the ratio AB/AC, which is less than one. The efficiency scores derived in this way lie between zero and one. In this case, since the comparison is measured relative to a cost frontier, the derived efficiency measure reflects total economic or cost efficiency. Efficiency measures that are computed relative to a production frontier - which shows output as a function of input quantities - reflect technical efficiency only.

The main tasks of benchmarking, therefore, are to measure the efficiency frontier, and the scope that firms have to improve their efficiency. Ideally, benchmarking can also be used to decompose efficiency scores into different components, i.e. allocative and technical efficiency. Many techniques can, in theory, be used to perform such decomposition of efficiency scores.

Figure 2: Cost frontier



Source: CEPA

In many distribution network benchmarking approaches, only one input variable (cost) is used, with an assumption of constant prices faced by each company. This means that the split between allocative and technical efficiency is not meaningful. In practice, the approaches discussed in detail in this report are measuring a hybrid of technical and allocative efficiency, because the data does not permit the separation of the two.

The focus of most of the methods discussed is on the estimation of the frontier, and the extent to which companies deviate from the frontier. An important part of the judgement of regulators is not only the position of the frontier and inefficiency of companies based on current technology, but how this frontier might evolve, i.e. 'frontier shift'. This latter aspect is not a focus of this report, but some of the techniques discussed (e.g. Malmquist indices) do provide ways of analysing the data in this way.

2.2 Types of benchmarking technique

There are a variety of approaches to the measurement of the relative efficiency of firms in relation to an efficient frontier of a sample. Broadly speaking, these approaches can be classified into three main types:

- Programming techniques;
- Econometric (parametric) techniques; and
- Process approaches.

Programming techniques relate outputs to inputs without recourse to econometric estimation: the efficiency frontier is *calculated* from the data. Data envelopment analysis (DEA) is a widely used approach in this category. Index approaches to determining efficiency (partial and total factor productivity) also calculate efficiency scores, and so are included in this category, although they do not result in the calculation of an efficiency frontier.

Econometric methods, in contrast, require an assumption about the relationship between inputs and outputs, and estimate the parameters of a function representing this. Econometric methods can be further categorised as deterministic or stochastic. The deterministic approaches assume that all the deviation from an estimated frontier is due to inefficiency. Under a stochastic approach, however, inefficiency is decomposed into inefficiency and measurement error.

Process techniques attempt to assess efficiency using 'bottom-up' techniques. One such approach used by regulators relies on reviews of company practices and plans. It is also possible to use engineering data to calculate what costs should be for a particular company, based on its own individual characteristics. Another approach is to use surveys to canvas views on potential cost savings in specific areas.

These approaches are summarised in Figure 3.

Figure 3: A hierarchy of benchmarking techniques

		Single-year data	**Multi-year data**
Programming techniques	Linear programming approaches	Data envelopment analysis (DEA)	Panel data => Malmquist index
		Parametric Programming Analysis (PPA)	
	Index approaches	Partial factor productivity (PFP)	Panel data PFP
		Total factor productivity (TFP)	Panel data TFP
			Malmquist index
Econometric (parametric) techniques	Deterministic	Corrected ordinary least squares (COLS)	Pooling data allows increased sample size
	Stochastic	Stochastic frontier analysis (SFA)	
Process approaches	Engineering economic analysis	Engineering economic analysis (EEA)	
	Process approaches	Process benchmarking	

Source: CEPA

In addition to the method of determining the frontier, approaches differ on other factors:

- Whether the method is used to assess the efficiency frontier: The most widely used methods do make an assessment of the efficiency frontier, but some index measures just assess trends in efficiency.
- The frequency of data that is needed to apply the method: Some methods can only be applied using data from two or more time periods, whereas most can be applied to data for a single point in time.

The remainder of this sub-section discusses the main techniques available to regulators to compute productivity and efficiency measures. It is arranged under three main headings:

- Programming techniques
- Econometric frontier approaches; and
- Process approaches.

2.2.1 Programming Techniques

2.2.1.1 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric method that uses linear programming to determine (rather than estimate) the efficiency frontier of the sample. The approach works by solving individual linear programming problems for each firm or observation, in which the firm's inputs and outputs are assigned a set of weights in order to maximise the ratio of weighted outputs to inputs (subject to the constraint that all efficiency scores are less than one). Under this approach, an efficient firm is one where no other firm – or linear combination of other firms - can produce more of all the outputs using less of any input. This means that the efficiency frontier is constructed from the 'envelope' of these linear combinations of feasible and undominated input and output combinations.

The efficiency of each firm versus the frontier is calculated in terms of a score, θ, on a scale from 0 to 1; with the frontier firms receiving a score of 1. Efficiency scores are calculated for a firm by comparing it to a linear combination of sample firms that produce as much of each output with the minimum combination of inputs. θ measures how much the inputs need to be reduced to bring the firm onto the efficiency frontier. As the frontier comprises a series of linear segments, there are a number of possible values for this efficiency score: the efficiency score is the minimum of all the possible values.

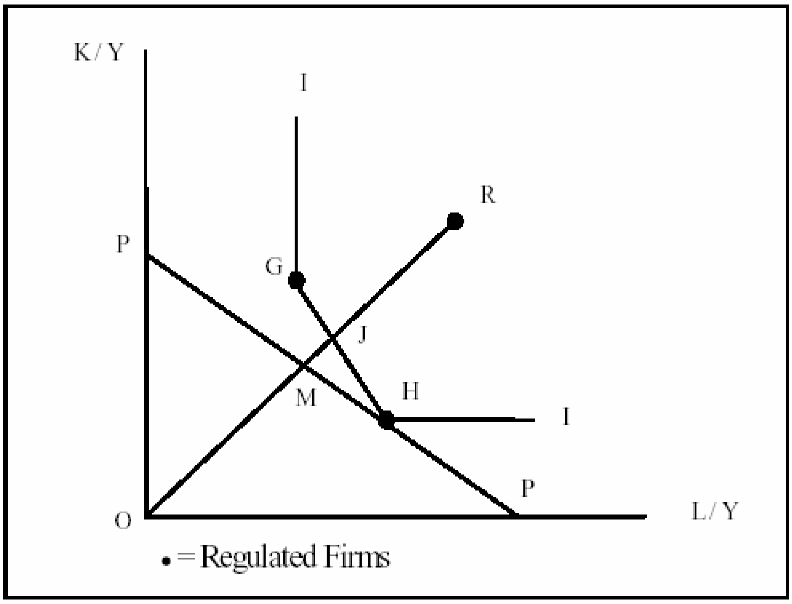
This is illustrated in Figure 4, for an input-oriented model with constant returns to scale. The figure shows three firms (G, H, R) that use two inputs (capital K, labour L) for a given output Y. The vertical and horizontal axis represent the capital and labour input per unit of output respectively and the line PP shows the relative price of the two inputs.

It is possible to recover the weights attached to each variable as for each firm from the DEA programme. For example, the programme can deliver the position of J in Figure 4 below as a weighted sum of G and H. For instance, J represents a 0.55 weight on G and 0.45 on H (normalised to 1).

As discussed in section 2.1, efficiency can be decomposed into technical efficiency measuring the ability of a firm to minimise inputs to produce a given level of outputs, and allocative efficiency, which reflects the ability of the firm to optimise the use of inputs given the price of the inputs. In the diagram, firms G and H produce the given output with fewer inputs and form the efficient frontier that envelops the less efficient firm R. The technical efficiency of firm R relative to the frontier can be calculated from OJ/OR. However, being on the frontier does not necessarily imply productive efficiency. A firm will only be 100% productively efficient if it is at point H, where the line representing the price vector of input prices, PP, is tangential to the frontier. The allocative efficiency reflects improvements that could be made by changing the proportion of different inputs, and is measured OM/OJ. The overall efficiency of firm R is measured from OM/OR.

As the efficiency of each firm is measured relative to other firms, the most efficient firms will receive scores that are greater than 100%, i.e. display 'super efficiency'. This occurs when the firm is more efficient than any linear combination of other firms, and the efficiency score can be interpreted as the amount that a company could increase its costs and still be the most efficient company.

Figure 4: DEA, assuming constant returns to scale



Source: Jamasb & Pollitt, 2001

A key step in DEA is the choice of appropriate input and output variables. The variables should, as far as possible, reflect the main aspects of resource-use in the activity concerned. Misspecification of variables can lead to perverse results, potentially with less efficient firms defining the frontier. DEA can also account for factors that are beyond the control of the firms and can affect their performance, e.g. environmental variables.

Key assumptions

DEA requires the selection of input and output variables to be made, the choice of which can significantly impact the results. There is also an assumption that the sample includes the most efficient firm, which may not always be the case. However, no assumption about the underlying technology is required other than that the production function is convex. This contrasts with regression approaches where a functional form for the cost function must be assumed. Variable returns to scale can be permitted under DEA, though sometimes it is preferable to restrict analysis to constant returns to scale (as done by the Netherlands regulator). DEA makes no allowance for stochastic errors and does not deliver standard errors to indicate the significance of individual inputs and outputs.

Variants

DEA models can be input or output oriented and can be specified as constant returns to scale (CRS) or variable returns to scale (VRS). They can also be modified to include a second-stage regression that regress the efficiency scores on other input variables. If appropriate panel data is available, the approach can also be extended to allow the calculation of Malmquist productivity indices, an alternative measure of TFP growth to the Tornqvist index described below (section 2.2.1.3).

Constant and Variable Returns to Scale (CRS and VRS): VRS can be used in DEA with only limited additional complexity, through the addition of a convexity constraint. VRS models effectively ensure that firms are only compared with other firms of a similar size. The assumption of CRS is only really appropriate in the case where all firms are operating at the optimal scale, or where firms are free to choose their scale (e.g. they can choose or be forced to merge). If this is not the case then the results may be biased in favour of larger companies.

It should be noted that the imposition of an additional constraint on the model has a localised effect on the results. Consequently, some firms may see their efficiency scores altered markedly be the specification of CRS versus VRS whilst for other there may be little impact.

Second-stage regression models: One problem associated with DEA is that as the number of variables increases, the number of peers identified for any given firm is reduced, raising the likelihood that relatively inefficient firms define the frontier. The use of a second-stage regression model is one way of getting around this. The initial DEA efficiency scores are regressed on the additional variables and the results are then used to adjust the initial efficiency scores. Because the distribution of the error variables is not normal, limited dependent variable techniques (e.g. Tobit analysis) are used for the regression models.

Output- and input-oriented models: The linear programme solved by DEA approaches can be output-oriented, in which the level of output is maximized for a given level of input factors, or input-oriented, in which input factors required for a given level of output are minimized. The output approach can be used to determine a production function, the input approach a cost function. The difference between them is only important when models with variable returns to scale are used. An input-oriented specification is generally regarded as the appropriate form for electricity distribution utilities, as demand for distribution services is a derived demand beyond the control of utilities that has to be met.

Advantages

DEA has a number of advantages, which have made it a popular methodology among regulators. It has been used in published regulatory analyses for Norway, Australia and the Netherlands and widely used elsewhere (see below). In particular:

- DEA can be implemented on a small dataset. Although the power to differentiate firms diminishes as the sample size falls, DEA still gives meaningful results. Regression analysis tends to require larger minimum sample size in order to stand up to statistical testing.
- Once the estimation preparation has been done the methodology is quick and straightforward to implement using programs that are freely available. Companies can easily crosscheck regulatory results.
- Inefficient firms are compared to actual firms rather than some statistical measure. This comparator firms can be identified and reported to add to the plausibility of the results.
- DEA is a non-parametric approach and so no assumptions are required about the technology or the specification of the cost / production function. DEA does this in a way which most favours the companies being analysed and hence reduces the arbitrariness which comes from scores based on assumed functional forms.
- DEA can account for factors that are beyond the control of the firms but affect their performance, e.g. environmental variables, either directly as inputs or outputs (Netherlands) or via second stage regressions (New South Wales).
- The technique is easy to extend to multiple outputs. Until the development of parametric distance functions regression analysis of production functions was restricted to single output specifications.
- DEA requires only physical measures of inputs and outputs, rather than financial measures. These tend to be far easier to obtain. Regulators have often used

financial measures of cost as physical inputs within DEA to get round the lack of data on input prices (e.g. Norway, Netherlands).

- DEA has the advantage that it is an operations research methodology and can be illustrated easily. It is thus a reasonably transparent method. Regression analysis tends to be treated with more suspicion by companies, complex forms of which give rise to implausible parameter values. OFGEM addressed this problem last time by imposing a very simple linear functional form.

Disadvantages

However, there are also a number of disadvantages that must be taken into consideration:

- The efficiency scores tend to be sensitive to the choice of input and output variables and, in some circumstances, inappropriate choices may lead to relatively inefficient firms defining the frontier. This is because there is likely to be at least one factor (use of input or production of an output) for which a firm is distinct. Even if this is not in fact an important variable, its use in a DEA could put that firm on the frontier. For example, the efficiency rankings of the Dutch electricity distribution companies changed significantly when network length was switched from being an input to an output variable in the DEA analysis (Nillesen & Telling, 2001).
- The method does not allow for stochastic factors and measurement errors. In practice, there are always data handling errors and individual companies are subject to stochastic shocks. Both the Norwegian and Dutch regulators had to impose arbitrary restrictions on the translation of efficiency scores into X factors in order to prevent very low DEA scores (which may have reflected positive cost shocks) from leading to very high X factors.
- As the frontier is determined by a piecewise linear function, where there are large gaps between data points it is likely that more efficiency combinations of inputs and outputs can be found. This is likely to be an issue where there are only a few data points but a large number of input variables are being considered. This has the effect of leading efficiency scores to be calculated relative to a linear combination of two or more very different firms. Under CRS, these firms could be of very different scale and hence constitute an unrealistic comparator.
- Gaming is possible under DEA, enabling firms to look better relative to the frontier. The key problem with this is that gaming may affect non-gaming firms significantly. (Jamasb, Nillesen, & Pollitt, 2003).
- As more variables are included in the models, the number of firms on the frontier increases. Therefore, it is important to examine the sensitivity of the efficiency scores and rank order of the firms to model specification. This is a problem in small samples.

- No information on statistical significance or confidence intervals is provided. This means that the analysis relies heavily on the initial choice of inputs and outputs being correct. Regression analysis can lead to the dropping of insignificant variables (the Netherlands regulator did make some use of this). The inclusion of statistically insignificant or absolutely small effect variables can give companies an opportunity for high efficiency scores by putting all of their weighting within the DEA on these variables.

- Physical measures of capital, a key driver of total costs for many network utilities, may not be appropriate as such measures do not capture the age profile of assets or differences in design (e.g. voltage levels). This is a problem for both DEA and regression analysis which includes variables such as transformer capacity or network length.

- The use of second-stage regression to increase the number of variables without reducing the number of peers for individual firms requires the imposition of a functional form, removing one of the key benefits of DEA. By doing second stage regression analysis separate from the DEA this leads to inefficient modelling of the interaction of the environmental and non-environmental effects. Regression based distance function analysis can efficiently include both environmental and non-environmental effects within the same estimation procedure.

Application to distribution

DEA has been widely used in the regulatory analysis of electricity distribution. It is fundamentally a method for weighting single factor efficiency scores in order to arrive at a potential reduction in measured inputs. It would seem to be particularly applicable in the early stages of regulation when not much is known about the potential for cost reduction and the underlying efficiency frontier. DEA makes few assumptions and relies on the data that is available. DEA crucially assumes that all firms have access to the same technology and hence that they can choose to be like other firms in the comparator group. Electricity Distribution in the UK would seem to be a good candidate for DEA given the existence of similarly organised regional utilities adhering to similar technical standards. If DEA can be used in any regulated industry in the UK electricity distribution would seem to be the one. Norway has a reasonably successful experience with DEA. However care needs to be taken to explain the method and to make the results transparent. The Netherlands regulator had to revise its efficiency scores following a failed attempt to make use of DEA based X factors.

DEA models can be specified as input-oriented or output-oriented (i.e. either minimizing inputs for a given level of output, or maximising output for a given level of input). Typically, an input-oriented specification is regarded as appropriate for electricity distribution as the demand for distribution services is considered to be exogenous, and effectively beyond the control of distribution utilities. However, quality can also be treated as an output.

Use in benchmarking studies by regulators in practice

DEA is perhaps the technique most widely implemented, with several electricity regulators - including in Norway, Netherlands, Denmark, Colombia and the UK - explicitly using it in their price setting processes. The approach, however, has varied in terms of:

- The level of costs benchmarked, e.g. electricity regulators in Belgium, Colombia, Denmark, Northern Ireland and Norway have benchmarked total controllable costs, whilst the Dutch, Finnish and UK regulators have focused on opex;
- The use of international comparators: Most regulators have tended to limit themselves to domestic comparators, particularly for distribution companies where the number of companies is generally greater, e.g. Norway where there are around 180 regional companies and Netherlands where there are 19, as this eases problems associated with data comparability. However, where domestic comparators are unavailable international samples have been used, e.g. for electricity transmission regulation in the UK and Netherlands and fixed line telecommunications regulation in the UK.
- The input/output variables used:

Figure 5: Examples of input / output variables used for DEA analysis by electricity distribution regulators

Regulator	Inputs used	Outputs used
Norway	Capital (book value and replacement cost), goods/ services, losses, labour	Number of customers, energy delivery, length of line and sea cables
Netherlands	Opex	Units, peak demand HV, peak demand LV, network length, customers small, customers large
NSW, Australia	Total operating and maintenance costs, transformer capacity, network size	Electricity sold, customers, peak demand

Source: Jamasb & Pollitt, 2001

- Reliance on other techniques: In some cases, e.g. Netherlands, DEA has been the primary means of benchmarking efficiency. However, in other instances, e.g. New South Wales electricity regulator and Oftel with respect to the regulation of BT, DEA has been used as just one of a variety of techniques, none of which has been preferred over the others.

Figure 6: The experience of DTe

In 2000, the Dutch energy regulator, DTe, undertook DEA to benchmark opex for its 19 electricity distribution companies, with companies being required to remove the implied inefficiency versus the frontier over the following three-year price control period. The analysis gave NUON, one of the largest companies, an efficiency score of 65% and so DTe imposed an X factor of 8% per annum (real).

However, NUON argued that the methodology used incorporated a bias against large companies due to the use of coincidental peak demand as an output variable. It therefore presented analysis based on three sets of data – one for each of the three entities that had merged to form NUON – and output variables that distinguished between network types, e.g. HV versus LV, that placed NUON on the efficiency frontier.

DTe accepted NUON's revised data and, using its own model, gave NUON a revised efficiency score of 95% and X factor of 2% per annum. The decision opened up challenges from several other companies.

DTe's experience of benchmarking underlines the susceptibility of DEA to the choice of input and output variables and highlights the risks associated with relying on a single technique for determining the efficiency frontier, especially when the results feed directly into the regulatory determination.

- Translation into regulatory formula: In many instances the efficiency gap implied by the regulator is used to set company-specific X factors, e.g. Netherlands electricity distribution. However, in other cases, (e.g. NSW distribution, UK transmission) the results of the DEA analysis are just one of several factors used to determine the X factors or, as in the cases of Finland and Sweden, do not explicitly drive the regulatory process at all.

<u>Assessment</u>

DEA is a widely used model, requiring few assumptions about the functional form of cost functions, and it is easy to apply and interpret. Care needs to be taken in the specification of the variables for use in the model, in particular for small samples of firms, but provided this is done, it is a valuable benchmarking tool.

2.2.1.2 Parametric programming approach (PPA)

As with DEA, this technique uses linear programming to find the efficiency frontier. The difference, though, is that the frontier is assumed to have a particular functional form, in common with COLS and other parametric techniques. The translog production function is one that has often been used, for which the Cobb-Douglas production function is a special case. Further details of this are set out in Annex 2.

The approach was developed in the 1970s and was seen to be an enhancement of DEA analysis, with the advantage that it involved the use of a specific production function.

Application to Distribution

If the approach were to be applied to distribution network operators, the 'output' variable *u* would be costs, and the input variables *x* would be the various cost drivers (such as the scale parameters of line length, customer numbers etc). Although this approach has been implemented in the electricity sector, it does tend to give odd results. There is no guarantee that the linear programme will ensure the inclusion of particular variables in the efficient frontier. Pollitt (1995) in implementing PPA for electricity generation observed that although capital, labour and fuel data were analysed, only two of the three were selected to be part of the efficient frontier. This was implausible from an engineering point of view. There have been no recent studies of electricity distribution that have utilised this approach.

Use in benchmarking studies by regulators in practice

There have been some applications of this technique to assessing the efficiency of coal fired steam generation plant (Koop & Smith 1980). However, the approach has not been applied by regulators in practice as far as we are aware.

Advantages

- Advantage over DEA seen to be that there could be an imposed specification of the production function.
- It is sufficiently flexible to handle constant and variable returns to scale.

Disadvantages

- Difficult to implement in empirical work. In many cases it is not possible to construct the frontier because there is insufficient data to do so, while preserving the restriction on the parameterisation of the production/cost function.
- Difficult to implement in practice where there are multiple outputs. Even if specific outputs are known to be important, the restrictions in the model means that they may not affect the frontier in the fitted PPA.
- Does not produce standard errors of the estimates, and therefore does not allow inferences to be made about parameter values.

Assessment

Overall, PPA suffers from most of the disadvantages of DEA, and in particular that the frontier position is vulnerable to precise variable specification, but it does not have the compensating advantages of econometric approaches like COLS. We do not, therefore, consider its use further. We are not aware of its use by other regulators.

2.2.1.3 Total and Partial Factor Productivity Indices

Index methods are designed to compare the efficiency with which companies deploy their inputs. The rationale for the use of these methods is that the trend in industry unit costs can be decomposed into two factors:

- The trend in input prices; and
- The trend in the efficiency with which inputs are used.

In RPI-X regulation, the 'X' can be thought of as the trend in efficiency, and so to this could be benchmarked against the trend in efficiency.

Productivity comparisons may be made based on partial productivity or total factor productivity measures. Both methods essentially construct ratios of measures of output to measures of input. Different indices use different methods to weight inputs and outputs, and it is this that gives the methods their different qualities.

Partial factor productivity (PFP)

Partial factor productivity (PFP) measures compare the ratio of a single output to a single input across firms and over time (for example labour productivity). However, partial productivity measures can be highly misleading as they are often significantly impacted by capital substitution effects (where capital is substituted for labour, therefore improving labour productivity). The main problem with PFP is that it is not clear what can be done with them. Australian regulators have used them to exam many different aspects of the efficiency of their distribution utilities. However one cannot sum up the efficiency savings that these measures give for each function and suggest that the total efficiency saving is achievable for the company as a whole. This is to neglect the fact that companies may choose to substitute one type of expenditure for another hence giving them best performance on some measures but not on others leaving best performance on all measures simultaneously unachievable.

Use in benchmarking studies by regulators in practice

PFP indices are commonly used by Australian regulators, e.g. Office of the Regulator General, Victoria (ORG). However, Victoria's distribution firms appealed against decision and this lead to a revision in the approach. (Kaufmann & Beardow, 2001a)

Advantages

- Easy to compute and understand
- Can be used to cross check DEA and COLS results for plausibility and transparency

Disadvantages

- Does not allow for evaluation of uncertainty associated with calculating benchmark
- Although can control for some differences in operating environment, many it cannot control for
- The restriction to some of the factors used in production means that the approach can be misleading.
- Cannot give an overall measure of potential for cost improvement which has a strong theoretical rationale.

Assessment

The advantage of PFP is its relative simplicity. However, TFP indices (see below) are also relatively simple to calculate, and give a more balanced view of productivity.

Total factor productivity (TFP)

In a multi-input, multi-output environment, the total factor productivity (TFP) indices provide a more informative measure of performance. They can be used both to compare firms at a specific date and also to compare a particular firm's performance over time.

In order to compare TFP performance over time and / or between firms, it is necessary to construct an index that relates changes (or differences) in outputs to changes (or differences) in inputs. The most common index used in the empirical literature is the Tornqvist index[3] (see Figure 7), which measures the ratio of all outputs to all inputs, using revenue and cost shares as the output and input weights respectively[4]. (When revenue / cost share data is unavailable, it is possible to estimate the weights from econometric cost functions.)

Productivity measures may also be expressed in terms of unit costs. Trends in unit costs over time will be driven by changes in physical productivity, as well as movements in input prices. Unit cost measures may be based on operating costs or total costs. In comparing the performance of different industries over time, UK regulators have analysed trends in real unit operating expenditure (RUOE) and real unit total expenditure.

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[3] *An alternative index would be the Fisher Ideal index*

[4] *The weights used are the arithmetic average of the weights in the two time periods being compared.*

Figure 7: The Tornqvist index

The Tornqvist index is based on information on input and output quantities and cost shares. It is expressed as follows:

$$\ln Q_{st}^{T} = \sum_{i=1}^{N}\left(\frac{\omega_{is}+\omega_{it}}{2}\right)(\ln x_{it} - \ln x_{is})$$

Q_{st}^{T} is the Tornqvist index from period s to period t

ω_{is} is the cost share of the ith input in the tth period

x_{it} is the quantity of the ith input in the tth period.

It can also be expressed as:

$$Q_{st}^{T} = \prod_{i=1}^{N}\left[\frac{x_{it}}{x_{is}}\right]^{\frac{\omega_{is}+\omega_{it}}{2}}$$

This measure, therefore, is the weighted geometric mean of the input quantity ratios for each period, weighted by the average cost shares.

<u>Application to Distribution</u>

The approach is sufficiently flexible to allow a large number of input and output variables. TFP would be useful in order to assess the trend in efficiency over time. This is important in assessing whether X factor targets are being met. Some regulators (such as in Australia and in the US) have discussed using average TFP as a benchmark for the regulated industry. As a longer term objective tying X to the TFP growth rate in the distribution sector might be a desirable goal.

<u>Advantages</u>

- The approach is relatively easy to implement and understand
- If a TFP measure combined with an appropriate input cost measure is used to determine changes in costs, this should be consistent with the determination of price trends in a competitive market.
- Comparisons can be made between firms, as well as for the same firm at different times.
- TFP growth rates in electricity distribution can be easily compared to those in related sectors or the economy as a whole (this is not true of other methods).

Disadvantages

- TFP is a non-statistical approach and so it does not allow for the evaluation of uncertainty associated with the results.
- It provides only limited ability to control for differences in the business environments of firms in the sample group.
- If the TFP trend is used across an industry, less efficient firms may find it easier than efficient firms to outperform the TFP trend and earn large profits.
- The approach is unable to distinguish scale effects from efficiency differences
- TFP can be calculated in many different ways. A recent Australian review of the future of regulation highlighted the fact that although methodologically straightforward to explain, the question of which outputs and inputs to include in TFP remains.
- It may be too early to implement a TFP based X factor in the UK because there are still substantial efficiency gains to be shared between customers and companies following the restructuring of the industry.

Use in benchmarking studies by regulators in practice

TFP approaches have been used in North America, in the telecoms, gas and electricity industries. Kaufmann and Lowry (1998) note that the use of TFP based X factors in the US and Canada is the alternative to the UK approach. However the result of using TFP measures in the US is to impose extremely low efficiency targets, by UK standards. These targets (0-2%) look unchallenging in UK context and coupled with extensive revenue sharing agreements result in a lack of pressure to cut utility costs in the US. The use of such measures in North America seems to reflect the relative power of industry stakeholders within the US regulatory system.[5]

Assessment

Tracking TFP growth in the UK electricity distribution sector is clearly important. This is because it does indicate whether there is any convergence in productivity growth rates within the sector and whether we can switch to a system of X factor setting based on TFP growth rates. Such a system could allow X factors to be set for a longer period before review and hence improve incentives to reduce costs and cut the cost of regulation on the industry.

However, as we shall show (section 4), the UK has posted another impressive improvement in efficiency of its electricity distribution sector with high dispersion of productivity growth

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[5] *IPART (1999), Regulation of Electricity Network Service Providers - Incentives and Principles for Regulation - Discussion Paper No.32, Sydney: IPART, pp.15-16.*

rates around a high average. This implies that it may be too early to consider TFP in calculating the X factor.

Malmquist index of productivity

Malmquist indices are one way in which productivity can be tracked over time. In contrast to other index methodologies, the Malmquist index does this with reference to a particular production technology. In principle, this can be specified in any of the ways described under the other benchmarking methodologies.

The index definition

Under this approach, a production function is defined, which gives a relationship between the inputs and outputs. Each set of inputs can be used to produce a range of outputs, i.e. there is a trade off between output variables.

A distance function is defined, which states how far away a given set of inputs and outputs is from the production frontier. This is expressed as $d_0^s(y_t, x_t)$, which is the distance between the input and outputs observed in period t against the technology used in period s.

Given the above, the Malmquist index is defined as follows:

$$m_0(y_s, x_s, y_t, x_t) = \left[\frac{d_0^s(y_t, x_t)}{d_0^s(y_s, x_s)} \times \frac{d_0^t(y_t, x_t)}{d_0^t(y_s, x_s} \right]^{\frac{1}{2}}$$

The first of the fractions in the square brackets represents the ratio of the distance at time t compared to technology s, to the distance at time s compared to technology s, so it increases if the distance from the technology increases. The second fraction does the same for technology at time t. The Malmquist index is the geometric average of these two.

Assumptions

The index definition depends not only on the technology, but also on the distance function defined (i.e. the measure used to state how ‘far’ a particular company is away from the production frontier).

Advantages

- Decomposable into catch-up and frontier shift components, unlike Tornqvist approach
- No input price info is required (like Tornqvist)
- Underlying assumptions of allocative efficiency and cost minimisation by the firms required under Tornqvist can be dropped

Disadvantages

- Panel data is required (unlike Tornqvist)
- Where there is uncertainty about the definition of the technology, this gets translated into the index. This applies in particular when estimates of segments of a production frontier vary significantly over time.
- There are problems in using VRS or CRS.
- The results tend to be unstable for a given company in a given year and sensitive to the choice of inputs and outputs.

Assessment

Malmquist indices are useful in the context of the use of DEA. They provide a way to exploit panel data and detect TFP trends over time. Fundamentally Malmquist indices help address the issue of whether there is convergence in efficiency scores towards the frontier over time. The UK approach to regulation, as originally envisaged, was that there would be convergence towards the efficient frontier. Thus if there is no convergence over time this poses important regulatory questions about whether the method of assessing efficiency actually reflects achievable targets or whether the regulator is allowing efficient reorganisation of the industry (to allow the most inefficient firms to be taken over and reorganised).

2.2.2 Econometric frontier approaches

Econometric methods estimate a cost (or production) frontier[6] from the relevant data (for example, other regulated companies or international comparators). The estimated frontier is based on the key drivers of cost, as selected by the modeller. Depending on the approach, any deviation from the frontier is then attributed to inefficiency (deterministic frontier approach); or to a combination of inefficiency and random error (stochastic frontier approach (SFA)).

2.2.2.1 Deterministic statistical approach (DSA)

The most commonly used deterministic approach is corrected ordinary least squares (COLS), the standard regression technique, with the efficiency measures computed from the residuals.

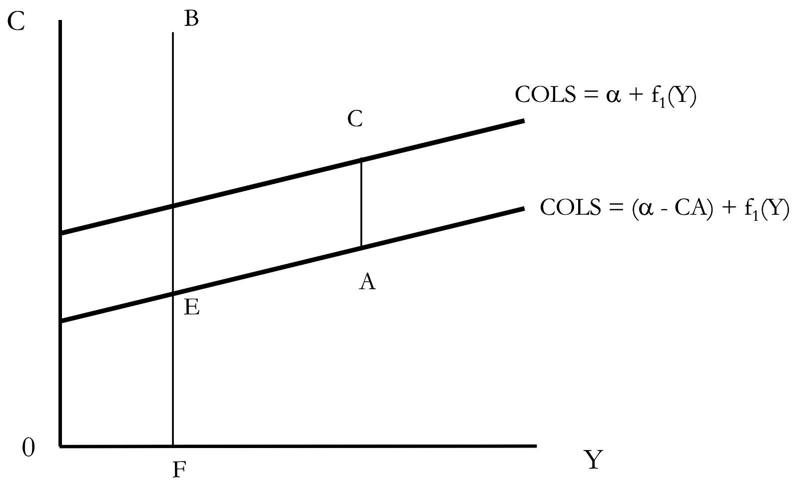
[6] *More recently, distance functions have also been used. These can be thought of as a representation of the production technology in a multi-input, multi-output environment.*

Definition of the technique and rationale

With this approach, the frontier is estimated (rather than calculated) using statistical techniques. A functional form for the production / cost function is specified (see below), and this is estimated using ordinary least squares (OLS) techniques. The calculated line of best fit is then shifted to the efficient frontier by adding the absolute value of the largest negative estimated error to that of the other errors (for a cost function). This is therefore a 'corrected' form of OLS is used, COLS, rather than the standard form. The correction reflects the assumption that error terms must be greater than zero and ensures that the function passes through the most efficient unit and bounds the other units. The distance measures for the inefficient units are then calculated as the exponential of their corrected residuals.

Figure 8 illustrates a COLS model with a single cost input C and one output Y. The cost equation $C_{OLS} = \alpha + f_1(Y)$ is estimated using OLS regression and then shifted by CA to $C_{COLS} = (\alpha - CA) + f_1(Y)$ on which the most efficient firm A lies. The efficiency score for an inefficient firm B is calculated as EF/BF.

Figure 8: COLS



Source: Jamasb & Pollitt, 2001

A number of different functional forms can be used in the estimation of COLS models. Further details of this are set out in Annex 2.

Key assumptions

- The COLS method requires specification of a cost or production function and therefore involves assumptions about technological properties of the firms' production process.
- It is assumed that all deviations from the frontier are due to inefficiency. There are therefore no measurement errors.
- It is also assumed that the data set includes the most efficient firm

Calculating efficiency scores

Similar to DEA, the method estimates the efficiency scores of the firms on a 0 to 1 scale. Deviations from Cost and production functions can be calculated using the shifted frontier and taking the ratio of the distance from the frontier to axis divided by the distance from the firm to the axis.

It is possible to use a cost function to obtain separate measures of technical and allocative efficiency. This can be done in a number of ways but requires the input price data and usually the estimation of system of equations including the cost function and factor share equations.

Multiple outputs

OLS can be used to estimate a functional form based on the translog function (see above), which measures the 'distance' of a company from the production frontier, which is essentially a corrected residual. Recently, input distance functions have been developed which allow easy extension of efficient production function analysis to multiple output contexts (see Coelli et al, 1998). These functions allow COLS to be used in multiple input – multiple output contexts. They also allow the extension to panel data in multiple output context.

Variants

Cost system analysis and distance function analysis are usually estimated by maximum likelihood estimation for the parameters of the production function and for the distribution of errors, $f(\varepsilon)$. However the principle of shifting the frontier to envelope all of the data (and the assumption that all deviation from the frontier is inefficiency) as with the COLS approach remains.

Advantages

- Easy to implement

- Allows statistical inference about which parameters to include in the frontier estimation.
- Requires no assumptions about the distribution of the inefficiency scores.

Disadvantages

Although an attractive approach due to its simplicity, and one that has been utilised by a number of regulators including Ofgem, COLS does have a number of drawbacks. In particular:

- The estimated parameters may not make engineering sense
- The method makes no allowance for stochastic errors and relies heavily on the position of the single most efficient firm in the sample
- Similar to DEA, COLS assumes that all deviations from the frontier are due to inefficiency.
- It is not possible to identify firms to which inefficient firms are being compared in the same sense as DEA. All firms are being compared to a frontier defined by one frontier firm. However there may be no 'nearby' frontier firms.
- Complex to analyse efficiency scores into technical and allocative efficiency.

Use in benchmarking studies by regulators in practice

A number of UK regulators have made use of COLS in establishing the efficiency frontier, either alone or in conjunction with other methodologies. For example, Ofwat utilised standard regression techniques to estimate the operating and capital maintenance cost efficiencies across companies. It is interesting to note that Ofwat rejected the SFA methodology on the basis that it required an assumption about the particular distributional form of the inefficiency term. SFA was, however, used in conjunction with DEA to crosscheck the results of the regression analysis.

Ofgem also utilised COLS – in combination with bottom-up Engineering Economic Analysis (section 2.2.3.1) - in the case of the 1999 electricity DPCR to benchmark opex efficiency; and both Oftel and the Northern Ireland electricity regulator have used COLS as one of a variety of methodologies to benchmark costs. (Oftel now benchmarks total controllable costs rather than opex and uses US firms as comparators for BT.) In all cases the results of the benchmarking analysis fed directly into the regulatory decision.

Use of COLS by non-UK regulators, however, has been limited. In New South Wales the regulator did make use of DSA using the distance function variant and a larger sample of firms.

Application to Distribution

A COLS variant of DSA has been applied in the UK. However it is important to point out that COLS is a statistical technique and as such is potentially data intensive. While potentially it would be possible to define a cost function with several outputs. If this functional form is flexible (as theory might suggest) it will have a large number of variables which increases the need for more data. The Ofgem version of COLS has been limited by the use of just 14 data points. The inclusion of panel data would allow a more realistic functional form to be tested.

Assessment

COLS is a useful technique because of its simplicity, which makes it is easy to understand and interpret. It is also very flexible, allowing its use even when there are a relatively small set of comparators. These advantages make it useful tool for analysing benchmarking data despite its problems, such as the reliance on a single frontier firm, and such drawbacks must be taken account of in interpreting results.

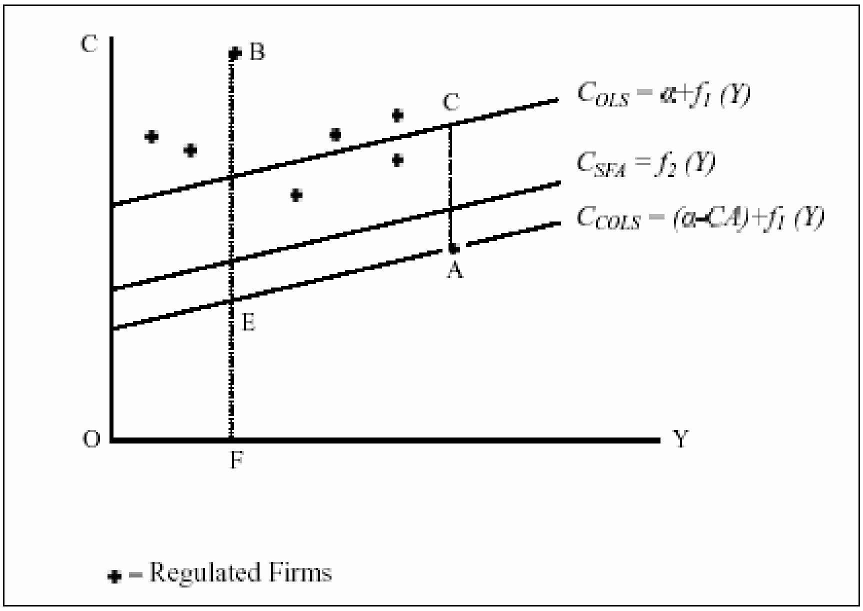
2.2.2.2 Stochastic frontier analysis (SFA)

Stochastic frontier analysis (SFA) is similar to COLS described above, in that it requires the specification of a production function based on input variables. The difference is that it does not assume that all errors are due to inefficiency, so errors in parameters are incorporated into the model.

The underlying functional form is typically Cobb-Douglas, translog or Constant Elasticity of Substitution (CES), as described above. A model of the form described under COLS is estimated with two error functions rather than one. The first of these will be assumed to have a one-sided distribution as under COLS. The second error term, however, would have a symmetric distribution with mean zero. However, accounting for stochastic errors requires specification of a probability function for the distribution of the errors and distribution of inefficiencies (e.g. half normal or gamma). As for the result of stochastic factors and their effect on the position of the most efficient firm, the estimated scores are higher than those estimated under COLS.

Figure 9 shows the estimated cost equation $C_{SFA} = f_2(Y)$ using SFA and the frontier as estimated under COLS. A firm, such as A, which lies below the stochastic frontier might be regarded as 100% efficient, i.e. the difference between its actual costs and its expected costs on the frontier are effected by a negative cost shock. Efficiency scores therefore tend to be higher under SFA than COLS as the latter method assumes that the most efficient firm will be subject to some negative stochastic shock.

Figure 9: SFA and COLS



Source: Jamasb & Pollitt, 2001

SFA can be extended to a multi-input, multi-output model in the context of a cost frontier.

Estimation of the parameters with SFA is more complex than with COLS, requiring the use of maximum likelihood estimation (MLE). SFA allocates deviations from the frontier between noise and inefficiency in a rather arbitrary way, while being constrained by the assumptions about the shape of the errors. In practical application this may mean that errors are often completely allocated to noise and hence there is no measured inefficiency or completely to inefficiency (in which case DSA and SFA yield very similar results).

Calculating allocative and technical efficiency is not as straightforward as with the other techniques. These approaches typically rely on assumptions about the functional form for the relationship between errors in input share equations and allocative efficiency, or make use of a decomposition algorithm.

Advantages

- SFA reduces reliance on measurements of a single efficient firm.
- Can incorporate tailored business conditions
- Incorporates the possibility of measurement error, stochastic factors.
- The mean of the efficiency term can be explained by the inclusion of environmental variables in the analysis. Such inclusion handles environmental variables in a statistically robust way.

Disadvantages

- Requires a functional form to be specified
- A statistical distribution also needs to be specified for the inefficiency factor
- Can be difficult to implement in practice due to the length of the algorithms required
- Suffers from a lack of transparency in the derivation of results, again due to the complexity of algorithms required.
- Estimating allocative and technical efficiency using SFA is complicated. The most advanced methods require panel data. Technical efficiency with this approach requires an assumption to be made about the form of the error distribution.
- Even if there are no errors in efficiency measurements, some inefficiency may be wrongly regarded as noise.
- Complex functional forms and stochastic errors appear to bias estimates of inefficiency downwards. Some inefficiency would be classified as noise – a real moral hazard problem.
- Estimation of the parameters with SFA is more complex than with COLS, requiring the use of maximum likelihood estimation (MLE).
- In practice the technique may not be implementable and give rise to all firms being 100% efficient.

Application to distribution

SFA is a technique that has been much used in analysis of electricity distribution. Usually this involves the specification of a translog functional form in the presence of a large dataset. Inputs and outputs used under other methods can be used. In large samples there is no reason to believe results will not be robust. However, in a sample of 14 firms for one year it would be surprising if SFA worked and gave sensible results given the instability of the technique in practice and the lack of degrees of freedom.

Use in benchmarking studies by regulators in practice

Perhaps due to the complexities of implementing SFA in practice and the lack of transparency associated with the results, regulators have tended not to rely on SFA in setting X factors. However, in some cases SFA has been used as a crosscheck on other approaches. For instance, Oftel and the NSW electricity regulator have used SFA as one of a range of techniques to assess cost efficiency; and the Swedish electricity regulator has used SFA for follow-up analysis, though not explicitly in the tariff-setting process.

Assessment

Although SFA is perhaps statistically the most elegant method, it has been difficult to implement (Coelli & Perelmann 1996 provides an example). Regulators have therefore traditionally been reluctant to use SFA techniques in setting X factors. This is because in small samples the technique is either difficult to implement or gives rise to high efficiency scores. Rather regulators have put more effort into data collection and verification in order to reduce the argument for SFA on the grounds that the data has noise in it. This effort does increase the legitimacy of COLS and DEA in a regulatory context. However as techniques for estimating SFA frontiers continue to improve. SFA should be utilised in a panel data context. If Ofgem were to use all 12 years of data available to it, it would have 168 data points. This is more than enough for the estimation of an econometrically plausible SFA.

2.2.3 Process approaches

2.2.3.1 Engineering economic analysis (EEA)

Engineering economic analysis (EEA) can be used to calculate the optimal cost level for a particular firm by defining a 'model' firm and by building up the inputs and costs in a 'bottom-up' manner. Essentially, the engineering analysis leads to the creation of a production function. Data for individual companies is then used in the production function to determine the overall appropriate cost level for the company.

Through this approach company business plans are reviewed and challenged in order to identify specific efficiency initiatives for each relevant area of cost or activity.

Application to distribution

The application of EEA to distribution would involve the following steps:

- Examining the key features of each distribution region, including the terrain, and the dispersion of customers
- Designing a least cost network to serve these customers, given the physical features; and
- Estimating the cost of building and maintaining this least cost network.

Advantages

- Does not rely on the actual efficiency of firms to determine efficiency – it could be that all firms are some distance away from the efficiency frontier.
- Reduces regulator's reliance on cost information provided by companies

Disadvantages

- Relies on judgements of engineering consultants both for the determination of the appropriate inputs, and also the appropriate cost of those inputs. This can be subjective.
- The approach is data intensive. Detailed information on the pattern of regional demand and other topographical issues needs to be collected and processed.
- There is an issue about how past investments should be treated. Investment could have been approved by the regulator, but circumstances meant that it is not needed. The EEA approach would strand the investment.
- Uncertainty about demand growth means that it may not be optimal to oversize a system, but to expand gradually. This means that the system could be more expensive to build and maintain than it would have been, although the investment strategy was correct as it avoids constructing potentially stranded investments.

Use in benchmarking studies by regulators in practice

This approach has been used for electricity distribution in Chile. The model firm was used to implement a form of yardstick regulation, an approach emulated by other Latin American countries, e.g. Peru.

The algorithms used by National Grid to determine its charging structure can also be used to determine a broad brush estimate of the cost of building and operating a transmission network to specified security standards. Estimates of optimal system size and costs have not, to date, been used to inform judgements about the overall level of charges that National Grid levies for transmission, but in theory they could be.

Benchmark costs of expansion are also used in the UK in the determination of distribution charges. An approach has been considered in Spain, also to use to determine distribution charges. Estimates of optimal system size and costs have not, to date, been used to inform judgements about the overall level of charges that National Grid levies for transmission, but it is clear that they could be.

Assessment

This approach is very data intensive, and to apply properly in the UK would require detailed data collection on segments of the supply regions of the DNOs. It also extremely reliant on assessments of consultants on numerous elements of the application of the methodology, such as the cost of inputs, and the method of designing optimal network configuration. In addition, the actual network may differ from the optimal network because of the way in which demand growth evolved, as well as inefficiency. The approach may lend itself to explaining dispersion in costs, but the intensity of data collection is likely to make it impractical for use in the UK at present.

2.2.3.2 Process benchmarking

Process benchmarking involves assessing business processes and plans for individual companies by expert consultants, who determine the scope for performance improvement. This is done by examining individual functions, and using experience and relevant external benchmarks of different business functions to estimate the extent that a company can reduce its costs.

Analysis undertaken in this type of work includes:

- Identification of cost savings in specific business functions common to all businesses, including HR, and finance.
- The impact that new technology (e.g. new applications of IT) could have on business functions;
- Analysis of any specific unfavourable contracts that could be renegotiated at lower cost
- Identification of specific operating cost savings that could be achieved in the business operations.

<u>Application to distribution</u>

Ofgem has applied this type of analysis to all the businesses it regulates (electricity and gas, transmission and distribution). Examination of published reports on reviews of distribution activities do not reveal any specific problems in applying the approach to distribution.

<u>Advantages</u>

- Conceptually is easy to apply.
- The results are tangible, and can be used to effect change in the companies subject to the review.

<u>Disadvantages</u>

- Relies on the quality of judgements made by the consultants.
- The thorough investigation needed can be time consuming and expensive.

<u>Use in regulatory determinations</u>

Process benchmarking has been widely used by a number of regulators. Ofgem used the approach to inform judgements in the 1999 distribution review (section 3). It has also been used by ORR and Ofwat, as well as other regulators abroad, either alone or in support of other quantitative techniques.

Assessment

Process benchmarking has been extremely important in regulatory determinations in the past. The identification of realistic actions that can reduce costs, and an assessment of their impact on costs is of enormous value to regulators, and can make credible any judgements about the scope for cost reductions made by other means. Such approaches should remain part of the regulatory toolkit, although a discussion of the detailed methods used is beyond the scope of this report.

2.3 Conclusions – benchmarking methods

The discussion above on the techniques has shown there to be advantages and disadvantages to each, and a summary of these is set out in the figure below.

The discussion indicates that on theoretical grounds we can reject the use of Parametric Programming Analysis. However, other techniques cannot be rejected, and whether their use is valuable will depend on the features of the data to which they are applied. In the analysis of Ofgem data, we therefore set out the application of DEA, COLS, SFA, and index techniques, and conclusions on the practicality of their use in the UK distribution sector are drawn in the conclusion to this report. While we recognise the value of the process techniques, their application is beyond the scope of this study

Figure 10: Key characteristics of the main methodologies

Key characteristics	Main advantages	Main disadvantages
DEA		
Non-parametric approach that calculates, rather than estimates, the frontier using linear programming techniques	• No imposition of prior set of input and output weights on the data required • No specification of a cost / production function required • Can incorporate uncontrollable factors, e.g. environmental • Can calculate technical and allocative efficiency • With panel data, can extend to calculate Malmquist productivity indices	• Sensitive to choice of input and output variables • No allowance for stochastic factors and measurement errors
TFP		
Non-parametric approach that calculates changes in the use of efficiency with which multiple inputs are transformed into multiple outputs.	• Simple to apply and interpret	• Unable to distinguish scale effects from efficiency differences[7]
COLS		
Statistical approach that estimates a production function, and shifts this to reflect the efficiency of the most efficient firm to determine the frontier.	• Straightforward to carry out and interpret • Allows statistical interpretation of relationships	• Requires specification of a cost / production function • Relies heavily on position of frontier firm
SFA		
Statistical approach that estimates a production function, but attempts to separately estimate inefficiency and error in measurement of the frontier.	• The impact of measurement errors and other random effects is taken into account in arriving at efficiency scores	• Requires specification of a cost / production function • Difficult to implement on small samples
EEA		
Determination of cost of providing service by bottom up assessment of cost of creating and maintaining an optimal network.	• Provides good explanation for dispersion in cost of different companies.	• Data intensive • Reliance of consultants' estimates • Model used to construct benchmark data not transparent

[7] *Without recourse to econometric estimation.*

3. Review of the 1999 distribution Price Control Review

The 1999 DPCR[8] involved detailed efficiency benchmarking (although limited use of the technique had been used in the 1994 DPCR). Despite highlighting the benefits of benchmarking total costs, Ofgem actually took the approach of benchmarking operating costs (opex) and capital costs (capex) separately. With respect to opex, Ofgem took a two-strand approach, considering the efficiency levels implied by both top-down and bottom-up analysis. Capex was benchmarked essentially on the basis of a bottom-up analysis of the efficient level of costs.

This section reviews the approach taken to assessing the efficient level of opex for the distribution businesses.

3.1 The 1999 methodology

Opex covers the every day running costs of a business and accounts for approximately 40% of allowable revenue for the distribution companies[9]. As such, forecasts of efficient opex feeding into the price review have a significant impact on the X factors set for individual companies and therefore also on the level of prices.

Due to the considerable historical variation between the Public Electricity Suppliers (PESs) in achieving opex reductions and forecasting opex trends together with the inaccuracy of company forecasts, Ofgem decided to undertake a detailed assessment of the efficient level of opex for a given company as part of the 1999 DPCR.

In order to reduce the risks associated with relying too heavily on a single technique, a two-strand approach was taken to establishing the efficient level of opex for each distribution company. This involved:

- ***A regression analysis***: A top-down analysis of the cost drivers of opex to determine the efficiency frontier.
- ***An efficiency study***: A bottom-up study to assess the potential for the distribution businesses to reduce base opex

[8] *Final proposals for price controls for DNOs were published in December 1999[8], and revised controls took effect from April 2000. At that time, distribution activities were combined with supply activities in PES. Subsequent legislation has separated the licences of these activities.*

[9] *The following charges are excluded: extra high voltage (EHV) charges; top-up and standby charges; non-trading rechargeables; prepayment meter distribution business surcharges; special metering charges; special meter reading charges; other minor activities and charges; and connection charges.*

3.1.1 Regression analysis

The May consultation paper identified a number of potential methodologies for establishing the efficiency frontier, in particular, the use of: simple ratios; corrected ordinary least squares regression (COLS); data envelopment analysis (DEA); and stochastic frontier analysis (SFA).

The approach chosen by Ofgem for the 1999 DPCR was a simple form of COLS with one dependent variable (controllable opex) and one independent variable (a composite of three scale variables). For 1997/98 data, the analysis essentially determined a relationship between base opex (as defined below) and a measure of network scale. In order to establish the frontier, the slope of the plot was then adjusted so that the line passed through the second lowest data point – the second most cost efficient firm -whilst maintaining the value of the intercept. The distance of each data point from the frontier then determined each firm's potential for efficiency improvement.

3.1.1.1 Data refinement

As noted in section 2, any benchmarking exercise requires high-quality data collated on a consistent basis across comparators. Consequently, before undertaking the regression analysis, considerable refinement of the raw opex data for the base year 1997/98 provided by the PESs was undertaken to ensure that controllable opex was reflected consistently across companies. The key steps involved are set out below and summarised in figure 11.

<u>Controllable opex: stripping out uncontrollable costs</u>

Analysis conducted by Ofgem's consultants concluded that network depreciation, network rates, NGC exit charges and profits/losses from the sale of fixed assets were not controllable by the PESs. These charges, amounting to approximately 1/3rd of total opex, were therefore excluded from the analysis; leaving engineering, customer service and corporate costs as the controllable portion of opex.

<u>Adjusted controllable opex: Adjustments for differing accounting policies</u>

The approaches taken by the PESs to capitalising expenditure, allocating costs between different business activities and recharges varied significantly. Adjustments were therefore made to the data to reflect these. In particular:

- Capitalisation of opex: Regulatory policy allowed for considerable flexibility in defining the division between opex, non-operational capex and network capex. For example, the repair of underground cables and meter recertification costs have been variously defined by the PESs. In addition, some items of non-operational capex, e.g. expenditure on IT systems, are provided by third party contractors rather than by the PES itself, further distorting the raw data provided by companies. As a result, several items were reclassified from network capex to opex (e.g. repairs, metering and non-operational IT depreciation) and project IT depreciation was removed from opex

- The PESs displayed significant differences in their corporate structures and cost allocation procedures. Historically, accounting guideline CSC194 had been used to define the allocation of costs between distribution, supply and other activities. However, this often resulted in a somewhat arbitrary cost allocation.

- Ofgem therefore asked its consultants to implement an allocation system based on usage that was consistent with proposals for separating out the distribution businesses of the PESs. This resulted in the following adjustments:

- Advertising and marketing: These costs were allocated entirely to the supply business unless they demonstrably related fully to distribution activities, e.g. publication of tariff leaflets.

- Customer records and services: The costs of maintaining records were allocated entirely to supply, with service costs divided between distribution and supply according to the number of contacts received in relation to each activity. (Contacts regarding metering were allocated to the supply business due to proposals to move meter reading to this side of the business.)

- Billing: Billing costs were allocated predominantly to supply, with a maximum of £0.5m per annum attributable to distribution.

- Metering: Metering costs were allocated to the supply business, in line with proposals to move metering to the supply side of the business.

- Corporate: The allocation of corporate costs was based on turnover, historic cost operating profit, employee numbers and historic cost net assets, with equal weight attached to each. This resulted in around 2/3rds of corporate costs remained with the distribution business for the RECs and around 1/3rd for the distribution businesses of the Scottish PESs. Formerly, the allocation was based on salaries and net assets, resulting in around 90% of corporate costs being allocated to distribution.

<u>Standardised controllable opex</u>

Further adjustments to the data were then made in order to make them more comparable. In particular:

- Data management services (DMS): one-off costs associated with provision of DMS and the opening of the franchise supply market were removed and an allowance was made for ongoing costs associated with DMS.

- Non-trading rechargeables (NTRs): costs associated with work for third parties that are not covered by the price control were excluded. NTRs are a significant element of reported opex but considerable variation between PESs suggesting inconsistencies in reporting prompted the assumption that NTR costs were equal to NTR revenues for all PESs.

- Other one-off costs, e.g. restructuring charges, were removed
- Other services: costs associated with commercial provision of services outside the distribution business were removed
- Provisions: the effects of changes in accounting provisions were removed
- Other: the effects of efficiency measures introduced part way through the base year were annualised and unidentified costs / unexplained cost increases were removed

Base opex: Regional adjustments

The final set of adjustments made reflected regional factors. Only London, ScottishPower and Hydro-Electric were affected in this case. In particular, adjustments were made for:

- 132 kV network: This network is part of the distribution business in England and Wales but part of transmission in Scotland. Analysis of the proportion of costs attributable to the 132kV system, lead to upward adjustments in base opex for ScottishPower and Hydro-Electric.
- Labour costs: An upward adjustment was made to London's based opex to reflect higher average earnings in the London area. The assessment was based on the New Earnings Survey.
- Scottish islands: Following feedback from the PESs, a £2m adjustment for Hydro-Electric was added in the final determination to reflect the additional costs associated with serving Scottish islands.

Figure 11: Opex data refinement

Total reported opex	
Subtract:	network depreciation
	network rates
	NGC exit charges
	profit/loss from sale of fixed assets
= Controllable opex	
Adjust for:	capitalisation policy
	allocations and attributions policy
= Adjusted controllable opex	
Adjust for:	data management services (DMS)
	non-trading rechargables (NTR)
	other one-off costs
	other services
	other factors
= Standardised controllable opex	
Adjust for:	regional labour costs
	132kV network in Scotland
= Base opex	

3.1.1.2 Conducting the regression analysis

The regression analysis essentially determined a relationship between base opex (as defined above) and a measure of network scale for the year 1997/98. In order to overcome the problem of having only 14 data points (one per PES), the measure of scale consisted of a composite variable reflecting customer numbers, the number of kWh distributed and network length as set out below.

Composite variable = $(\text{customer nos})^{\alpha}(\text{units})^{\beta}(\text{length})^{\gamma}$, with the restriction $\alpha + \beta + \gamma = 1$

Regression: Base opex = A + B x Composite variable + ε

By rearranging and simplifying the above definition, the composite variable was then expressed as adjusted customer numbers:

Adjusted customer nos = customer nos x [1 +β (δU / U) + γ (δL / L)] [10]

The regression equation therefore becomes:

Base opex = A + B x Adjusted customer numbers + ε

where U is the average value of units per customer and δU is the deviation in the data point value from U; and similarly for L and δL.

The regression was initially run with weights of 70%, 15% and 15% for customer numbers, units distributed and network length, respectively, and the intercept (which can be interpreted as a measure of fixed costs) fixed at £25m on the basis of analysis of the efficient level of such costs. However, following consultation and subsequent analysis, the weights were altered to 50%, 25% and 25% and no constraint was imposed on the intercept. The data points for both Eastern and Southern (the two most cost efficient firms) were excluded from the sample on the basis that they were outliers.

Given bottom-up analysis that basically confirmed the level of the calculated intercept as being an appropriate level of fixed costs, the regression line was then pivoted to pass through both the intercept and the second lowest observation, that of Eastern Electricity, to establish the frontier. The frontier is therefore based on the position of this firm. This approach, rather than altering the intercept and shifting the line vertically upwards under a standard COLS approach, was taken as a result of expert judgment that the fixed costs were higher than COLS would suggest. Consequently, although the analysis was based on a statistical regression, the efficiency frontier finally used appears to have been based on a combination of regression analysis and expert industry judgement. Ofgem's final determination of the efficiency frontier is shown below in Figure 12.

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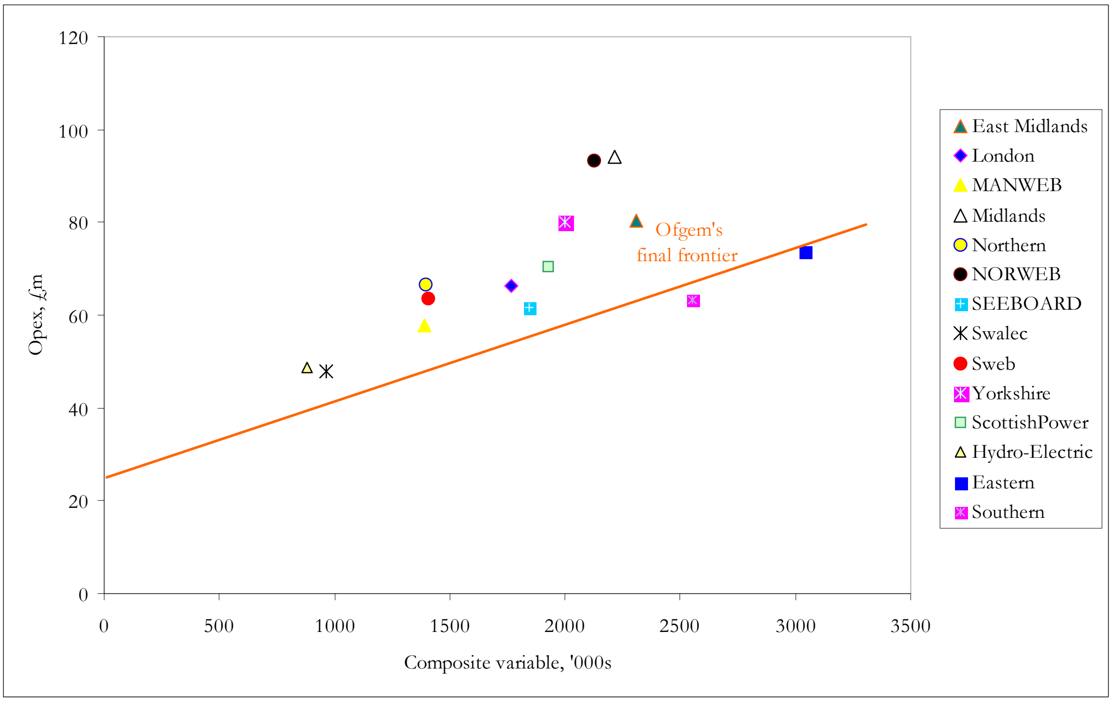
[10] *$\alpha+\beta+\gamma = 1$ implies that composite = (customer nos)×(units / customer numbers)$^{\beta}$×(length / customer nos)$^{\gamma}$*
Define U as average units per customer, L as average network length per customer and δU and δL as the deviations in the data point values from the average . Then the composite variable may be expressed as:
Composite = customer nos x $(U + \delta U)^{\beta}$ x $(L + \delta L)^{\gamma}$
The composite variable is proportional to (composite)/(U.L), which is customer number adjusted for deviation from the average units per customer and line length per customer. Dividing through the above expression by (U.L), this can be expressed as:
Adjusted customer numbers = (customer numbers)$(1+\delta U/U)^{\beta}(1+\delta L/L)^{\gamma}$
which is approximately equal to
(customer nos)$(1+\beta\,\delta U/U)(1+\gamma\,\delta L/L)$)
(as $\beta<1$ and $\gamma<1$, and ignoring second order terms). This can be approximated by
Adjusted customer nos = customer nos x $(1+\beta\,\delta U/U+\gamma\,\delta L/L)$)

Figure 12: Ofgem's final determination of the efficiency frontier



Source: Ofgem data, CEPA calculations

Although there are a number of reasons why a company's costs may diverge from the frontier, including the need for further data refinement and/or misspecification of the cost drivers, further analysis was deemed to suggest that any divergence was predominantly a result of inefficiencies. It is then possible to calculate each PES' degree of inefficiency versus the frontier and so the potential percentage cost saving. The final implied potential opex savings as determined by Ofgem and set out in the 1999 report are shown in Figure 13.

Figure 13: Potential opex savings implied by top-down analysis cited by Ofgem

	Potential opex saving		Potential opex saving
Eastern	0%	SEEBOARD	13%
East Midlands	24%	Southern	-4%
London	19%	Swalec	18%
Manweb	20%	Sweb	27%
Midlands	36%	Yorkshire	30%
Northern	31%	ScottishPower	24%
Norweb	37%	Hydro-Electric	23%
Unweighted average			22%

Source: Ofgem, December 1999

Although the precise methodology behind these final alterations has not been made explicit, what is clear is that the amendments benefited all 14 companies concerned, with the implied potential for opex savings being reduced by 1 - 3 percentage points in each case. The upward shift in the intercept improved the efficiency scores of the smaller companies in particular.

3.1.2 Efficiency study

Ofgem also commissioned consultants to conduct a bottom-up study to assess the efficient level of base year (1997/98) opex theoretically achievable by each distribution business based on the application of best practice. The analysis was then used to identify potential opex savings in each case. Data were collected primarily through the business plan questionnaire, with follow up meetings arranged with the PESs to clarify particular issues.

In particular, the analysis included:

- An examination of the underlying cost reductions since 1994/5 and the methods used to achieve these: the four best performing PESs achieved savings in engineering costs of up to 40% over the period.
- The benchmarking of costs associated with the main distribution activities:
  - Engineering costs: these form the majority and include network repairs and maintenance, system control and non-capitalised planning and construction. Various benchmarks were established based on best practice and the costs of the best performing companies. For instance, cost / network km benchmarked at £575/km. The engineering costs for each PES were also calculated based on profile of network assets and using best practice cost/asset.
  - Meter operation (including repair and maintenance, meter recertification and meter changes): A PES-specific benchmark has been set for metering following

feedback from the consultation process. The initial approach was to set a benchmark of £2.30/customer/annum was determined on the basis of the average costs of the better performing PESs.

- Corporate and administrative functions: A benchmark of £7m/annum was determined, again on the basis of the average costs of the better performing PESs.
- Customer service: initially no benchmark was calculated for customer service opex as the costs allocated to the distribution business were small. However, following consultation, Ofgem introduced a customer service and billing benchmark of £1.50/customer/annum.

Each component of the analysis resulted in an estimated range of the efficiency savings achievable by each PES. These were then combined to give an overall level of opex savings per company.

- Supporting analysis of human resource and IT costs: Sickness and overtime rates, pay rates versus the New Earnings Survey and IT costs were all benchmarked to support the analysis conducted on engineering costs.

However, further adjustments were made to the analysis on the back of feedback from the PESs that using the best performers in each activity as a benchmark was unrealistic due to differing approaches to providing data under the BPQ. These included: allowing PESs that beat the established benchmarks credit; adjusting for meter reading costs; and the assumption that NTR costs were equivalent to revenues.

Having established the 'efficient' level of costs for each PES, the potential savings for each were calculated. These ranged from –1% for Southern Electricity and 41% for Norweb and averaged 25%.

3.1.3 Final determination

Although the efficiency study generally led to slightly higher estimates of potential opex savings than Ofgem's top-down analysis, the two approaches were broadly consistent (Figure 14).

Figure 14: Final Ofgem efficiency rankings

	Opex efficiency ranking based on Ofgem's top-down	Opex efficiency ranking based on efficiency study
1	Southern	Southern
2	Eastern	Eastern
3	SEEBOARD	SEEBOARD
4	Swalec	Hydro-Electric
5	London	ScottishPower
6	Manweb	Swalec
7	Hydro-Electric	East Midlands
8	East Midlands	Manweb
9	ScottishPower	London
10	Sweb	Sweb
11	Yorkshire	Midlands
12	Northern	Yorkshire
13	Midlands	Northern
14	Norweb	Norweb

Source: Ofgem, December 1999

It was Ofgem's view that all PESs could be expected to move towards the efficiency frontier over the 1999-2004 control period, and that efficient companies should be allowed to retain the benefits of any out-performance during the control period. The August consultation paper put forward two possible approaches to determining allowable opex costs based on the above analysis, establishing an upper and a lower band, both of which assumed that all firms would reach the efficiency frontier over the 7-year period to the end of the 1999 PCR. The lower allowance also assumed a shift in the efficiency frontier of 1% per annum from 1998/99, based on the forecast improvement in productivity for the UK economy as a whole (2.5%) but taking into account assumed electricity load growth of around 1.25%.

However, it was argued that some firms may not be able to achieve the frontier and that the long glide path potentially enabled inefficient firms who cut costs rapidly to realise higher returns than efficient companies. Consequently, in its final determination, Ofgem took a conservative approach to determining each company's inefficiency versus the frontier and the degree of catch-up to be achieved by high cost companies. Ofgem determined that allowable opex should decline by an average of 2.3% per annum, based on:

- The lesser potential reduction implied by the efficiency study and regression analysis, with high cost firms moving only ¾ of the way to the frontier by 2001/02 and then retaining that position relative to the frontier thereafter.

- A £3m per annum allowance for each PES for asset management IT systems
- A £1m per annum allowance for each PES for ongoing costs in consideration of proposals for business separation
- An allowance for each PES for one-off costs which reduces to zero by 2002/03

In addition, each PES received a separate allowance for DMS work and for any adjustment to the licence fee payable by distribution businesses.

3.2 Assessment of the 1999 approach

While the final efficiency frontier determined by Ofgem for the 1999 DPCR cannot be said to be based on a recognised academic method, it does represent a combination of frontier analysis and industry expert judgement. As such, the adjustment of the estimated intercept with reference to industry judgement and the removal of the most efficient firm from the analysis on the basis that it was an outlier appear robust. However, due to the lack of transparency about the final adjustments made to the methodology and data, we were unable to replicate the results precisely.

Our comments in the remainder of this section focus on the regression methodology itself, as set out in the Ofgem consultation documents.

Given the limited amount of reliable data available to Ofgem, the selection of a regression-based approach to the top-down analysis is appropriate. Nevertheless, we have a number of concerns regarding the precise methodology, several of which are examined further later in this study. In particular:

- ***Adjustments to raw data***: It would appear that alterations were made to the data used for the analysis in the final stages of the 1999 DPCR. While we accept that these were based on expert industry judgement and that a pragmatic approach towards the setting of X factors is both necessary and desirable, such alterations introduce a degree of endogeneity into the results. The rationale for the changes was also not made explicit.
- ***Determination of weights***: The precise rationale behind the final level of the weights on the components of the composite variable has not been made explicit. Criticisms have therefore arisen that their determination was somewhat arbitrary (e.g. T G Weyman-Jones, 2001).
- ***Determination of frontier***: The regression methodology involved a pivot in the OLS regression line rather than the vertical shift that is standard under COLS methodology. Neither approach can be said to result in a more accurate assessment of the frontier. The decision to pivot the line rather than shift it appears to have arisen as a result of expert judgement that the inefficiencies in opex are embedded in both fixed and variable costs – an assumption that we believe to be realistic.

- ***Reliance on the position of Eastern***: The Ofgem frontier relies heavily on the position of Eastern. However, the decision to use the second-most efficient firm based on expert industry judgement that the most efficient frontier was an outlier appears robust and has the effect of increasing the efficiency scores for all firms.

- ***The use of a purely domestic data set***: The methodology used relies on the data set actually containing a firm that operates on the efficiency frontier. This may well not be the case. Including international distribution firms in the sample increases the chances of including a frontier firm in the group and widening the options for benchmarking methodologies. Although international benchmarking does raise issues of data comparability, with ownership of electricity distribution becoming increasingly international, the rationale for including foreign companies in the data set is rising.

- ***Benchmarking of opex***: Benchmarking opex alone – or any other individual component of total cost – raises two concerns. First, it may introduce the possibility of regulatory gaming in that firms substitute capex for opex and, second, it may mean that some important effects are not being captured. For instance, a firm that looks inefficient on opex may be relatively efficient in terms of total expenditure performance, or vice versa. This is explored further in section 8.1

- ***Subsequent developments***: In retrospect the changes in operating costs across firms have not been as the 1999 analysis would suggest. Firms operating significantly away from the frontier would have been expected to have shown greater improvement in operating efficiency than their counterparts operating close to the frontier in 1999, resulting in convergence in efficiency scores. This does not appear to have been the case from the 2001/02 data (section 4) and may suggest that the frontier was not correctly defined. However, there are a wide variety of factors that affect a firm's ability to reduce costs.

- ***Explaining outliers***: There were firms that exhibited very different efficiency scores from their peers, and it is possible that there were good engineering reasons for this. It does not appear that any investigative analysis was undertaken to establish whether this were good reasons for the diversity.

4. APPLYING THE 1999 METHODOLOGY TO 2001/02 DATA

The first step in our analysis involved applying the 1999 regression methodology (section 3) to the 2001/02 data. This provides an initial view of the improvements that the firms have made in terms of opex efficiency since 1997/98 and the implications for new benchmarks should the 1999 methodology be utilised.

4.1 The data

The data used for the analysis was that provided by Ofgem and derived from 2001/2 regulatory accounts. Small amendments were made to the base opex figures for London, Scottish Hydro-Electric and ScottishPower to be consistent with the regional adjustments described in section 4[11]. The base opex data for 2001/02 is thought to be broadly representative of the true position of the DNOs but has not been 'cleaned' to the degree that the 1997/98 data has. We understand that data used for the 2005 DPCR will, however, be constructed so that it is fully comparable across companies. Due to the preliminary nature of the 2001/02 data used in this analysis, the underlying data have not been reproduced here at Ofgem's request.

The data suggest that all companies have shown some movement towards the frontier since 1997/98. Indeed, on average the distribution companies have outperformed the expected reduction in opex between 1997/98 and 2001/02 (20% reduction versus targeted 16%, unweighted average). The degree of improvement has differed markedly across firms, though, and the data suggest that opex performance is now more disparate than it was in 1997/98.

Theoretically, those firms furthest from the frontier in 1997/98 should have shown the greatest improvement, resulting in a degree of convergence in the data. In practice the trend has been different; with one of the firms closest to the frontier in 1997/98 showing the greatest improvement, whilst one of the 'worst' performing firms in 1997/98 is now some distance behind the pack having shown little improvement over the period. As can be seen in Figure 15, there are several firms for which the targeted improvement was very different from the actual, giving rise to concern about the direct use of this methodology to set efficiency targets.

Increases in measured efficiency could be a result of increases in scale as well as reductions in opex. However, in setting the X factors Ofgem is implicitly targeting a reduction in opex.

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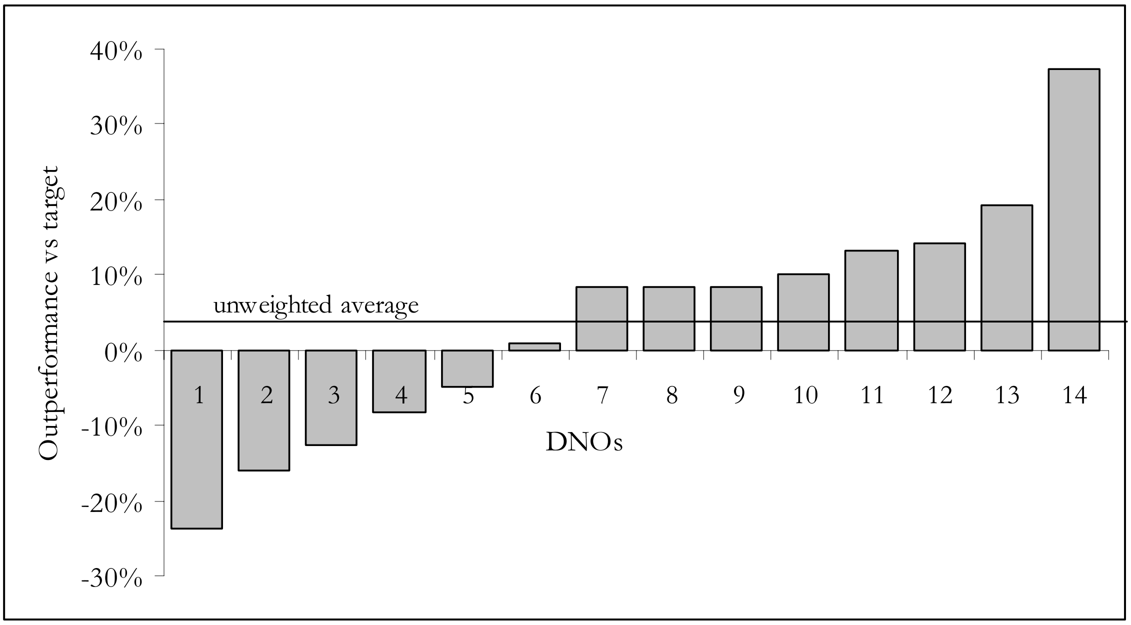
[11] *The regional adjustments applied to the 1997/98 data were applied to the new data but uplifted for inflation.*

Figure 15: Out-performance of opex efficiency improvement targets, 1997/98 – 2001/02



Source: Ofgem data, CEPA calculations

One possible cause of this increased dispersion may be regulatory gaming. In particular, as a result of merger activity there are now only 8 independent DNO groupings, increasing the scope for companies to allocate costs amongst themselves to achieve the most favourable opex benchmarking outcome for the group. Further analysis on the impact of mergers is contained in section 8.3.

4.2 Methodology

In our initial application of the 1999 methodology to the new data, we have followed the method used as closely as possible, and in particular have:

- Used the same composite scale variable (with weights of 50%, 25%, 25% on customer numbers, units distributed and network length).
- Used linear regression techniques;
- Used a freely-determined intercept; and
- Pivoted the regression line through the second most efficient company to establish the frontier.

A key issue, though, is the treatment of outliers. In 1999, two outliers – Eastern and Southern, the two most efficient companies – were excluded from the calculation of the regression line. Our analysis shows that the results are sensitive to the treatment of outliers and so we set out four scenarios:

- Inclusion of all data
- Exclusion of one outlier
- Exclusion of the most and least efficient outliers
- Exclusion of the two most efficient outliers

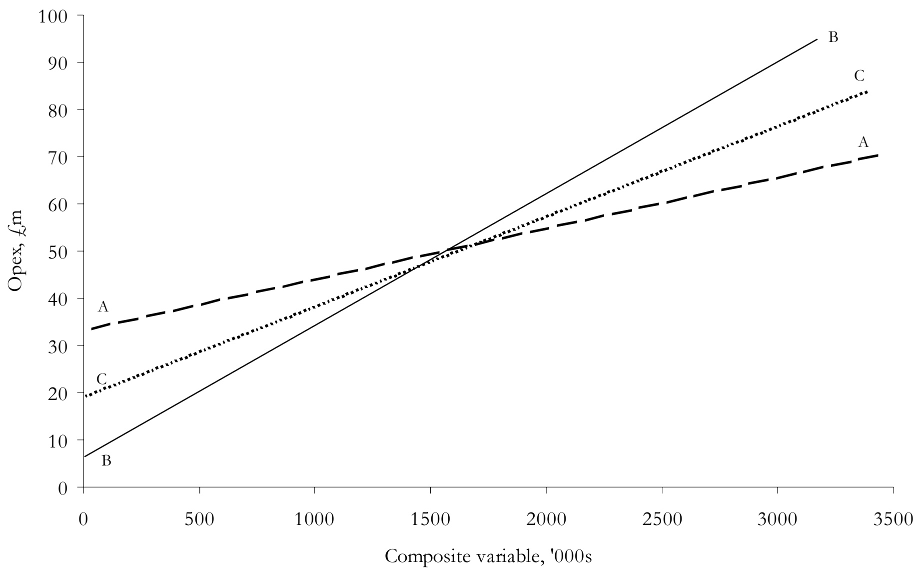
We therefore started by running four linear regressions, one for each of the scenarios detailed above, with the intercept freely calculated, the weights of the composite variable as in the 1999 methodology and the frontier being drawn through the second most efficient firm. The implied potential opex savings where then calculated for each firm.

The results of the analysis are set out below.

4.3 Results

Figures 17 and 18 summarise the results of the initial linear regressions detailed above. The full results are provided in Annex 5.

Figure 16: Regression lines, 2001/02 data



AA – All 14 firms; BB – ex. two most efficient outliers; CC – ex. most and least efficient outliers

Source: CEPA calculations

Figure 17: Summary results table

	All 14 firms (AA)	Ex. most efficient firm	Ex. two most efficient firms (BB)	Ex. most and least efficient firms (CC)
Calculated intercept	32.8	16.1	6.6	19.5
R-squared	0.23	0.54	0.69	0.62
Standard error	14.45	11.51	9.93	8.69
Firm defining efficiency frontier	A	B	B	A
Implied potential efficiency improvement, unweighted average	22.4%	15.0%	20.8%	15.1%

Source: CEPA

As can be seen from Figure 18, both the value of the intercept and the efficiency scores are sensitive to the treatment of outliers. Given that, broadly speaking, the intercept represents an estimation of the level of fixed costs the model used should ideally have an intercept that is deemed to be in line with an engineering assessment of the level of fixed costs. (A study conducted for the 1999 review estimated fixed costs to lie in the region of £20-25m per firm.) An intercept of as low as 7 or as high as 33 may therefore be difficult to justify economically. It is also clear that the intercept used should bear some relation to that used in the previous price control period unless there is reason to believe that the nature of economies of scale has altered radically over the last four years or that the original rationale of an IRS approach was flawed.

With respect to the efficiency scores, it is clear that the resultant estimated potential for opex improvement varies considerably across companies, far more so than under the 1999 review, reflecting the increased dispersion amongst the data points discussed in section 4.1 above. This raises questions about the appropriateness of the methodology, in particular the selection of cost drivers and the benchmarking of opex.

4.4 Conclusions

The concerns regarding this methodology reflect those outlined in section 3.3 concerning 1999 methodology. However, the increase in the disparity between companies since 1997/98 highlights two issues in particular:

- First, it highlights some of the problems associated with a small data set, particularly a data set comprising purely domestic comparators. Most frontier methodologies, including COLS, assume that the data set includes an 'efficient firm'. In the absence of rapid technological progress in the global electricity distribution industry between 1997/98 and 2001/02, the considerable improvement of one of those firms closest to the frontier in 1997/98 over the period suggest that it was actually at least some distance away from the 'true' frontier in 1997/98.

- Second, the marked divergence in company performance – for example, the failure of one of the 'worst' performers in 1997/98 to show significant improvement despite the incentives on it to do so and the substantial improvement of one of the firms closest to the frontier – raises the question of whether there are factors that affect company performance that have not been taken into consideration. In other words, there is a need to assess the appropriateness of the cost drivers used and the choice of the benchmark variable. These issues are explored further in sections 7 and 8, respectively.

5. The Implications of Using Alternative Methodologies

This section assesses the implications of utilising alternative benchmarking methodologies. For this analysis, the independent variable – customer numbers, units distributed and network length -and benchmark variable – opex – are as for the 1999 methodology.

The techniques assessed are:

- COLS
- SFA
- DEA
- TFP
- Malmquist productivity indices

A technical discussion of these techniques are contained in section 2.2.

5.1 Corrected ordinary least squares (COLS)

This section presents the results and conclusions on the use of COLS, with opex as the dependent variable and the composite variable (with 1999 weights) as the independent variable. The 1999 methodology used a linear regression form. Our analysis here is again focused on the linear form (section 5.1.1). However, we briefly present results and conclusions on the use of a quadratic regression form (section 5.1.2).

5.1.1 Linear form

The difference between this approach and that performed in 1999 concerns the 'correction' of the estimated OLS line. Under the 1999 methodology the line was pivoted rather than shifted, meaning that the intercept remained at the level estimated by the OLS regression but that the slope altered.[12] Under COLS the estimated regression line is shifted vertically so that it passes through the frontier firm – in this case deemed to be the second most efficient firm (as in the 1999 methodology). The intercept therefore changes from the level estimated in the OLS regression but the slope remains unchanged.

As for our replication of the 1999 methodology, we ran the COLS analysis for four scenarios:

- Including all data
- Excluding one outlier

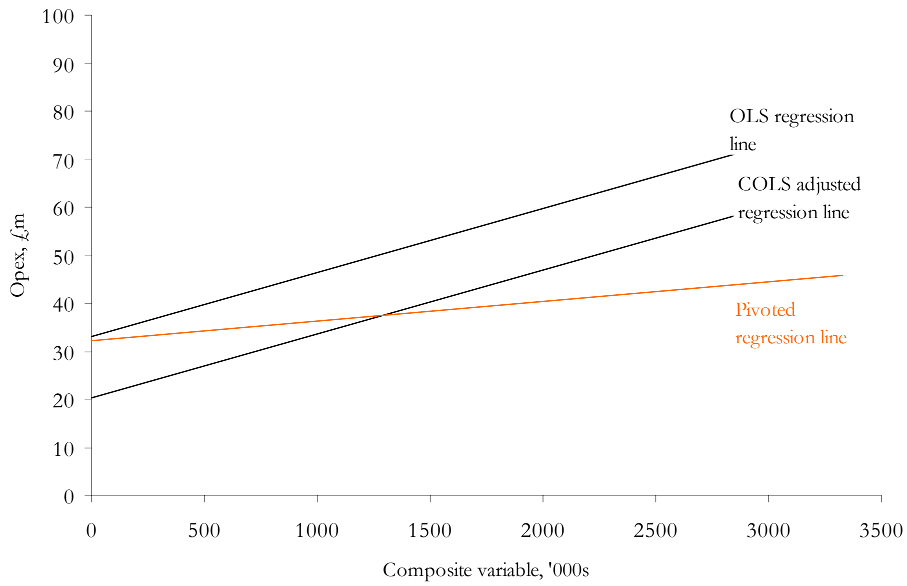
[12] *It should be noted that in the final top-down analysis Ofgem moved away from the regression analysis as described in section 3.*

- Excluding the most and least efficient outliers
- Excluding the two most efficient outliers

The OLS line calculated in each case is identical to that calculated in section 3. However, the calculated frontier differs due to the differing approach to shifting the OLS regression line to obtain the frontier. The vertical shift under COLS means that in all cases, except where all 14 data points are included in the analysis, the intercept falls to a level that is inconsistent with the view that fixed costs lie in the region of £20-25m per firm. Indeed, when the two most efficient firms are excluded from the data set the intercept becomes negative. Such an efficiency frontier would be difficult to reconcile with reality.

We therefore only show the results for COLS using all 14 data points. Figure 18 below shows the estimated OLS regression line, COLS adjusted frontier and pivoted frontier (as under the 1999 methodology) for the 2001/02 data using all 14 data points. The implied potential efficiency gains given the COLS efficiency frontier are out in Figure 19. Detailed results for the COLS analysis are provided in Annex 5.

Figure 18: COLS regression, 2001/02 data, all firms



Source: CEPA

Figure 19: Summary results table, 2001/02 data, COLS, all 14 firms

OLS intercept	32.8
Corrected intercept	21.7
R-squared	0.23
Firm defining efficiency frontier	A
Implied potential efficiency gain, unweighted average	16.3%

Source: CEPA

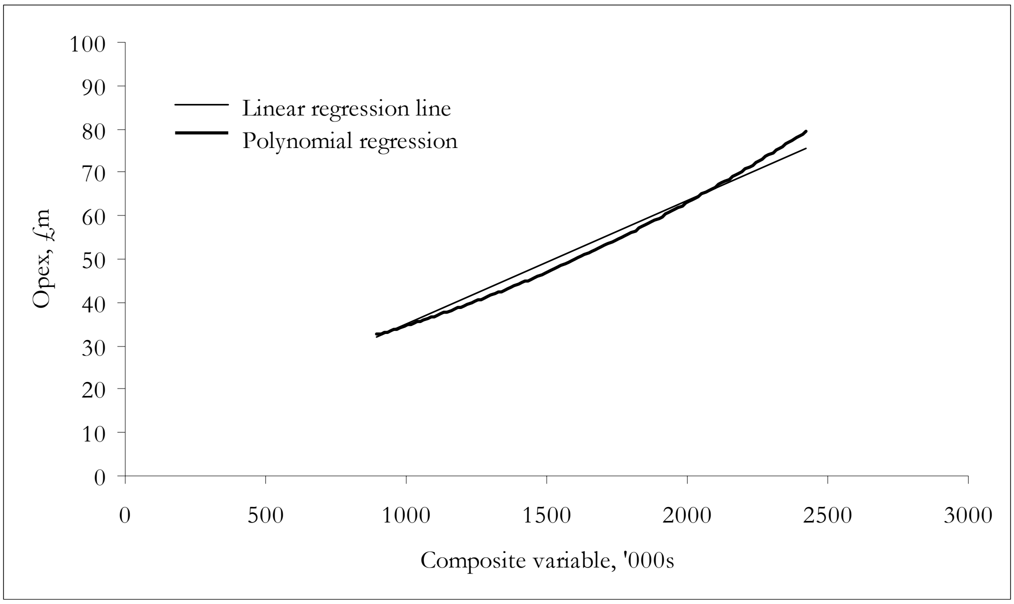
5.1.2 Polynomial form

The use of a polynomial regression function can often provide a better fit to the data set and take into account (dis)economies of scale. Indeed, as can be seen in Figure 20, the use of a quadratic function of the form

$y = Ax^2 + Bx + C$

provides a better fit to the data than the linear form; and the efficiency scores of the least efficient firms in particular would be improved by such an approach.

Figure 20: A quadratic function can improve the fit to the data



Data excludes two most efficient firms

Source: CEPA

5.1.3 Assessment

Given the limited data available to Ofgem, regression analysis provides an appropriate framework for benchmarking, although whether the regression line should be pivoted or shifted is open to debate. The advantage of using COLS over the pivoting methodology used in the 1999 DPCR is that the form of the shift conforms to standard econometric theory and practice. It also results in a more realistic slope to the frontier than occurs under the pivoting methodology, which results in high increasing returns to scale (for which there is little empirical evidence).[13] However, shifting the curve rather than pivoting it implies that all cost inefficiency is embedded in fixed costs – an assumption that would appear to be unrealistic.

Of the four linear regressions conducted, our preference would be to focus on the first, i.e. including all 14 firms. The reasons for this are:

- First, it is preferable to include all the data points in the analysis as this removes the need to make a decision with respect to the removal of outliers;
- Second, the resultant shifted intercept conforms to the view that fixed costs lie in the region of £20-25m / annum;
- Third, several firms lie close to the frontier, raising confidence in the results.
- However, due to the considerable dispersion in the data, the analysis is not particularly robust to the removal of outliers.

With respect to the polynomial form, there are two issues that need to be considered here: first, whether diseconomies of scale should be explicitly allowed for; and second, the expected stability of the fitted curve over time.

It is our view that Ofgem should not explicitly allow for diseconomies of scale as, should they be prevalent, large firms should be encouraged to mimic more efficient smaller firms by disaggregating their activities appropriately. Further, polynomial frontiers have a tendency to exhibit a high degree of instability over time vis-à-vis their linear counterparts. Consequently, we do not believe that polynomial COLS provides a suitable methodology for efficiency benchmarking in this case.

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[13] *As discussed in section 5, there may be a rationale for using CRS rather than VRS as assumed in the standard COLS model. However, with only 14 data points, we do not have sufficient data to impose a CRS restriction as there are insufficient degrees of freedom to produce robust results.*

5.2 Stochastic frontier analysis (SFA)

SFA is another econometric approach to estimating the efficiency frontier (section 2). However, despite its theoretical advantages over COLS, it has proved difficult to implement in practice, particularly with limited data. This section details the results and conclusions on the use of SFA on the 2001/02 data as provided by Ofgem.

Due to the general instability of SFA results in practice, SFA runs were conducted using both opex and a measure of total expenditure (totex) as the dependent variable. A full definition and further discussion of totex are provided in section 8.1. In each case, the independent variable was the composite variable as in the 1999 methodology. Details of four runs are set out in Figure 21 below.

Figure 21: Specification of SFA runs

	Dependent variable	Independent variable	Error distribution for noise term
1	Opex	Composite variable	Truncated normal
2	ln (Opex)	ln (Composite variable)	Truncated normal
3	Totex	Composite variable	Truncated normal
4	ln (Totex)	ln (Composite variable)	Truncated normal

The implication of using natural log functions rather than the straight data is to alter the shape of the estimated frontier. However, this means that the results obtained are not directly comparable to those of the 1999 methodology.

Only one of the four runs actually provided a reasonable result – SFA using log forms and a truncated normal distribution for the noise term. (The results are provided in annex 5.) In the other three cases, almost all firms were placed on the frontier. In other words, all the disparity in opex performance between firms was fully attributed to noise. We can reject such results as it is clear that the most efficient firm's improved performance since 1997/98 is not purely due to noise in the data.

5.2.1 Assessment

Although one of the SFA runs provided apparently reasonable results that ranked the companies broadly in the same order as the 1999 methodology, we would not recommend that SFA is an approach utilised for Ofgem's benchmarking analysis going forward. The reason for this is that the lack of data available for analysis is likely to mean that the method is unreliable. Specifically, it is far from certain whether running the above methodology on a new data set for 2002/03 or other years would produce reasonable results. Indeed, the experience of the Dutch regulator, DTe, is a case in point. DTe stated that it would assess the use of SFA as part of its benchmarking process. However, in the event the results obtained were unstable and the technique had to be dropped, giving rise to considerable criticism from stakeholders. (DTe February 2000)

5.3 Data envelopment analysis (DEA)

As discussed in section 2.2, a key advantage of DEA is that the weights on the output variables - customer numbers, units distributed and network length – do not need to be specified as under regression analysis. Instead the technique calculates the optimum set of weights for each individual firm. Consequently, DEA analysis uses data for the individual components of the composite variable rather than the composite itself.

We ran the DEA analysis with a single input variable – opex – and three output variables – the components of the composite. Summary results of the DEA run, considering both constant and variable returns to scale, are provided in Figure 22.

Figure 22: DEA summary results – opex

	All 14 firms		**Ex. most efficient firm**	
	CRS	**VRS**	**CRS**	**VRS**
Efficiency scores – unweighted average	61.3%	77.4%	78.4%	84.8%
Standard deviation	29.3%	17.2%	19.7%	14.4%
No. firms defining frontier	1	2	2	4

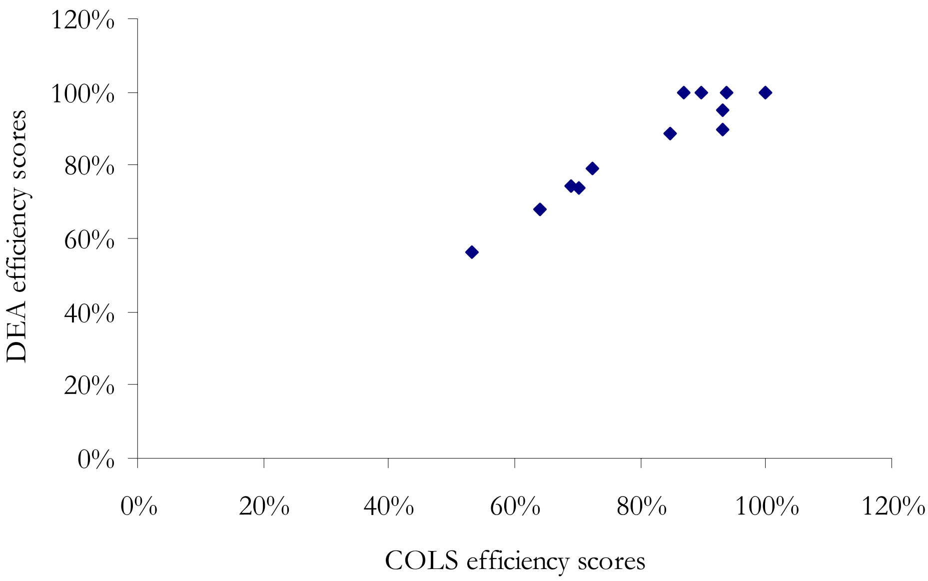
Source: CEPA

As can be seen from the above table, the DEA analysis again results in a high degree of dispersion in DNOs' implied potential efficiency savings (1-efficiency score). Under the CRS formulation, the most efficient firms display 'super efficiency' in that they could increase their level of opex significantly and still define the frontier. Excluding the most efficient firm improves the efficiency scores of all firms and two firms now determine the frontier. Applying a VRS assumption – which is appropriate if scale is not deemed to be a choice variable for firms (see below) – effectively imposes a restriction on the data and so the number of firms defining the frontier rises.

5.3.1 Assessment

One of the key drawbacks of the DEA methodology is that it is difficult to assess the significance of the results without comparing them to the results obtained using other techniques, e.g. COLS. COLS assumes VRS and so the relevant comparison here is between the COLS results and the VRS results excluding the most efficient outlier (as the COLS methodology used assumes that the frontier passes through the second most efficient firm). The correlation between the efficiency scores under each methodology is illustrated in Figure 23.

Figure 23: DNO opex efficiency scores under COLS and DEA



Source: CEPA

As can be seen from the chart above, the results obtained from the two methodologies are comparable. However, the rationale for using VRS as opposed to CRS is not clear. First, the empirical analysis provides weak evidence for increasing returns to scale (IRS) in electricity distribution; and second, allowing for IRS is not in consumers' interests as it basically rewards small companies that have scale inefficiencies and enables merging firms to capture all the gains from merger[14]. Consequently, assuming that firms are free to merge, a CRS assumption may be more appropriate.

Assessing the reliability of the DEA CRS results is complex. It is not possible to compare them to the results of COLS analysis as the limited size of the data set means that there are insufficient degrees of freedom to implement a CRS restriction on the COLS regression. Consequently, an assessment of the robustness of the DEA results relies on an assessment of whether the implied change in scale required for each firm to achieve the efficiency frontier is realistic and whether the firms' efficiency rankings are broadly as would be anticipated. It should be noted that due to the additional restriction added to the DEA model under CRS, the efficiency scores for some firms are materially impacted by the use of CRS. Similarly, excluding the most efficient firm from the analysis has a significant impact on some firms. (Section 2.2)

[14] *Ofgem's merger policy introduced in 2002 (annex 2) goes some way to redressing this latter problem but imposes a standardised level of costs on merging firms unrelated to firm size.*

Overall, we believe that DEA is a theoretically appealing benchmarking technique that is easily and practical to implement and that increases flexibility with respect to the treatment of weights of the independent variables and CRS / VRS compared to COLS. However, it cannot be relied upon in isolation due to the difficulties in assessing the significance of the results obtained.

5.4 Total factor productivity (TFP)

The TFP methodology basically calculates the improvement in productivity of all factors over the specified time period. Consequently, using a partial cost measure such as opex is not appropriate and so, in contrast to the analysis above, we examine totex in this section.

The TFP indices, using the Tornqvist methodology (section 2.2), are set out in Figure 24. As can be seen from the table, all the firms have improved their TFP over the period 1997/98 – 2001/02 through a combination of reducing input costs and raising output; though again there is significant variation in performance.

Perhaps the most interesting aspect of the results is that those firms that have displayed only limited improvements in opex performance despite being some way from the frontier have generally shown good improvements in TFP over the period. This suggests that examining opex efficiency alone may unfairly penalise some companies.

5.4.1 Assessment

Arguably, X-factors should ideally be set in line with the average TFP index for some external benchmark industry in the long run (section 2.2). However, this requires that there is a high degree of convergence between firms' performance. Given that this has clearly not been achieved in UK electricity distribution as yet, Tornqvist indices are not appropriate for setting the X factors directly. It is, however, worthwhile to monitor change in Tornqvist indices to assess when sufficient convergence has occurred for them to be used directly in determining price controls.

Figure 24: Tornqvist indices, 1997/98 - 2001/2, totex

Rank	Output quantity index	Input cost index	Tornqvist index[15]	Av. annual TFP improvement, 1997/98-2001/02
1	1.03	0.84	1.22	5.2%
2	1.02	0.84	1.21	4.9%
3	1.02	0.85	1.20	4.7%
4	1.04	0.88	1.17	4.1%
5	1.03	0.88	1.17	4.0%
6	1.04	0.90	1.17	3.9%
7	1.03	0.89	1.16	3.8%
8	1.07	0.92	1.15	3.6%
9	1.04	0.92	1.13	3.2%
10	1.06	0.95	1.11	2.7%
11	1.05	0.97	1.08	2.0%
12	1.05	1.00	1.05	1.3%
13	1.07	1.03	1.04	0.9%
14	1.02	0.99	1.04	0.9%
Unweighted average	1.04	0.92	1.14	3.2%

Source: CEPA

5.5 Malmquist indices

Malmquist indices are another way of tracking productivity over time. However, the key advantage over the TFP approach is that the Malmquist index does this with reference to a particular production technology, and so can be used to decompose the efficiency gains into catch-up and frontier shift components.

We have calculated the Malmquist indices for both opex and totex and examined the split between the catch-up and frontier shift components. We have used the change in the frontier based on COLS analysis of opex and totex to decompose the index.

[15] *Tornqvist index = output quantity index / input cost index*

5.5.1 Opex

The Malmquist indices for opex (Figure 25) are instructive in assessing firms' changes in performance between 1997/98 and 2001/02. They suggest that between 1997/98 and 2001/02, all but one of the DNOs have fallen further behind the frontier, and the extent of the relative underperformance versus the frontier varies considerably across firms.

Figure 25: Malmquist indices, 1997/98-2001/2, opex – summary results

Opex	Malmquist index	Catch-up	Frontier shift
Unweighted average	1.27	0.79	1.63
Standard deviation	0.17	0.13	0.13

Source: CEPA

The extent of the move in the frontier highlights concerns about using a single firm to define the frontier, and whether opex is indeed the appropriate variable to benchmark.

5.5.2 Totex

Again the indices show that all firms improved their totex efficiency over the period and, although there is significant variation between firms, the dispersion is less marked than under the opex measure. In particular, the indices suggest that firms that appear to have improved little in terms of opex efficiency over the period despite being a considerable distance from the frontier, have actually performed relatively well with respect to totex.

With regards the split between catch-up and frontier shift, the results are slightly more positive than those presented for opex. Although the majority of the improvement in totex performance is attributed to frontier shift, firms have more or less kept pace with the frontier and, in some cases, outperformed it slightly.

Figure 26: Malmquist indices, 1997/98 - 2001/2, totex – summary results

Totex	Malmquist index	Catch-up	Frontier shift
Unweighted average	1.13	1.00	1.14
Standard deviation	0.06	0.04	0.05

Source: CEPA

5.5.3 Assessment

In general, the Malmquist is useful, because it can quantify the decomposition of efficiency improvements into frontier shift and catch up. The analysis reported here does highlight the concern about the use of opex or totex as the benchmark variable, and the use of a single firm to define the frontier.

5.6 Conclusion

The analysis reported here has demonstrated that there is a value to using different techniques to inform judgements about the efficiency frontier. It has, however, highlighted concerns about the variable that should be used to benchmark firms, and in particular whether opex or a definition of totex should be used. The wide and increasing dispersion in performance raises the question as to whether there is something not captured by the techniques as applied so far. These issues are addressed in the following sections.

6. Assessing the Composite Scale Variable

A firm's level of costs is clearly dependent on its scale and so should be taken into account when benchmarking costs. In the 1999 DPCR Ofgem chose to use a composite scale variable composed of customer numbers, units distributed and network length (defined below). To the extent that DNOs' Universal Service Obligations (USOs) mean that the scale of operation is exogenously determined, this is entirely appropriate. However, it should be noted that, at the margin, a DNO's ability to influence sales via its pricing strategy may mean that the use of a sales variable (specifically units distributed) as a cost driver may incentivise DNOs to load charges onto fixed costs and price marginal sales at marginal cost in order to maximise its scale variable.

In this section we assess which measures of scale are likely to be appropriate in the case of the UK electricity distribution sector and how these should be incorporated into the benchmarking process given the limited availability of data.

Figure 27: Composite scale variable used in DPCR3

Composite variable = (customer numbers)$^{\alpha}$(units distributed)$^{\beta}$(network length)$^{\gamma}$, with the restriction $\alpha + \beta + \gamma = 1$

The weights chosen for the final determination were: α=50%, β=25% and γ=25%, reportedly on the back of negotiations with the distribution companies.

6.1 Approach

We have conducted an analysis of the sensitivity of the efficiency frontier (using the 1999 methodology) and the implied potential efficiency savings to alterations in the weights attached to the components of the composite variable. We consider the implications of using the initial weights determined by Ofgem in the May report (70%, 15%, 15%), utilising a two-variable composite, i.e. attaching a 0% weight to one of the variables, and of using a single scale variable cost driver, i.e. attaching a 0% weight to two of the component variables. Finally, we assess the implications of using the average weights suggested by DEA analysis.

As noted in section 2.2, it is possible to recover the weights calculated by DEA programme. These weights reflect the production technology calculated by DEA for the average firm, thus reflecting the diversity between firms. DEA calculates the most generous weights for each firm individually. The DEA analysis conducted for the 2001/02 data using opex as the input variable, the three components of the scale composite variable as the output variables and all data points with CRS suggested average weights for the component variables as shown in Figure 28.

Figure 28: Average weights chosen by individual firms within DEA analysis

Variable	Weight
Customer numbers	21%
Units distributed	43%
Network length	36%

Source: CEPA

The analysis involved four stages:

- First a correlation matrix was compiled to assess the correlations between the three components of the composite variable.
- The efficiency scores and implied potential efficiency savings were then calculated for each company under each of the scenarios for the composite variable described above.
- A correlation matrix was also constructed to assess the correlations between the resultant efficiency scores was compiled to assess the correlations between the results.
- Finally, the results were used to assess whether there is any justification for changing the weights on the components of the composite.

6.2 Results

The correlation matrix for the three components of the composite is provided in Figure 29. The implied potential efficiency scores for each firm under the nine scenarios considered are provided in Figure 30. The firm used to define the frontier in each case (the second most efficient firm) is shown in bold typeface. The correlation matrix showing the correlation between the resultant efficiency scores is shown in Figure 31. More detailed results and the value of the composite index for each company are reported in Annex 7.

Figure 29: Correlation matrix for scale variables

Correlation coefficient	Customer numbers	Units distributed	Network length
Customer numbers	1.00	**0.97**	**0.77**
Units distributed	**-**	1.00	**0.75**
Network length	-	-	1.00

Source: CEPA calculations

Figure 30: Sensitivity analysis to weights on the composite component variables - summary results (2001/02 data, 1999 methodology)

Adjusted customer no. '000s, 2001/02	**1999 methodology – final weights**	**1999 methodology – initial weights**	**2-variable composite 1**	**2-variable composite 2**	**2-variable composite 3**	**Customer no. only**	**Units distributed only**	**Network length only**	**Av. DEA weightings**
Weight on customer no.	50%	70%	0%	50%	50%	100%	0%	0%	21%
Weight on units distributed	25%	15%	50%	0%	50%	0%	100%	0%	43%
Weight on network length	25%	15%	50%	50%	0%	0%	0%	100%	36%
Implied potential efficiency savings									
Unweighted average	20.8%	19.5%	20.3%	21.9%	17.1%	17.4%	18.0%	25.1%	20.6%
Standard deviation	23.4%	22.4%	23.5%	24.7%	20.8%	21.7%	19.2%	21.4%	23.0%

Source: CEPA

Figure 31: Correlation matrix for resultant efficiency scores – methodology and data

Correlation coefficient	1999 methodology – final weights	1999 methodology – initial weights	2-variable composite 1	2-variable composite 2	2-variable composite 3	Customer no. only	Units distributed only	Network length only	Average DEA weightings
1999 methodology – final weights	1.00	1.00	0.98	0.99	0.98	0.99	0.97	0.97	0.75
1999 methodology – initial weights	-	1.00	0.97	0.99	0.99	0.99	0.96	0.97	0.74
2-variable composite 1	-	-	1.00	0.95	0.95	0.99	0.99	0.93	0.83
2-variable composite 2	-	-	-	1.00	0.99	0.97	0.95	0.99	0.74
2-variable composite 3	-	-	-	-	1.00	0.96	0.93	0.97	0.72
Customer no. only	-	-	-	-	-	1.00	0.99	0.96	0.80
Units distributed only	-	-	-	-	-	-	1.00	0.95	0.86
Network length only	-	-	-	-	-	-	-	1.00	0.79
Average DEA weightings	-	-	-	-	-	-	-	-	1.00

Source: CEPA

6.3 Assessment and recommendations

In our opinion and based on the data supplied by Ofgem for the purposes of this study, the composite scale index should consist of two scale variables – units distributed and network length. The rationale for this is threefold:

- As can be seen from Figure 29, the three scale variables contained in the composite are highly correlated, particularly customer numbers and units distributed which can almost be perfectly substituted for one another. It would therefore appear that it is unnecessary to include all three variables in the composite – a view supported by the high degree of correlation between the efficiency scores in each case (Figure 31) - and that either customer numbers or units distributed should be omitted.
- Figure 31 shows that of the two possible appropriate two-variable scale variables (2-variable composites 1 and 2), the first is more highly correlated with the composite with DEA weightings, thus reflecting the underlying average technology. The DEA weights are those that would, on average, show the highest efficiency scores, and so are the most generous for the companies.
- Finally, with the move towards competition in metering, customer numbers are no longer as important a factor in determining the costs of distribution companies.

7. Cost drivers

Efficiency benchmarking in regulated utilities tends to focus on cost rather than production performance as the level of outputs is assumed to be exogenous. Considerable preparation is required in obtaining suitable cost data for benchmarking analysis as, as far as possible, the data must be comparable across companies. Differences in external factors across the comparator group can impact costs in a manner beyond the control of companies. This is particularly important where firms' operating territories are defined (as in the case of the DNOs). Where particular factors can be quantified an explicit adjustment to the cost data can be made. For example, Ofgem made regional adjustments to the opex data in the 1999 review to take account of differences in labour costs and the Scottish 132kV network. Where factors are not quantifiable, the effect must be taken into account via the specification of a cost function, whereby costs are modelled as a function of exogenous variables[16]. These exogenous variables are 'cost drivers', which can be defined as measurable factors that impact costs.

The 1999 methodology used a measure of scale as the sole cost driver (section 6). In this section, we make an assessment of whether Ofgem should consider using additional factors in the specification of the frontier. To do this, we:

- Categorise potential cost drivers into a few high level categories;
- Select appropriate drivers from each category, based on the correlation coefficients with other variables in the category;
- Check that the selected variables do not correlate with each other, to ensure that they do indeed capture different effects; and
- Test the significance of the cost drivers using second stage regression techniques.

7.1 Determinants of costs in distribution

There are a number of ways of categorising cost drivers. We have chosen to categorise them under four key headings that aim to capture the major differences between the DNOs:

- ***Scale***: The composite variable, consisting of customer numbers, units distributed and network length, used by Ofgem aims to capture differences in scale. Other examples of scale variables include service area and transformer capacity.

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[16] *Cost drivers should reflect external conditions rather than variables over which the company has influence (i.e. choice variables). Choice variables reflect how a firm responds to external conditions and so are captured by measures of efficiency / performance.*

- ***Topography and climate:*** Many of these variables, e.g. wind patterns and vegetation cover, are hard to capture. However, they can be proxied through the use of other more readily available variables such as percentage of network underground.
- ***Customer mix:*** The proportion of each type of customer served, e.g. industrial versus residential customers, varies between DNOs. Such differences can be captured by looking at variables such as the percentage of output at each voltage level.
- ***Quality*:** Although Ofgem sets performance standards that must be met by all DNOs, quality of service does vary across companies. Data on factors such as minutes lost can be used to assess differences in quality.

The choice of cost drivers should be based on a full understanding of the cost structure of the industry concerned and consideration of the availability of appropriate high-quality data; although the selection of variables has often been based on precedent[17]. In the case of electricity distribution, an industry that has seen dramatic structural change in many countries in recent years, historical precedent may not be appropriate. Figure 32, taken from Jamasb and Pollitt 2002, shows the range of cost drivers used for efficiency benchmarking in the electricity industry based on a survey of 20 studies.

Differences in scale across DNOs were accounted for in the 1999 DPCR benchmarking methodology via the composite scale variable. The appropriateness of this composite was discussed in section 6. Quality is actually an endogenous variable for companies and so is discussed separately in the following section. The remainder of this section considers whether there are any other cost drivers for the UK electricity distribution industry that Ofgem should be taking into account in its benchmarking methodology to ensure that firms are not treated unfairly.

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[17] *Kaufmann & Beardow 2001*

Figure 32: Frequency of use of main input and output variables used in 20 benchmarking studies of electricity distribution utilities

Input variable (no. of instances used)	Output variable (no. of instances used)
Units sold	
Total (2)	Total (12); Residential (6); Non-residential (6)
Customer numbers	
Total (1)	Total (11); Residential (5); Non-residential (5)
Network size	
Network size (11); LV (2); MV (1); HV (2)	Network size (4)
Transformer capacity	
Total (11); MV (1); HV (1)	Total (1); no. of transformers (1)
Service area	
Service area (2)	Service area (6)
Maximum demand	
Maximum demand (1)	Maximum demand (4)
Purchased power	
Purchased power (2)	Power sold to other utilities (1)
Losses	
Transmission / distribution losses (4)	-
Labour	
Labour / wages (15); Administrative labour (1); Technical labour (1)	-
Cost measures	
Opex (7); Opex + annualised standard capital costs (1); Administrative / accounting costs (2); maintenance costs (1); Capital (5); Capex user cost + labour costs (1); Materials (1)	-
Misc.	
Industrial demand (1); Customer dispersion (2); Share of industrial energy (1); Network size / customer (1); % system unload (1); Residential / total sales (1); Outage (1); Residential customers / network size (1); Inventories (1); Line length x voltage (1)	Service reliability (1); Load factor (1); Net margin (1); Revenues (1); Distance index (1); Network density (1); Categorical variable for urban areas (1)

Source: Jamasb & Pollitt 2002

7.2 Selecting cost drivers

Based on our knowledge and understanding of the electricity distribution industry, a long list of high-potential cost drivers was drawn up under the four category headings discussed above. For those variables for which high-quality data is readily available from Ofgem, correlation matrices were then constructed for each category of driver. These were used to inform our view of which cost drivers should be selected in each category. Clearly two drivers that are highly correlated should not both be selected. The final determination of which drivers to select was based on an assessment of:

- The relationship between the variable and the characteristic to be captured
- The quality of the data
- The availability and timeliness of data
- The ease with which data can be collected
- The plausibility of the relationship

Figure 33 sets out the long list of potential cost drivers (other than scale), with brief notes for those excluded from further analysis.

Figure 33: List of high-potential cost drivers

Potential cost driver	Notes
Topography and climate	
% network underground	Proxy for degree of urbanisation
Customer density, customers/km²	Measure of spatial distribution of customers
Energy density, GWh/km²	Measure of spatial distribution of customers
Load factor, %	No reliable measure readily available from Ofgem
Categorical variable for urban areas	Measure of degree of urbanisation – length of roads is a possible proxy; No reliable measure readily available from Ofgem
Climate measure	No reliable measure readily available from Ofgem; Potentially other sources of applicable data (e.g. Met Office)
Customer mix	
% LV1	The cost of supplying electricity differs across voltage levels. Therefore a company's supply profile in terms of voltage level may be an important factor.
% LV2	
% LV3	
% HV	
Other	
% losses	Calculated as losses / total units distributed; This variable potentially captures a number of factors, including climate, inefficiency, network length and % LV, and so cannot be allocated to one of the above categories.

The correlation matrices for each cost driver category are provided in Figures 34 to 36. Correlation coefficients above 0.65 shown in bold typeface. The raw data are provided in annex 7.

Figure 34: Correlation matrix for topography and climate variables

Correlation coefficient	% network underground	Customer density	Energy density
% network underground	1.00	**0.70**	**0.69**
Customer density	-	1.00	**1.00**
Energy density	-	-	1.00

Source: CEPA calculations

Given that the area of operation is defined exogenously for individual distribution companies, significant differences in topographic and climatic conditions faced need to be taken into account when assessing the efficient level of costs. For instance, a benchmarking study of European electricity distributors[18] assessed the proportion of the network in forested and mountainous areas on the basis that such areas are more difficult to access, raising operating and maintenance costs. The density and dispersion of the consumer base is also likely to be important, with highly densely populated urban areas such as London likely to have lower operating costs than sparsely populated areas such as the Scottish islands.

On the basis of the data provided to us by Ofgem, we have considered three measures of topography and climate: the percentage of the network underground (which can be seen as a proxy for urbanisation or terrain), customer density and energy density. As shown in Figure 34, all three measures are reasonably highly correlated suggesting that only one variable need be used as a cost driver. We suggest that this be customer density.

Figure 35: Correlation matrix for customer mix variables

Correlation coefficient	% HV	% LV1	% LV2	% LV3
% HV	1.00	-0.36	-0.58	-0.17
% LV1	-	1.00	**0.73**	**-0.81**
% LV2	-	-	1.00	-0.61
% LV3	-	-	-	1.00

Source: CEPA calculations

The cost of supply varies across voltage levels. As the mix of customers faced by a firm is exogenous where the firm faces a Universal Service Obligation (USO) in a specified territory, the mix of voltage levels may be an important exogenous cost driver.

The correlation matrix suggests that two variables need to be selected. % HV shows low correlation with each of the other variables and so is a good choice. Of the other three, the

[18] *Eurelectric, 2002*

reasonably high positive correlation between % LV2 and % LV1 and the negative correlation between % LV3 and % LV1 means that % LV1 is a good proxy for the other two. We have therefore selected % HV and % LV1.

Taking into consideration the analysis above, we selected four cost drivers:

- Topography and climate: customer density
- Customer mix: percentage HV and percentage LV1
- Other: percentage losses

As can be seen from Figure 36 below, these four variables are not highly correlated with each other or with the scale variable, units distributed, and so can be considered an appropriate set of drivers.

Figure 36: Correlation matrix for selected cost drivers

Correlation coefficient	Network length	Units distributed	Customer density	% LV1	% HV	% losses
Network length	1.00	0.75	-0.39	0.37	0.25	-0.19
Units distributed	-	1.00	-0.21	0.07	0.41	-0.46
Customer density	-	-	1.00	-0.24	-0.10	-0.01
% LV1	-	-	-	1.00	-0.36	0.33
% HV	-	-	-	-	1.00	-0.71
% losses	-	-	-	-	-	1.00

Source: CEPA calculations

7.3 Testing selected cost drivers

To assess the significance of the cost drivers identified above, we again used the 1999 regression methodology as the base model. With a large data set it would be possible to run a regression using all four cost drivers as independent variables. However, given just 14 data points such an approach is not possible due to insufficient degrees of freedom. We therefore conducted a second-stage regression analysis, regressing the efficiency scores resulting from the 1999 methodology applied to the 2001/02 data on each of the three non-scale cost drivers, e.g.

$\theta = A + B \text{ x customer density} + \varepsilon$

where θ is the efficiency score under the 1999 methodology, ε is an error term and A and B are constants.

The results of the second-stage regression analysis are provided in Figures 37 to 40. Parameter values of below 5%, suggesting significance of the variable at the 95% level, are shown in bold typeface.

Figure 37: Results of 2nd-stage regression analysis – customer density

	All 14 firms		Ex. two most efficient firms		Ex. most and least efficient firms	
	Intercept	**Customer density**	**Intercept**	**Customer density**	**Intercept**	**Customer density**
R-squared	0.003		0.06		0.04	
Coefficient	0.797	7.94×10^{-6}	0.753	4.35×10^{-5}	0.847	3.45×10^{-5}
Standard error	0.063	7.21×10^{-5}	0.047	5.48×10^{-5}	0.050	5.69×10^{-5}
P-value	**0.00%**	91.2%	**0.00%**	42.7%	**0.00%**	54.4%
z-statistic	12.61	0.11	15.96	0.79	16.98	0.61

Source: CEPA calculations

Figure 38: Results of 2nd-stage regression analysis – % LV1

	All 14 firms		Ex. two most efficient firms		Ex. most and least efficient firms	
	Intercept	**% LV1**	**Intercept**	**% LV1**	**Intercept**	**% LV1**
R-squared	0.087		-0.001		0.040	
Coefficient	0.606	2.225	0.762	0.077	0.804	0.613
Standard error	0.117	1.277	0.087	0.823	0.088	0.831
P-value	**0.00%**	8.2%	**0.00%**	92.5%	**0.00%**	46.1%
z-statistic	5.17	1.74	8.77	0.09	9.18	0.74

Source: CEPA calculations

Figure 39: Results of 2nd-stage regression analysis – % HV

	All 14 firms		Ex. two most efficient firms		Ex. most and least efficient firms	
	Intercept	% HV	Intercept	% HV	Intercept	% HV
R-squared	0.25		0.03		0.03	
Coefficient	0.157	1.532	0.936	-0.396	0.712	0.350
Standard error	0.290	0.692	0.247	0.577	0.255	0.597
P-value	58.7%	**2.7%**	**0.02%**	49.2%	**0.5%**	55.7%
z-statistic	0.54	2.21	3.79	-0.69	2.79	0.59

Source: CEPA calculations

Figure 40: Results of 2nd-stage regression analysis – % losses

	All 14 firms		Ex. two most efficient firms		Ex. most and least efficient firms	
	Intercept	% losses	Intercept	% losses	Intercept	% losses
R-squared	0.536		0.123		0.433	
Coefficient	0.196	9.140	0.553	3.296	0.467	5.911
Standard error	0.171	2.589	0.180	2.669	0.152	2.262
P-value	25.2%	**0.04%**	**2.1%**	21.7%	**2.1%**	9.0%
z-statistic	1.14	3.53	3.08	1.24	3.07	2.61

Source: CEPA calculations

7.5 Conclusions and recommendations

As can be seen from Figures 38 to 40, none of the four cost drivers is consistently significantly correlated to the efficiency scores obtained from the 1999 methodology - although percentage HV and percentage losses are significant against the efficiency scores based on the entire data set. This suggests that utilising a single composite cost driver measuring differences in scale should be sufficient for Ofgem's purposes.

8. FURTHER ISSUES

We examined three further possible adjustments to the 1999 methodology:

- The implications of benchmarking total costs rather than opex;
- The incorporation of quality measures into the benchmark; and
- The impact of mergers on the efficiency scores for opex

8.1 Benchmarking total cost

In 1999, Ofgem assessed efficiency on the basis of opex. A company that had too high an opex for a particular level of the composite variable was deemed to be inefficient. This measure, however, ignores any difference in the quality of firms' capital. A company which has, in the past, invested in equipment and technology that reduces operating costs would appear to be more efficient than a company which had not invested, irrespective of whether the capital expenditure was worthwhile in the impact it had on operating costs. Benchmarking only opex could have a particularly serious impact on a company that has historically invested less than the industry average. Not only would its regulatory capital value be relatively low (so it would earn a lower return), but it would also appear to be inefficient on opex benchmarks, and as a result would be expected to reduce costs faster.

Benchmarking total costs (totex) rather than individual components of cost, e.g. opex, also avoids the potentially distortionary effects of regulatory gaming associated with the substitution of opex for capex. On one level such gaming may simply manifest itself in changes in company accounting policies, resulting in additional audit work for the regulator in 'cleaning' the data to make the data comparable across companies. In more extreme cases the substitution effect may be real in that a company moves away from its optimal input mix. The inefficiencies associated with such substitution will remain for the full lives of the assets concerned.

Although ideally benchmarking should therefore apply total costs rather than individual components, in practice this is difficult to implement due to the heterogeneous nature of capital and the difficulties in measuring capital expenditure accurately and consistently. Consequently, while the May consultation document highlighted the benefits of total cost analysis, in the 1999 DPCR Ofgem conducted such analysis only as a supporting check on its analysis of opex and capex efficiency; and, in the final determination, attached little weight to it.

Nevertheless, assessing totex efficiency in conjunction with opex efficiency may be informative, particularly where there is considerable diversity in opex performance across companies.

There are a number of ways of defining totex. The key issue is to utilise a measure of capex that smoothes the potentially large year-to-year fluctuations. The definition of totex used in the following analysis is:

$Totex_t$ = base $opex_t$ + $depreciation_t$ + ROC_t x RAV_t

where ROC is the allowed return on capital (6.5% real) and RAV is the regulatory asset value, and deprecation is regulatory depreciation. The calculated level of totex for each company is set out in Annex 9.[19]

We consider the impact on the efficiency scores and implied potential cost savings of benchmarking totex rather than opex. We first use the 1999 methodology as the base model with the use of totex rather than opex as the benchmarked variable being the one change. Consequently, the three-variable scale composite is the sole cost driver. The sensitivity to outliers is again assessed, with the model being run for all 14 data points, excluding the two most efficient firms, and excluding the most and least efficient firms. We then assess the implications of benchmarking totex using DEA.

8.1.1 Results

Summary results of the regression analysis are reported in Figure 41, with the results from the opex analysis provided along side for comparison. Figure 42 shows the correlation coefficients of the implied potential efficiency savings under opex and totex. Summary results of the DEA analysis are reported in Figure 43, with the correlation coefficients of the efficiency scores under opex and totex provided in Figure 44. More detailed results and the raw data are provided in Annex 9.

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[19] *The analysis conducted by Ofgem at the time of the 1999 DPCR used totex = base opex + average network capex, with the average being taken over the period 1990/91-1999/2000.*

Figure 41: Benchmarking totex, COLS summary results

	Opex			Totex		
	All firms	**Ex. two most efficient firms**	**Ex. most and least efficient firms**	**All firms**	**Ex. two most efficient firms**	**Ex. most and least efficient firms**
Intercept	32.8	6.6	19.5	61.6	41.1	37.1
Firm defining frontier	A	B	A	C	D	C
R-squared	0.23	0.69	0.62	0.76	0.88	0.82
Implied potential efficient saving						
Unweighted average	22.4%	20.8%	15.1%	15.7%	15.9%	16.3%
Standard deviation	17.7%	23.4%	20.1%	10.5%	10.3%	11.5%

Source: CEPA

Figure 42: Correlation matrix – COLS opex and totex implied potential efficiency savings

	Totex – all firms	**Totex – ex. two most efficient firms**	**Totex – ex. most and least efficient firms**
Opex – all firms	0.32	-	-
Opex – ex. two most efficient firms	-	0.31	-
Opex – ex. most and least efficient firms	-	-	0.47

Source: CEPA

Figure 43: DEA efficiency scores – totex

	Opex		Totex	
	CRS	**VRS**	**CRS**	**VRS**
Unweighted average	61.3%	77.4%	85.1%	92.6%
Standard deviation	29.3%	17.2%	13.1%	8.3%
No. firms defining frontier	1	2	1	6

Source: CEPA

Figure 44: Correlation matrix – DEA opex and totex efficiency scores

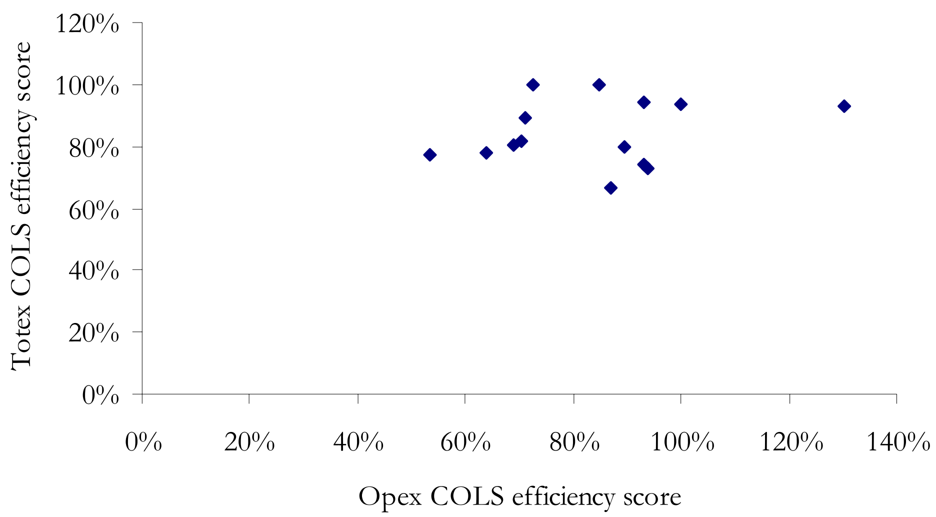
	Totex - CRS	Totex - VRS
Opex – CRS	0.80	-
Opex - VRS	-	0.42

Source: CEPA

8.1.2 Assessment

The results from the totex analysis highlight the potential problems of benchmarking a single cost component. Although there is a degree of correlation between the scores under opex and totex – in that firms that score well under opex also tend to score well under totex - performance is less diverse on totex than on opex and a number of firms that looked particularly inefficient on the opex measure appear far closer to the frontier under totex. The correspondence between the DEA and regression analysis scores are not as good as for opex; and the DEA VRS scores do not appear to be robust due to the large number of firms placed on the frontier. However, the DEA CRS scores confirm the general observations from the regression analysis, in that totex performance is much more consistent across companies than that of opex (Figure 45).

Figure 45: DNO COLS efficiency scores for opex and totex



Source: CEPA

Complications involved in measuring the capex element of totex mean that it is not straightforward to rely on totex analysis for the benchmark. However, the benefits of using totex rather than opex mean that further investigation is merited to see whether a reasonable totex variable can be constructed that is not itself subject to distortion from gaming. An alternative would be to use totex to assess the divergence in opex performance rather than acting as the benchmark for establishing X factors per se.

8.2 Benchmarking quality

Quality was not directly included in the 1999 DPCR benchmarking analysis. Instead, the X factors were adjusted by up to 0.5 percentage points to reflect performance on quality measures versus specified targets and up to a further 0.25 percentage points based on the number of customer complaints received. It has been argued that the incentives associated with this system were larger than the level of the penalties might suggest on the basis that PESs believed that Ofgem would take a harder line on capital underspend for companies failing to meet quality targets.

However, Ofgem's approach to quality has since altered radically. Under the new Information and Incentives Programme (IIP) (see Annex 3) specific measures have been designed to assess performance in respect of: the number of supply interruptions; the duration of supply interruptions; and the quality of customer service, in particular on the quality of telephone interactions between customers and the distribution businesses.

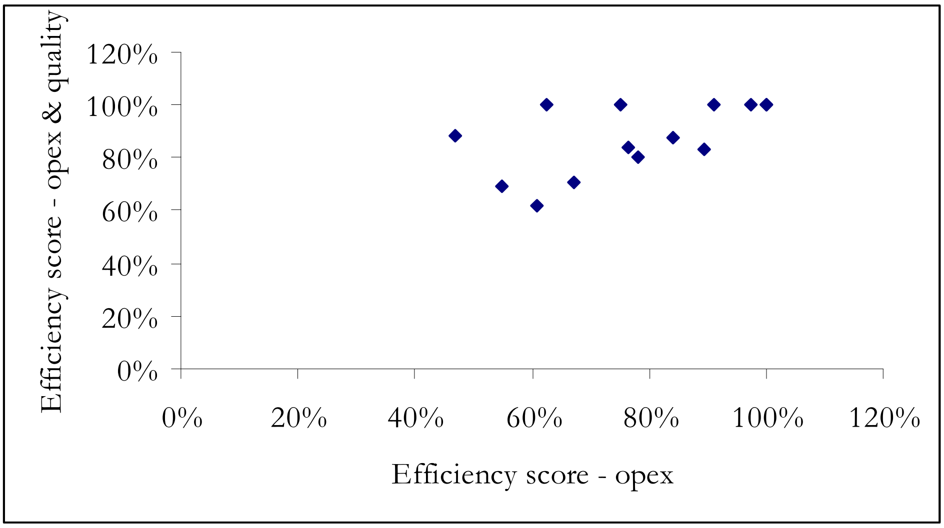
Ofgem has proposed, and the companies have agreed, to incentive schemes that reward and penalise good and poor performance in these areas respectively. The maximum reward or penalty for this is limited to +/-2% of revenue.

In the remainder of this section assesses the issues as to whether quality should continue to be incentivised in this way or whether is should be included in the benchmark explicitly, i.e. by benchmarking some combination of costs and quality.

Ofgem measures two main quality variables - minutes lost per customer, and number of interruptions per customer – on the basis that continuous supply is of prime importance to consumers. However, the two variables are highly correlated (correlation coefficient of 0.82) and so it is only necessary to incorporate one of them in the analysis. Due to the increased weight attached to it by Ofgem, we suggest that this is minutes lost per customer.

We have run a DEA analysis using opex and quality (minutes lost / customer) as the output variables and the three components of the composite as the input variables. The summary results are presented in Figure 46 alongside those of the DEA analysis using opex as the only input variable for comparison.

Figure 46: DEA efficiency scores, 2001/02 data



Source: CEPA

As can be seen from the figure above, the impact of including quality is to improve every firm's efficiency score. In particular, those firms that looked least efficient in terms of opex performance alone move significantly closer to the efficiency frontier when quality is included as an input variable and, in some instances actually move ahead of the frontier.

In isolation, these results suggest that failure to take into account differences in quality across firms may penalise some firms for providing a higher quality service. To the extent that customers value higher quality service, this would seem to be unjust. However, it is important to assess the significance of the above DEA results.

In order to do this, we conducted a second stage regression analysis to assess the significance of minutes lost / customer. The summary results of this are set out in Figure 47.

Figure 47: Results of 2nd-stage regression analysis – minutes lost / customer

	All 14 firms		Ex. two most efficient firms		Ex. most and least efficient firms	
	Intercept	Mins lost / customer	Intercept	Mins lost / customer	Intercept	Mins lost / customer
R-squared	0.002		0.050		0.005	
Coefficient	0.679	0.001	0.879	-0.001	0.895	-4.1×10^{-4}
Standard error	0.204	0.002	0.151	0.002	0.159	0.002
P-value	**0.09%**	53.9%	**0.00%**	44.9%	**0.00%**	81.8%
z-statistic	3.33	0.61	5.82	-0.76	5.62	-0.23

Source: CEPA

The analysis clearly shows that minutes lost per customer are not closely correlated with companies' efficiency scores. Consequently, the above DEA results cannot be considered robust. There does not therefore appear to be a case for including quality explicitly in the benchmark.

Companies can, however improve quality in practice, and there is a trade-off between improving quality and reducing costs at the margin. Although there is not a statistical relationship between quality and efficiency scores, this does not mean that quality should not be rewarded as under the IIP.

8.3 Assessing the impact of mergers

Mergers have been prevalent in electricity distribution over the last decade of so. Since the last price review, there have been four further mergers between DNOs, reducing the number of independent groupings to eight. Annex 3 provides further details.

Analysis conducted at the time of the 1999 DPCR suggested that mergers typically saved the merging DNOs a total of around £12m in fixed costs, or almost half of average opex fixed costs. The introduction Ofgem's merger policy in May 2002 (Annex 3) implicitly splits this saving between customers and the merging firms[20]. Such savings could clearly impact the efficient level of costs and failure to take the effect into account may result in Ofgem treating firms who have not merged unduly harshly or merged firms unduly leniently.

This section aims to assess the significance of mergers on the level of efficient opex for the merging firms.

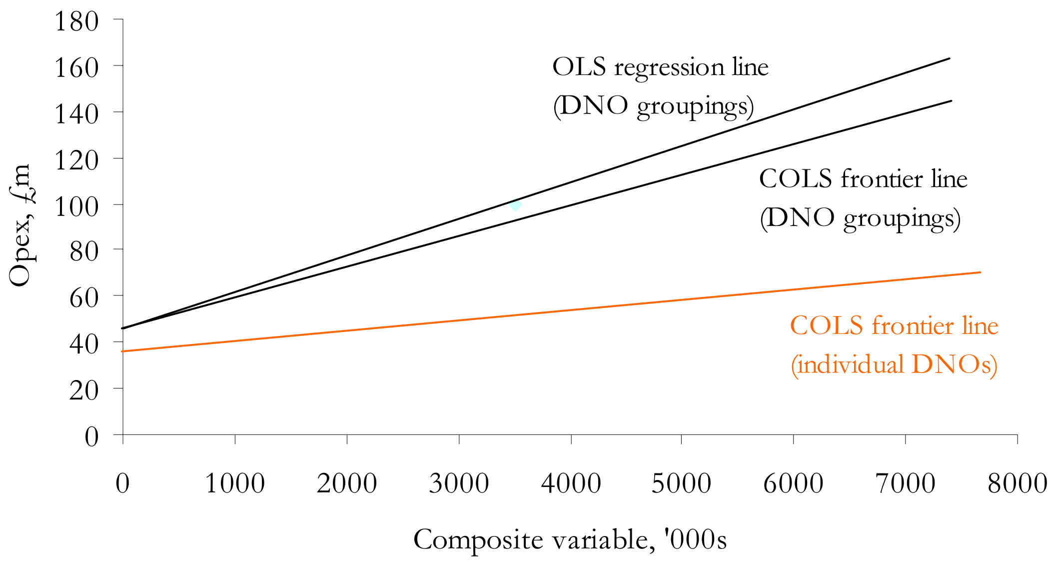
[20] *Under the merger policy allowable revenues are reduced by £32m over a 5 year period, this just under 50% of £12/yr for 5 years*

8.3.1 Regression analysis for DNO groupings

The opex and composite variable data were aggregated for each of the eight DNO groupings. An OLS regression was then run, with the efficiency frontier being established by pivoting the OLS regression line (as in the 1999 methodology) to pass through the second most efficient grouping. With just eight data points it is not practical to exclude any firms; and in this case there were no obvious outliers anyway.

Figure 48 shows the calculated regression line and frontier based on the eight DNO groupings. Summary results of the regression and the implied potential efficiency improvements for each grouping are shown in Figure 49.

Figure 48: COLS efficiency frontier for the eight independent DNO groupings



Source: CEPA

Figure 49: Summary results for regression analysis

OLS intercept	45.0
R-squared	0.90
Implied potential efficiency savings	
Unweighted average	6.3%
Standard deviation	8.5%

Source: CEPA

Further Issues

The above analysis shows that the efficiency scores for the three DNOs that have not merged with another DNO improve dramatically once DNO groupings are assessed rather than individual firms. Indeed, one of the three unmerged DNOs is now the most efficient. One interpretation of this result is that groupings are gaming the regulatory system by allocating costs between their component firms in the way that most suits them.

It may also be simply that companies have aimed to merge more efficient firms with less efficient ones, so that best practice in one can be exploited in the other. Clearly this is an issue that requires further investigation.

9. DISCUSSION AND CONCLUSIONS

In this report, we have analysed a wide variety of techniques and have applied them to data supplied by Ofgem on the distribution network operators. The data on companies on which this analysis is based has not been made fully consistent across companies. The data on which Ofgem will base judgements in the forthcoming review will be of higher quality, partly as a result of the Information and Incentives Project (IIP). Despite the shortcomings of the data utilised in this study, it is possible to draw some conclusions that may assist in the analysis of data in the forthcoming review.

Replication of the 1999 analysis on the new data, and comparing this with the 1999 results gives some immediately striking observations:

- All firms have become more efficient in terms of operating expenditure. They have all responded to the incentives embedded in the price controls.
- The firms have improved at different rates. It appears that one of the most efficient firm in 1999 in terms of opex was able to improve its efficiency by the largest amount, and one of the least efficient firms has improved by the smallest amount. There is now a wider variation in efficiency between different firms than was the case in 1999.

In the final price control determinations made in 1999 it was expected that the firms that were further away from the frontier would be able to improve their efficiency more than the most efficient firms, resulting in some convergence in performance. In the event, this does not appear to have been the case, raising the question of whether some of the assumptions lying behind the 1999 analysis were inappropriate. There are a number of possible interpretations of the observations of the data:

- The data itself may be inaccurate or may require further adjustment to take account of known differences between firms. Further adjustments might be necessary to make accounting data consistent across all companies, making firm conclusions difficult without these adjustments.
- The methodology used to establish the frontier assumed that a firm operating on that frontier was included in the data set. Given such a small data set this may not have been the case and so the estimated frontier may not have represented the true frontier. It is therefore possible that the firm used to define the frontier is actually moving towards the real frontier, and that all firms could make significant improvements in efficiency.
- There is something distinctive about the outliers, i.e. the most efficient firms and the least efficient firms, that means that their cost functions are unlike other firms, and so they should be treated differently.

- The input and output measures used in the analysis do not fully reflect the economics of the distribution business.

Without a detailed investigation, we can form no judgement about the quality of the data provided on companies and the adjustments that need to be made. In the 1999 review, data adjustments were made by the consultants PKF, and we understand that these have only partially been replicated on the latest data set, because the data and adjustments have been sourced only from regulatory accounts. However, we have no reason to believe that the data are systematically biased.

It is, of course, not possible to assess from this data alone whether the UK distribution sector as a whole could make substantial improvements in productivity in line with those made by the most efficient DNO. In international benchmarking studies, even the most efficient UK company was not as efficient as international companies, suggesting that there is scope for further efficiency improvements (Jamasb & Pollitt, 2002). International comparisons of distribution companies are, however, notoriously difficult, and further work would be necessary to establish the appropriate interpretation of this.

The analysis of this report, does, however, indicate that while the variables used in the 1999 analysis provide some insights into the relatively efficiency of firms, they do not give a complete picture.

9.1 Choice of technique – how benchmarking is performed

In 1999, the definition of the efficiency frontier was based on both regression analysis and expert judgement of the level of fixed costs. Both the regression approach and the final non-statistical determination of the efficiency frontier have been criticised, raising the question as to whether alternative approaches should have been considered.

We have considered a range of statistical techniques. Of these, SFA is statistically the most elegant as, theoretically, it is able to distinguish between the efficiency of firms and noise in the data. However, the limited size of the sample of UK DNOs means that in this context it is unable to do this. In three of four applications reported here, the technique was unable to detect different efficiency levels. We know from other evidence (industry observation) that some firms are more efficient than others, and which ones, but SFA could not detect this. Although one application of SFA did provide some significant results, we cannot be sure that it will be possible to derive useful results if it were to be applied to a new set of data as it does not appear to be robust to small changes in the methodology or data. It should, however, be possible to use SFA if Ofgem were to choose to use panel data (see below).

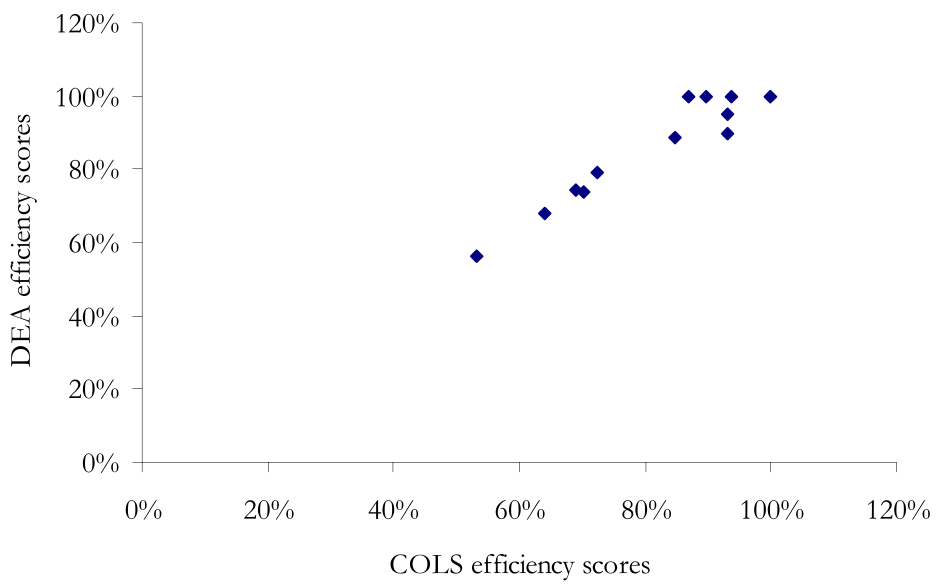
We also considered the use of PPA, but this technique can be rejected on theoretical grounds. This leaves DEA and COLS as the main practical alternatives for determining the efficiency frontier.

Our analysis shows that a COLS approach could be successfully applied to the 2001/02 data. The estimated efficiency frontier gave a plausible intercept (representing fixed costs) and a realistic relationship between scale and costs. Using the second most efficient firm to determine the frontier, three firms were very close to the frontier, and a group of seven within a few percentage points. A concern with the use of the approach, though, is that the frontier intercept is sensitive to outliers.

The DEA approach is theoretically more appealing than COLS as it determines efficiency using different input and output variables. This means that if different elements of the composite scale variable affect companies in different ways, these can be reflected in the efficiency scores, and the calculated scope for efficiency improvement to be used in X factors. DEA also enables the specification of CRS or VRS even with small data sets. However, the calculated efficiency scores are dependent on the variables selected, and the method itself does not provide a test of whether particular variables should be included in the model. If inappropriate variables are included in a DEA model, firms can appear to be efficient for spurious reasons. This means that the validity of the variables selected needs to be checked through other techniques, and in practice this means COLS. The results of applying DEA to the UK DNO data were consistent with those from COLS.

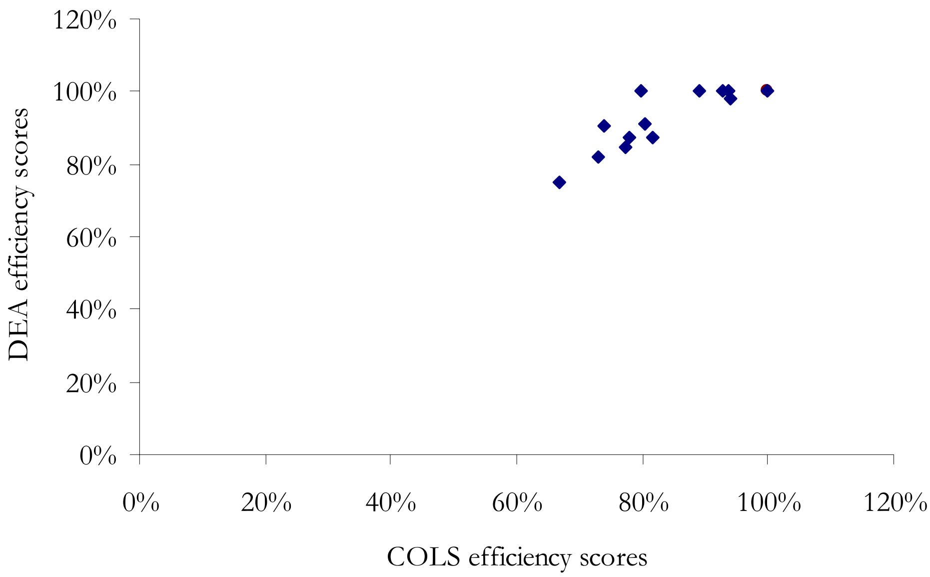
The two methods do not give precisely the same rankings of efficiency, but firms that are more efficient under one method are typically more efficient under the other (Figures 50 and 51).

Figure 50: DNO opex efficiency scores under COLS and DEA



Source: CEPA

Figure 51: DNO totex efficiency scores under COLS and DEA



Source: CEPA

This suggests that one possible approach to establishing an appropriate efficiency frontier would be to use a combination of DEA and COLS. In particular, emphasis could be placed on the DEA scores but with COLS being used to assess the appropriateness of the output variables used, the significance of the DEA efficiency scores obtained and assess whether particular companies were being treated unfairly under DEA. The choice of technique may, however, be less important than the choice of the variables to be included in the benchmarking exercise.

The index approaches examined do not provide estimates of the efficiency frontier. They do, however, show that companies are improving efficiency at very different rates. In the long-term, X factors should ideally be based on TFP. However, until there is sufficient convergence in firms' performance, it is not appropriate to use them in this manner. In the meantime, TFP may provide a useful methodology for assessing shifts in the frontier.

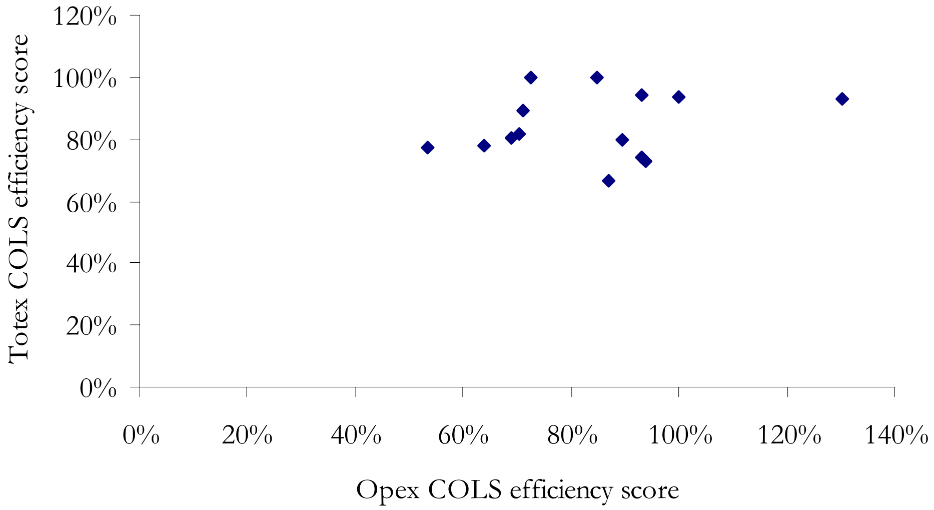
9.2 Choice of variables – what is benchmarked

9.2.1 Operating versus total expenditure

In 1999, Ofgem assessed efficiency on the basis of opex. A company that had too high an opex for a particular level of the composite variable was deemed to be inefficient. This measure, however, ignores any difference in the capital of firms. Companies that have, in the past, invested in equipment and technology that reduces operating costs will appear to be more efficient than those who have not done so, irrespective of whether the capital / operating expenditure trade-off does actually lower overall costs. Benchmarking opex alone could therefore be particularly serious for a company that has historically invested less than the industry average. Not only will its regulatory capital value be relatively low, but also it would appear inefficient on opex benchmarks, and as a result would be expected to reduce costs faster. Indeed, our analysis of the impact of benchmarking opex versus some measure of total costs (totex) suggests that the impact could be profound for some firms, particularly those that perform poorly with respect to opex alone. This can be seen from Figure 52, which compares COLS efficiency scores for both opex and a measure of total capital expenditure.

Ideally, therefore, efficiency should be benchmarked in terms of totex. However, complications involved in measuring the capital expenditure element of totex mean that this is not straightforward. Further analysis is required to assess whether a reasonable totex variable can be constructed that is not itself subject to distortion from gaming. Should benchmarking totex prove inappropriate, an alternative would be to use totex to assess the divergence in opex performance rather than acting as the benchmark for establishing X factors per se.

Figure 52:DNO COLS efficiency scores for opex and totex



Source: CEPA

9.2.2 Including quality

Quality is clearly important to customers. However, there is a trade-off between improving quality and reducing costs. Consequently, it may be appropriate to consider some measure of quality when benchmarking costs. DEA analysis using quality as one of the output variables indicated that there is such a trade-off and that efficiency scores of companies tend to converge when quality is included. However, when entered into a second-stage regression of efficiency scores, the impact of quality was found to be insignificant. It appears that too many other factors are contributing to quality (such as topography), so that quality itself cannot be used as a variable in the analysis. This suggests that maintaining a separate programme such as the IIP to incentivise quality improvements is appropriate.

9.3 The composite variable and cost drivers

Numerous factors drive costs in a distribution business. For instance, the density of the customer base affects the type of network that is built; the type of landscape and climate affect the cost of constructing and maintaining a network.

While from an engineering perspective these factors should be expected to affect costs, our second-stage regression analysis showed that these effects were not statistically significant. This may be because the companies are not sufficiently different from each other for the factors to have an important effect or, more likely, that interactions with other factors means that on a small sample it is not possible to detect the effects.

In terms of benchmarking the 14 UK distribution companies, therefore, it appears that these cost drivers should not be used in the comparisons, with a measure of scale remaining the only cost driver necessary. This does not, however, mean that these factors should be ignored, as we discuss below.

Our analysis does indicate, though, that the composite scale variable used by Ofgem in the 1999 DPCR could be simplified. The composite used consisted on a weighted average of three variables, customer numbers, units distributed and network length. For the UK DNOs, customer numbers is highly correlated with units distributed, and so it is not necessary to include both in the composite variable.

9.4 Panel data

The analysis contained in this study has focused on reporting results at one or two points in time. Ofgem is able to collect data at least annually and so has the ability to make use of panel data (i.e. time series data). The advantages of the use of panel data are widely recognised (e.g. by Coelli et al 1998). They include:

- Panel data allow a larger number of degrees of freedom in the estimation of parameters. This is especially important when the number of observations in a given year is small. It therefore allows more sophisticated statistical techniques to be utilised, potentially including SFA.
- It would allow prior assumptions about the way that inefficiency, inputs and outputs interact to be incorporated using COLS type analysis.
- Panel data could be used to calculate Malmquist indices of productivity growth using stochastic frontier methods or DEA. This allows the technical change and technical inefficiency change components to be decomposed.

- It can also be used to estimate the time varying effect of environmental parameters on the mean inefficiency using maximum likelihood estimation techniques.

The use of panel data would therefore provide Ofgem with a way to overcome some of the limitations currently encountered due to the small sample size for UK electricity distribution.

9.5 Key issues

Benchmarking is an important regulatory tool that can be used to assist with judgements about the scope for efficiency improvements across firms. However, it is only a tool and cannot substitute for judgement based on a wider range of evidence. It should therefore only be considered as an input into a pragmatic approach to setting X factors that draws on a range of analysis.

The analysis contained in this report highlights a number of issues that merit further investigation. In particular:

- Why was one of the most efficient company apparently able to reduce its operating costs so much? Are there special features of the area that the company serves that are not apparent in the standard variables that make it low cost, or does it have an approach to organising its business that makes it low cost?

- Why was one of the least efficient companies unable to make much headway in improving efficiency, despite strong incentives to do so? Is the system it owns inherently higher cost? Does it have an over-built system for the area it serves that will require ongoing maintenance, consistently handicapping it?

There are also some policy issues:

- In the context of recent mergers and the increasingly international nature of the industry, is scale considered to be a variable of choice by companies? If so, Ofgem needs to consider whether it should consider restricting the use of benchmarking techniques to those using constant returns to scale to encourage firms to choose an appropriate scale themselves.

- Panel data: As noted above, time series data could be used to improve the use of benchmarking data. Ofgem needs to consider whether it wishes to do this.

- International data: Given the likely uncertainty about the position of the frontier, international data may improve the estimate, provided that the underlying nature of the business is sufficiently similar. Despite the difficulties of international comparison, even the inclusion of a very limited additional sample of companies could have an important impact.

ANNEX 1: TERMS OF REFERENCE

Scoping study: Background to Work on Assessing Efficiency for the 2005 DPCR

1. Distribution price control review

During 2003 and 2004, the Authority will carry out the work to review the price control to apply to the 14 electricity distribution network operators (DNOs) with effect from 1 April 2005. This will replace the present control, which has applied from 1 April 2000.

1.2 Purpose of the work

The Authority requires advice, as set out in the requirement below, on the approach to assessing efficiency used for the DPCR. This work will provide background to the efficiency assessments and related work that the Authority will carry out during the DPCR.

2. Requirement

This piece of work should be structured as follows:

A. A description of Ofgem's approach to benchmarking at the last electricity distribution price control review (the regression analysis/frontier approach, as set out in documents published at the last DPCR in 1998 - 1999), which the Authority expects will include:

- Detail of the strengths and weaknesses of that approach.
- Identification of key issues and changes since then requiring changes of approach (e.g., mergers and questions regarding the continuing appropriateness of the same frontier approach)

B. Review available alternatives, in terms of:

- **Benchmarking methodologies** - in the light of data limitations, advise on the strengths and weaknesses of possible alternatives to the benchmarking approach used last time. Alternatives may include Data Envelopment Analysis, total factor productivity, stochastic frontier analysis, ordinary least squares, ratio analysis, and variations on these methodologies.

- **Cost drivers** – provide advice on how the Authority should decide which cost drivers to use, which may include how to account for firm-specific effects and how to use engineering analysis to inform variable selection.

C. A specific analysis of costs, in particular:

- A re-run of the approach used by Ofgem at the last DPCR, which examines how the approach used at the last DPCR would affect the DNOs now, using 2002 data. What does it show, and what simple improvements can be made?
- Then, if clear recommendations for a change in approach arise from (A) or (B), and where data is available, determine the impact of such a change(s) on the DNOs. (For example, this might include using a different cost drivers or using eight data points instead of fourteen to reflect mergers).

Please note that Ofgem will supply in spreadsheet form both the data used for the 1999 DPCR (published version) and the relevant data from 2002.

3. Timetable

An indicative timetable for the appointment of consultants and the milestones of the study is set out below.

Consultants' proposals in response to be submitted	16 June 2003 5pm
Ofgem to appoint successful consultants	17 June 2003
Outline draft report submitted by consultants	4 July 2003
Final report submitted by consultants	18 July 2003

4. Payment schedule

Ofgem will pay the consultant 40%of the agreed fee on receipt of a satisfactory draft report, and the remaining 60% of the agreed fee when it is satisfied with the final report.

5. Information we require from tenderers

Tenderers should set out in their response to these terms of reference:

- A brief statement outlining your understanding of the requirement, your approach and methodology for this area of work;
- Details of your company's experience in providing similar advice along with examples of previous work;
- The names of staff the tenderer will engage for this study and a summary of their relevant experience and expertise;
- Name and contact details for commissioning of work;

- Total firm price for completion of the project, please include a breakdown of daily rate for each member of staff who will be directly involved in delivering the service (including expenses and VAT).

- A statement on how conflicts of interest would be handled; and

- An indication that the tenderer accepts the proposed payment schedule and the indicative timetable for delivering the draft and final reports.

6. Contacts

If you would like to ask any questions regarding these terms of reference before preparing a response, please contact Adrianne Monroe on 020 79017401 or on email at adrianne.monroe@ofgem.gov.uk.

ANNEX 2: FUNCTIONAL FORMS USED IN BENCHMARKING MODELS

A2.1 Translog function used in Parametric Programming Approach PPA

Section 2.2.1.2 briefly described the Parametric Programming Approach, and noted that in applications a translog functional form is often used. This production function is of the form:

$$\ln u = a + \sum_{i=1}^{n} \alpha_i \ln x_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln x_i \ln x_j$$

and the Cobb-Douglas form is embedded within this, if all the γ_{ij} are set to zero. The parameters of the equation are found through a linear programme:

$$\min\left\{\sum_{k=1}^{K}\left[a + \sum_{i=1}^{n} \alpha_i \ln x_i^k + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij}^k \ln x_j^k - \ln^k - \ln u^k\right]\right\}$$

such that

$$\left[a + \sum_{i=1}^{n} \alpha_i \ \ln x_i^k + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln x_i^k \ln x_j^k - \ln u^k\right] \geq 0, k = 1,\ldots,K$$

where a is unrestricted, $\alpha_i \geq 0$, γ_{ij} $i=1,\ldots,n, j=1,\ldots,n$; K is the number of companies in the sample, which are indexed with k; x_i^k is the i^{th} input for the k^{th} firm; and a, α and γ are the parameters of the production function.

Solving this linear programme can be shown to be equivalent to minimizing the sum of the absolute residuals subject to the constraint that each residual is non-positive.

A2.2 Functional forms used with Corrected Ordinary Least Squares (COLS)

The production/cost function used with COLS can take a number of forms. The most common approach is to use a Cobb-Douglas production function:

$$u = A\prod_{i=1}^{n} x_i^{\alpha_i}$$

where u is the output variable, A is constant, x_i are input variables, and α_i are coefficients. This can be estimated by transformation to:

$$\ln u = a + \sum_{i=1}^{n} \alpha_i \ln x_i$$

Another approach that is used in the literature is the 'translog' cost function. This allows for more complex interaction between the variable inputs than the Cobb-Douglas form, but is still straightforward to estimate. The production function is represented as:

$$\ln u = a + \sum_{i=1}^{n} \alpha_i \ln x_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln x_i \ln x_j$$

ANNEX 3: RECENT DEVELOPMENTS IN THE UK ELECTRICITY DISTRIBUTION INDUSTRY

This annex summarises the key changes in the UK electricity distribution industry since the 1999 DPCR. In each case, it aims to draw out the major implications for efficiency benchmarking.

A3.1 Separation of distribution and supply

As a result of the introduction of competition in the supply of electricity to small business and domestic consumers, modifications were made to the licences of the PESs in April 2000 that resulted in the separation of electricity distribution from supply. In particular, the Utilities Act (2000) provides for the separation of licences for electricity distribution and supply activities and prohibits a single entity holding both types of licence[21]. A two-year transition period was set for companies to separate their activities.

A3.1.1 Implications for the efficiency benchmarking

Due to the then impending separation of the distribution and supply, the two activities were benchmarked separately in the 1999 DPCR. Consequently, the implications for the 2005 DPCR are likely to be limited to easing the collection of comparable data from DNOs as the issue of cost allocation between the activities is removed.

A3.2 Mergers

Mergers have been prevalent in the sector since 1995. At the time of the 1999 DPCR there were 12 independent groupings of distribution companies. However, since then there have been four further mergers:

- London and Seeboard
- London and Eastern
- Northern and Yorkshire
- SWEB and SWALEC

Consequently, the number of independent groupings in the sector has been reduced to 8 from 12 at the last review. Figure A1 sets out the eight remaining independent groupings.

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[21] *The Electricity Act (1989) provided for licences covering both supply and distribution.*

Figure A1: Who owns whom

Ultimate owner	Distribution business
Aquila	Midlands
EdF	Eastern London Seeboard
EON	East Midlands
Mid-American Energy Holdings	Northern Yorkshire
Scottish & Southern	Scottish Hydro-Electric Southern
ScottishPower	Manweb ScottishPower
United Utilities	Norweb
Western Power Distribution	SWALEC SWEB

Although mergers can bring benefits to both investors and consumers through efficiency savings, they also result in a reduction in the number of comparators available for meaningful benchmarking. Reduced efficacy in efficiency benchmarking can be detrimental in that efficiency savings are passed on to consumers more slowly than would otherwise be the case and, in the extreme, can result in inappropriate benchmarks being set. Ofwat and the Competition Commission have both taken a strong stance with respect to mergers in the water industry, with mergers only being allowed if they can demonstrate that large efficiency savings will be passed onto consumers. This implies that mergers should result in reduced marginal costs of production rather than merely reduced fixed costs[22].

Ofgem's distribution merger policy, announced in May 2002, is in line with this approach. In particular, for all subsequent mergers the allowable revenues of the merging group are to be reduced by £32m, spread equally across all companies concerned over a five-year period. This means that mergers that are not expected to result in considerable efficiency benefits are likely to be deterred.

[22] *Economic theory suggests that only reductions in marginal costs impact consumer prices (under perfect competition at least).*

A3.2.1 Implications for efficiency benchmarking

The most important effects on benchmarking of this are:

- Even if separate data on different DNOs continues to be reported, having multiple DNOs operated from within the same overall corporate grouping means that some costs are likely to be determined jointly. Companies may shift costs allocated between companies to influence benchmarking.
- If DNO data for merged companies is combined, this reduces the quality of statistical methods.
- If the most efficient firms merge with lower cost firms, the frontier will move to firms with higher costs, reducing the apparent scope for cost reduction in the industry.

A3.3 Information and Incentives Programme (IIP)

The Information and Incentives Programme (IIP), which came into force in April 2002 and is applicable until March 2005, amended the licence conditions of the DNOs to strengthen the incentives for DNOs to improve quality in key areas and impose standardised requirements for the reporting of quality data.

With respect to incentives for quality improvements, in brief, Ofgem will:

- Penalise companies by an amount of up to 1.75% of revenues annually for failure to meet quality targets relating to the number and duration of interruptions;
- Penalise companies by an amount of up to 0.25% of revenues annually for failure to meet quality targets relating to telephone responses to customers;
- Reward companies for exceeding their quality targets; and
- Reward frontier companies, i.e. those exhibiting best performance.

Data is to be reported under the new format for the first time for 2001/02. However, Ofgem has permitted a lower level of compliance with respect to the accuracy of data for the first year of the new standard.

Ofgem is continuing to develop an approach to determining the cost of implementing quality improvements, and plans further to refine price controls to reflect this.

A3.3.1 Implications for efficiency benchmarking

The implementation of this programme should have an impact on efficiency benchmarking.

If the efficiency frontier is set independently of the efficiency score of a particular firm, the incentives associated with the IIP should not distort decisions made by that company. It is possible, though, that it might.

Suppose that a particular firm has costs 10% above efficient costs, and could spend an additional 2% of costs to improve quality which it would receive back from the incentive scheme. Without the quality spend, costs appear to be 10% above efficient costs, so if it was expected to reduce these by three-quarters, it would need to cut costs by 7.5% of efficient costs. However, if costs were measured including the costs incurred to improve quality, the implied cost reduction would be 9% of efficient costs (Figure A2 below). This reduces the incentives to incur operating expenditure to improve quality.

If a particular company sets the frontier, the effects would be different. A frontier firm that incurs costs associated with improving quality would benefit twice: It would benefit from the revenue associated with the incentive and because the costs it incurs to increase quality will be recovered as it is setting the benchmark.

The increased cost associated with the quality improvement would also benefit the whole industry, because benchmark costs would be higher, irrespective of whether other firms invest in quality.

Clearly, careful thought is need to assess the practical impact of the IIP incentives on price controls.

Figure A2

	Actual	
	No quality spend	**Quality spend**
Efficient costs	100	100
Actual costs excluding quality costs	110	110
Quality costs	0	2
Actual costs	110	112
Target costs	102.5	103
Target costs less quality revenue	102.5	101

Source: CEPA

A3.4 Distributed generation

The recent Energy Policy White Paper re-emphasised the important role that distributed renewable energy sources, e.g. wind, will play over the next 20 years. Embedded small-scale electricity generation will take on a new importance. Substantial new investment in distribution is therefore likely to be required.

We understand that Ofgem is currently considering how to reflect these increased costs in the price controls of DNOs. Some costs could be passed to the new generators themselves as connection charges, but there will inevitably be other costs that spill over onto the networks themselves, and some allowance for these in price controls is likely to be thought necessary to encourage the development of distributed generation.

A2.4.1 Implications for efficiency benchmarking

Connection of distributed generation is clearly a factor that could increase costs for a company, making it appear to be less efficient. As with quality, this could lead to distortions in the benchmarking process unless appropriate adjustments are made to data:

- Spending by non-frontier firms could make them look less efficient, forcing tougher targets than otherwise;
- Frontier firms would benefit from any network spend on distributed generation, and the industry would benefit from this spend as well.

ANNEX 4: REPLICATION OF 1999 DATA

The data used to replicate the 1999 regression methodology is set out in Figure A3 below.

Figure A3: Raw data for 1997/98 regression analysis

PES, 1997/98	Base Opex, £m	Adjusted customer no., '000s
East Midlands	80.5	2309
London	66.2	1766
Manweb	57.9	1388
Midlands	94.2	2213
Northern	66.6	1394
Norweb	93.3	2126
SEEBOARD	61.7	1842
Swalec	47.9	963
Sweb	63.7	1405
Yorkshire	80	2000
ScottishPower	70.5	1925
Hydro-Electric	48.6	881
Omitted data points		
Eastern	73.7	3043
Southern	63.4	2554

Source: Ofgem

The full results of the OLS regression analysis are provided in Figure A4.

Figure A4: OLS regression statistics, 1997/98 data

Multiple R	0.89
R Squared	0.79
Adjusted R Squared	0.77
Standard Error	7.29
Observations	12

	Coefficients	**Standard Error**	**t-statistic**	**P-value**	**Lower 95%**	**Upper 95%**	**Lower 95%**	**Upper 95%**
Intercept	20.99	8.10	2.59	0.03	2.96	39.03	2.96	39.03
Customers	0.029	0.005	6.17	0.0001	0.02	0.04	0.02	0.04

Source: CEPA

ANNEX 5: APPLYING THE 1999 METHODOLOGY TO 2001/02 DATA – DATA ANNEX

Detailed results of the OLS regression analysis are provided in Figures A5 to A8.

Figure A5: OLS regression statistics, 2001/02 data, 1999 methodology, all data

Multiple R	0.48
R-squared	0.23
Adjusted R-squared	0.17
Standard Error	14.45
Observations	14

	Coefficients	Standard Error	t-statistic	P-value	Lower 95%	Upper 95%
Intercept	32.84	12.54	2.62	0.02	5.51	60.17
Customers	0.012	0.006	1.90	0.08	-0.002	0.03

Source: CEPA

Figure A6: OLS regression statistics, 2001/02 data, 1999 methodology, excluding most efficient firm

Multiple R	0.73
R-squared	0.54
Adjusted R-squared	0.50
Standard Error	11.51
Observations	13

	Coefficients	Standard Error	t-statistic	P-value	Lower 95%	Upper 95%
Intercept	16.15	11.62	1.39	0.19	-9.43	41.73
Customers	0.02	0.006	3.59	0.004	0.009	0.04

Source: CEPA

Figure A7: OLS regression statistics, 2001/02 data, 1999, excluding most and least efficient firms

Multiple R	0.78
R-squared	0.62
Adjusted R-squared	0.58
Standard Error	8.69
Observations	12

	Coefficients	Standard Error	t-statistic	P-value	Lower 95%	Upper 95%
Intercept	19.53	8.85	2.21	0.05	-0.19	39.24
Customers	0.02	0.005	4.003	0.003	0.008	0.03

Source: CEPA

Figure A8: OLS regression statistics, 2001/02 data, ex two most efficient firms

Multiple R	0.83
R-squared	0.69
Adjusted R-squared	0.66
Standard Error	9.93
Observations	12

	Coefficients	Standard Error	t-statistic	P-value	Lower 95%	Upper 95%
Intercept	6.61	10.94	0.60	0.56	-17.76	30.98
Customers	0.03	0.006	4.70	0.0008	0.01	0.04

Source: CEPA

ANNEX 6: THE IMPLICATION OF USING ALTERNATIVE METHODOLOGIES – DATA ANNEX

This annex contains the detailed results for the analysis carried out in section 5.

A6.1 COLS

Detailed results of the COLS analysis for 2001/02 data for all 14 data points are provided in Figure A9.

Figure A9: COLS regression statistics, 2001/02 data, all data

Multiple R	0.48
R-squared	0.23
Adjusted R-squared	0.17
Standard Error	14.45
Observations	14

	Coefficients	Standard Error	t-statistic	P-value	Lower 95%	Upper 95%
OLS intercept	32.84	12.54	2.62	0.02	5.51	60.17
COLS intercept	21.73	-	-	-	-5.60	49.06
Customers	0.012	0.006	1.90	0.08	-0.002	0.03

Source: CEPA

A6.2 SFA

Detailed results of the SFA analysis for 2001/02 data using log forms of the data and a truncated normal distribution for the noise term are set out in Figure A10.

Figure A10: Detailed results, SFA log form, 2001/02 data, all firms

Model specification			
Observations	14		
Error distribution	Truncated normal		
Results			
	Coefficient	***Standard error***	***t-ratio***
Constant	-0.78	2.70	-0.29
Composite variable	-0.38	0.36	-1.05
sigma-squared	0.08	0.040	2.05
gamma	1.00	0.08	12.33
log likelihood function	2.33		

Source: CEPA

ANNEX 7: ASSESSING THE COMPOSITE VARIABLE – DATA ANNEX

Figure A11 contains the data on the composite variable calculated for each of the nine weight scenarios.

Figure A11: Implied values of the composite variable under alternative weighting systems

Adjusted customer no. '000s, 2001/02	1999 methodology – final weights	1999 methodology – initial weights	2-variable composite 1	2-variable composite 2	2-variable composite 3	Customer no. only	Units distributed only	Network length only	Average DEA weightings
Wgt on customer nos	50%	70%	0%	50%	50%	100%	0%	0%	21%
Wgt on units distributed	25%	15%	50%	0%	50%	0%	100%	0%	43%
Wgt on network lgth	25%	15%	50%	50%	0%	0%	0%	100%	36%
Value of composite variable									
Eastern	3238	3092	2962	3004	3094	31356	3043	8930	2994
East Midlands	2422	2313	2333	2207	2422	2310	2543	6585	2332
London	1884	1862	1545	1476	2061	2001	2128	2980	1675
Manweb	1439	1390	1406	1419	1364	1387	1346	4543	1390
Midlands	2273	2233	2192	2078	2356	2256	2465	5950	2214
Northern	1417	1427	1331	1405	1389	1472	1311	4189	1352
Norweb	2191	2163	2063	2032	2229	2211	2255	5801	2097
SEEBOARD	1878	1951	1593	1769	1923	2108	1744	4475	1704
Southern	2673	2596	2484	2472	2647	2650	2653	7181	2519
Swalec	1020	970	961	1008	923	977	872	3253	953

Adjusted customer no. '000s, 2001/02	1999 methodology – final weights	1999 methodology – initial weights	2-variable composite 1	2-variable composite 2	2-variable composite 3	Customer no. only	Units distributed only	Network length only	Average DEA weightings
Sweb	1423	1378	1495	1501	1316	1332	1304	5230	1440
Yorkshire	2072	2034	1941	1914	2094	2079	2116	5475	1973
ScottishPower	1978	1894	2002	1946	1896	1853	1945	6384	1957
Hydro-Electric	897	774	1104	1041	691	636	749	4525	975

Source: Ofgem data, CEPA calculations

ANNEX 8: COST DRIVERS – DATA ANNEX

The raw data and detailed results for the analysis contained in section 7 are set out below.

Figure A12: Raw data for cost driver analysis

	Area	Network length	Network overhead	Network underground	Units HV	Units LV1	Units LV2	Units LV3	Network losses	Customer no	Interruptions	Mins lost
	km²	km	km	km	GWh	GWh	GWh	GWh	GWh	'000s		
Eastern	20,300	91,292	35,002	56,290	8,107	6,791	3,884	14,754	2,263	3,382	344,987	271,202
East Midlands	16,000	68,002	23,263	44,739	10,569	5,326	2,702	8,855	1,613	2,422	190,863	224,546
London	665	30,438	41	30,397	6,097	915	942	17,031	1,679	2,084	80,469	88,095
Manweb	12,200	45,872	21,668	24,204	4,398	732	753	8,624	1,301	1,434	73,990	89,648
Midlands	13,300	60,492	24,283	36,209	10,020	1,714	1,795	12,839	909	2,299	284,065	289,423
Northern	14,400	39,610	15,023	24,587	3,629	644	648	9,229	945	1,511	141,486	136,063
Norweb	12,500	58,031	13,747	44,284	7,916	1,168	1,656	13,666	1,001	2,270	128,136	146,201
SEEBOARD	8,300	45,365	12,235	33,130	2,781	3,070	2,131	10,910	1,431	2,112	197,039	204,135
Southern	16,900	73,804	27,712	46,092	8,246	1,412	2,548	17,810	2,143	2,706	279,213	245,871
Swalec	11,800	33,021	18,465	14,556	2,695	440	464	5,967	578	1,041	125,719	95,562
Sweb	14,400	48,795	29,437	19,358	3,657	1,257	1,638	7,884	978	1,357	145,269	116,679
Yorkshire	10,400	56,185	15,777	40,408	8,131	1,114	1,121	12,320	1,185	2,143	168,826	117,379
ScottishPower	22,950	65,597	24,460	41,137	4,898	1,174	2,656	11,688	1,466	1,906	145,409	166,742
Hydro-Electric	54,390	45,004	30,672	14,332	1,184	1,694	1,995	3,101	740	673	83,947	96,568

Source: Ofgem

Figure A13: Manipulated data for cost driver analysis

	% network underground	% units HV	% units LV1	% units LV2	% units LV3	% losses	Customer density	Interruptions / customer	Mins lost / customer	Energy density
	%	%	%	%	%	%				GWh/km2
Eastern	61.7%	24.2%	20.2%	11.6%	44.0%	6.7%	0.17	102.0	80	1.65
East Midlands	65.8%	38.5%	19.4%	9.8%	32.3%	5.9%	0.15	78.8	93	1.72
London	99.9%	24.4%	3.7%	3.8%	68.2%	6.7%	3.13	38.6	42	37.57
Manweb	52.8%	30.3%	5.0%	5.2%	59.4%	9.0%	0.12	51.6	63	1.19
Midlands	59.9%	38.0%	6.5%	6.8%	48.7%	3.4%	0.17	123.5	126	1.98
Northern	62.1%	25.6%	4.6%	4.6%	65.2%	6.7%	0.10	93.7	90	0.98
Norweb	76.3%	32.4%	4.8%	6.8%	56.0%	4.1%	0.18	56.5	64	1.95
SEEBOARD	73.0%	14.7%	16.3%	11.3%	57.7%	7.6%	0.25	93.3	97	2.28
Southern	62.5%	27.5%	4.7%	8.5%	59.3%	7.1%	0.16	103.2	91	1.78
Swalec	44.1%	28.2%	4.6%	4.9%	62.4%	6.0%	0.09	120.7	92	0.81
Sweb	39.7%	25.3%	8.7%	11.3%	54.6%	6.8%	0.09	107.1	86	1.00
Yorkshire	71.9%	35.8%	4.9%	4.9%	54.3%	5.2%	0.21	78.8	55	2.18
ScottishPower	62.7%	24.0%	5.8%	13.0%	57.2%	7.2%	0.08	76.3	87	0.89
Hydro-Electric	31.8%	14.8%	21.2%	25.0%	38.9%	9.3%	0.01	124.7	143	0.15

Source: CEPA calculations

ANNEX 9: FURTHER ISSUES – DATA ANNEX

A9.1 Benchmarking total costs

The detailed results of the regression analysis conducted for totex detailed in section 8.1 are set out below.

Figure A14: Totex regression results, 2001/02 data – all firms

Multiple R	0.87
R-squared	0.76
Adjusted R-squared	0.74
Standard Error	23.71
Observations	14

	Coefficients	Standard Error	t-statistic	P-value	Lower 95%	Upper 95%
Intercept	61.6	20.58	2.99	0.01	16.79	106.48
Composite	0.06	0.010	6.10	4.68×10^{-5}	0.04	0.09

Source: CEPA

Figure A15: Totex regression results, 2001/02 data – excluding two most efficient firms

Multiple R	0.88
R Squared	0.78
Adjusted R Squared	0.76
Standard Error	20.75
Observations	12

	Coefficients	Standard Error	t-statistic	P-value	Lower 95%	Upper 95%
Intercept	41.08	22.85	1.80	0.10	-9.83	91.99
Composite	0.08	0.01	5.98	0.00	0.05	0.10

Source: CEPA

Figure A16: Totex regression results, 2001/02 data – excluding most and least efficient firms

Multiple R	0.91
R Squared	0.82
Adjusted R Squared	0.81
Standard Error	20.96
Observations	12

	Coefficients	Standard Error	t-statistic	P-value	Lower 95%	Upper 95%
Intercept	37.10	21.34	1.74	0.11	-10.44	84.64
Composite	0.08	0.01	6.81	0.00	0.05	0.10

Source: CEPA

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