Choice of model and availability of data for the efficiency analysis of Dutch network and supply businesses in the electricity sector

Background report accompanying ‘Guidelines for price cap regulation in the Dutch electricity sector’

February 2000

Netherlands Electricity Regulatory Service

Disclaimer

Between October 1999 and February 2000 the consulting firm Frontier Economics was commissioned by the Netherlands Electricity Regulatory Service (DTe) to determine which models are suitable for analysing the efficiency of electricity companies in the Netherlands. This document reports their conclusions and recommendations. This survey was not intended to determine the efficiency of individual companies. The individual test results included in this report have an illustrative significance only and are intended to demonstrate the operation of the models.

Some of the data provided by the companies to date are of poor quality. DTe further notes that very low efficiency scores (e.g. of less than 50%) appear highly improbable at first glance. These call for a cautious interpretation and will be investigated in detail in the final analysis of the individual efficiency scores. The final data of the required quality (defined and audited by independent auditors) will become available to DTe in early April. DTe will use these data to analyse the actual efficiency of the companies in April and May 2000.

Although DTe and Frontier Economics benefited from the advice and comments of the industry contact group in the course of this survey, DTe bears full responsibility for the contents of this report. The members of the Contact Group were not asked to approve the contents of this report.

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Content

1. Introduction

The Netherlands Electricity Regulatory Service (DTe) is in the process of introducing price controls for the Dutch electricity sector. A key element of the new system is that electricity company charges will be controlled by an efficiency discount (X-factor). The X-factors will take effect from 1 January 2001 and will be determined partly on the basis of an efficiency analysis.

Efficiency analysis, or benchmarking, is a key element in the information and consultation document that DTe published on 20 July 1999.[1] Chapter 5 of that document describes the various methodologies that can be applied. Given the importance of the efficiency analysis, DTe envisages a period of consultation on the data and models that will be used to estimate efficiency and productivity for regulatory purposes.

This report covers the availability of data and the choice of models. On the basis of the investigations to date, DTe will send the companies an official request for data for final benchmarking purposes in early March. Final benchmarking will take place between 1 April and 31 May.

The report starts with a brief outline of the background to the efficiency analysis (Chapter 2), followed by a description of the methodological approach (Chapter 3). Chapter 4 contains a more in-depth discussion of the results of applying this methodology and data to the network companies. Chapter 5 covers the same process in relation to the national grid company, TenneT, and Transmissie Zuid Holland (TZH). Finally, Chapter 6 contains a number of conclusions and describes the way forward to the next phase of the efficiency analysis.

The results presented in this report are preliminary and DTe acknowledges that more analysis will be required before final conclusions can be drawn about the efficiency of the companies.

DTe would like to express its appreciation for the efforts of the Contact Group and the industry so far and will continue to seek the active involvement of the companies in the regulatory process.

Some of the companies have expressed reservations about the publication of preliminary analysis data. However, given its duty to maintain a transparent regulation system, DTe feels that publication is appropriate. DTe bears sole responsibility for the publication of this report.

1 Price cap regulation in the Dutch electricity sector. Information and consultation document, July 1999, Netherlands Electricity Regulatory Service.

2. Benchmarking and incentive regulation

In the July 1999 Consultation Document, DTe signalled its desire to move to a system of yardstick competition, preferably from the start of the second regulatory period (in 2004) in the case of the network companies. In the long run, under such a system all businesses can expect to deal with the same forward-looking X factor, equal to the expected rate of technological progress. Moreover, businesses can expect past efficiency gains to be passed on to consumers through an identical industry-wide price cut for all businesses, equalling the average industry out-performance of the previous control. This regime provides strong incentives for companies to beat the industry yardstick, which has the effect of driving the yardstick naturally to the frontier level of costs.

The problem with implementing this scheme immediately is that the companies are unlikely to all be equally efficient. Unless corrections are made for efficiency differences, in practice such a regime will result in windfall gains for inefficient companies that can easily catch up with the frontier, whilst efficient companies suffer financially, because average productivity growth in the industry will outstrip the rate at which they can push towards the frontier. Consequently, the aim of the benchmarking analysis is to establish with reasonable confidence the cost and price differentials that would exist if the distributors were equally efficient, as a basis for the determination of the X factors in the first regulatory period, and to ensure that yardstick competition can be applied in the following price review.

In addition to identifying the relative efficiency of the Dutch network companies, the benchmarking exercise should also provide valuable information on the speed at which the efficiency frontier has moved over recent years. While this information will be useful in helping to determine appropriate X factors, international evidence will also be examined as part of the process.

For the licensed electricity suppliers, the liberalised market will provide appropriate incentives to purchase electricity efficiently and undertake customer-related activities at the lowest possible costs. However, whilst part of the market is still monopolised, prices need to be regulated. The Guidelines document, to which this report provides background information, contains a description of the yardstick mechanism that DTe plans to introduce for purchasing costs. For network companies, the importance of benchmarking will recede as the efficiency benefits are passed on to consumers in electricity charges.

The situation for TenneT is a little more complex. It may not be possible to apply the yardstick competition model that DTe proposes to use for the network companies to TenneT, as TenneT's prices would be explicitly and automatically linked to the performance of transmission businesses outside the Netherlands through the yardstick mechanism.

Potentially, TenneT and the high voltage transmission businesses of the regional network companies could probably be grouped in a single category to permit the application of a yardstick competition system. If this cannot be achieved, then the regulated charges can be determined on the basis of comparative data. However, the distribution of efficiency gains to consumers cannot be determined automatically, in the manner that is intended for the network companies. Consequently, benchmarking analysis is likely to be a permanent feature of TenneT's price reviews.

Finally, it is important to stress that DTe is not proposing to adopt a mechanistic approach to the determination of X factors for the companies, based solely on efficiency scores from a benchmarking exercise. The values of the X factors will be based on a number of important and interrelated issues, including the valuation of the regulatory asset base (RAB) and acceptable thresholds for a number of financial ratios. The determination of the X factors is discussed in more detail in the `Guidelines' document.

3. Methodological approach for efficiency analysis

3.1 Introduction

Benchmarking involves identifying a suitable set of companies to which each individual regulated utility can be compared. These companies are known as comparators. This is not a straightforward exercise, because no two utility companies are exactly alike. They all have different output levels and output mixes, and operate under different environmental conditions. These differences mean that efficient cost levels are unlikely to be identical for each utility. However, benchmarking methods that model some of the differences can be used, providing that the differences between the comparator companies are not excessive. It is important that the group of comparators should include the most efficient reference companies. Otherwise the relative performance of the regulated utilities will be exaggerated, X factors will be set too low and consumers will not benefit from the larger cost savings that are quite feasible, but are not identified by the benchmarking exercise.

Three separate benchmarking exercises need to be performed: one for TenneT, one for regional network companies and one for licensed supply companies. Benchmarking for TenneT involves identifying a set of comparator companies in other countries. This means that detailed information must be gathered on other transmission system operators (TSO's) in Europe and the US. For regional networks and suppliers, the comparator group includes all the Dutch regional network companies and suppliers. These companies are obviously all engaged in similar activities. They lend themselves to comparison by virtue of the fact that they operate in the same country, under the same physical conditions and to the same accounting standards. DTe still intends to use relevant data on regional networks and supply from other countries, in as far as necessary.

The July 1999 Consultation Document described a number of benchmarking methods. These differ in terms of the calculation of the relevant benchmark and consequently, in their data requirements. The techniques identified in the July 1999 Consultation Document are:
Uni-dimensional measures of performance (or performance indicators).
Tornqvist measures of total factor productivity.
Regression analysis such as corrected least squares (COLS) or stochastic frontier analysis.
Data envelopment analysis (DEA).
Malmquist measures of total factor productivity.

The July 1999 Consultation Document described each approach in some detail and invited responses on whether any of the benchmarking methodologies should be given preference. The companies did not express any particular preference for a certain method. Most considered it far more important to ensure that the benchmarking methods used by DTe are easy to understand, and that they would be able to verify DTe's analyses for themselves. Others warned of the difficulties that DTe could face in obtaining reliable results from a benchmarking exercise, given the rapid changes in the industry. From the start, DTe has sought the constructive involvement of the companies in the benchmarking process, and will continue to do so in the future. This should help to ensure that the data on which the analysis is based is reliable and that the results are comprehensible.

The preliminary benchmarking analysis that we report in this document has revealed the extent to which the availability of data restricts the range of approaches that can be adopted. Only a single year of data has been made available so far, which clearly rules out total factor productivity analysis over time. However, the network companies seem likely to provide more time series data, permitting some productivity growth analysis. As soon as these data become available, there are plans to compile a Malmquist productivity index, based on weighted DEA.

The sample size for network companies is also restricted, in a cross-sectional sense as well as over time. There are only about 20 Dutch network companies, which tends to limit the usefulness of regression analysis. Regression techniques that estimate relationships between costs and cost drivers, such as customer numbers or customer density, can produce misleading results in small sample sizes. If one or two companies in a small sample have a particular characteristic in common and are also unusually inefficient, then regression analysis will indicate that this characteristic is a cost driver – because it is statistically correlated with high costs. In a sample of 20 companies, it is quite possible that such spurious correlations will arise. Stochastic Frontier Analysis is still more vulnerable to the effect of small sample sizes, since the decomposition of variation into random and efficiency-related components requires a large number of data points to be statistically significant. In the course of the next phase of the analysis, improvements in the quality of the data might enable us to compare Dutch companies with those in other countries.

While all methods are less effective with smaller sample sizes, DEA techniques are less data-intensive than econometric methods. The data restrictions therefore lead us to adopt a DEA approach as our principal methodology to estimate efficiency. Since model selection is not based upon econometric tests, an alternative process is needed to select the variables for the efficiency analysis. This is discussed in more detail later in this section. An overview of DEA and Malmquist linear programming can be found in Annex 4.

Despite the fact that a fairly large sample exists for the transmission businesses, the DEA approach has been retained for the efficiency analysis of TenneT. This is because this approach has maximum discriminatory power that enables both DTe and TenneT to identify the key determinants of measured efficiency, which can lead to further refinement of the data used for the analysis. An example of the value of this approach for regulatory purposes is the variation in TenneT's efficiency score, depending upon whether national output or company output is used. This prompts a deeper consideration of the definition of the analysis outputs, which will improve the reliability of the results.

3.2 Procedure for the performance of benchmarking exercises

The July 1999 Consultation Document describes the following procedure for the efficiency analysis:

- Identify a comparator group of companies.
- Identify the range of methodologies.
- Identify the inputs, outputs and environmental variables to be included in the analysis.
- Collect data on a consistent basis.
- Conduct the analysis.

Each of these points is discussed in more detail below

3.2.1 Identifying the comparator group

The comparator group for the network companies has been identified as the Dutch network companies, although UK data will be used if further comparators are required in order to benchmark certain companies with unusual characteristics. For TenneT, an international sample has been assembled and a preliminary analysis has been performed. An accurate definition and measurement of TenneT's output is needed in order to compare TenneT with other operators.

3.2.2 Identifying the methodology

As discussed above, the DEA methodology has emerged as the most appropriate approach, given the data limitations. DEA is an extension of simple ratio analysis, rigorously generalised to handle multiple outputs and inputs. The objective of this technique is to envelop the data by constructing a production possibility set, including all the inputs and outputs defined by the company. The efficient frontier is defined by those observations that cover all the other output/input relationships. Companies that are not at the frontier are ranked according to their distance from it.

Within the general DEA approach, there are a variety of frontiers to choose from. Figure 1 below shows the best practice frontiers that a regulator or regulated company can select to advance their respective cases in regulatory proceedings. The example is based on six companies, A, B, C, D, E and

F, that (for the sake of simplicity) each realise the same output volume, from two inputs: capital (K) and labour (L).

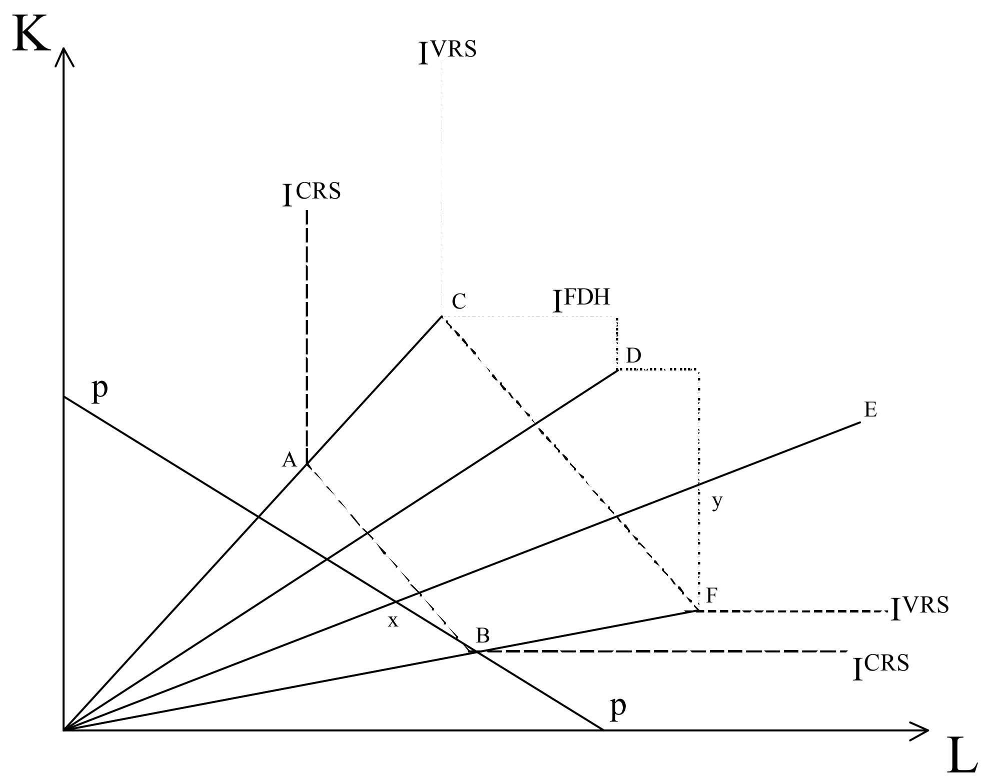
The first frontier, PP, is determined by company B, which incurs the lowest costs. Given the relative prices of capital and labour (dictated by the steepness of line PP), none of the other five companies produces its output as cheaply as company B. Company A uses fewer labour units, but more capital units and, given the relative prices of capital and labour, incurs higher costs than company B. This is the productively efficient frontier at which companies are both technically efficient (using the least inputs) and allocatively efficient (using inputs in the best proportions, given their relative prices).

Contrast this frontier with the frontier labelled I^{CRS}. This frontier is defined by the lowest ratio pairs. Company B has the lowest use of capital, relative to output, and company A has the lowest use of labour. Consequently, the frontier is defined as the linear combination of those two input levels. This is the technically efficient frontier, and differs from the productively efficient frontier defined above because it does not require company A to be allocatively efficient in its use of inputs.

A third frontier is labelled I^{VRS}. This frontier recognises that not all companies may be operating at their minimum efficient scale. DEA analysis assuming variable returns to scale would treat companies C and F as efficient, given their size, as are any combination of labour and capital inputs between points C and F.

The fourth frontier is the free disposal hull (FDH) frontier. This model adopts the least restrictive set of assumptions required to put a company on the frontier. In this case, there is no direct comparator for company D on the line defined by points A and B, or by C and F, and it is therefore deemed to be efficient. In other words, since D is more efficient than F in the use of labour, and more efficient than C in the use of capital, then it must be treated as if it were equally efficient to those two companies. Under the other DEA frontiers we have described, companies not on the frontier can be compared with virtual companies (i.e. a weighted combination of existing companies) and found to be inefficient. This is not the case with the FDH frontier.

Figure 1: ***Alternative best practice frontiers***



The foregoing clearly shows that the choice of frontier model has a very significant impact on a company's efficiency score. Consumers will benefit most if the regulator uses a model in which only productively efficient companies, that operate at efficient scale and with the right mix of inputs, would be classified as `efficient'. In this case, consumers will not have to pay higher prices to `subsidise' inefficient input choices and companies that are not operating at the minimum efficient scale. Companies, on the other hand, benefit most if the regulator uses models that more closely envelop the data. As we move from the frontier defined by PP to the one defined by I^{FDH}, we move from one company out of six being classed as efficient to five companies out of six being classed as efficient. Moreover, the one inefficient company left, company E, has had the measured level of its efficiency increase from $0x/0E$ to $0y/0E$. In other words, its efficiency has more than doubled. So which frontier should actually be adopted? Although no general rules exist, a number of factors should guide the final choice.

FDH-models

With the use of the FDH frontier, companies are only compared to existing companies. While this might appear to be a desirable feature (since the comparators are well known), there is one major drawback. With small sample sizes, most companies are found to be efficient by default, simply because there is no comparator in the sample with the same input/output combinations. Only in very large samples will the FDH frontier retain discriminatory power. Furthermore, in a regulatory context, FDH methods are justifiable only if companies are locked into particular input/output combinations, and cannot improve upon them. Thus, in the context of Figure 1 above, if company D is to be deemed efficient, it must maintain that it is unable to shed either labour or capital (in order to move to a point between C and F). This is equivalent to arguing that all linear combinations of labour and capital between points C and F are foreclosed to the companies, which is highly implausible in all but the most extreme cases.

Constant or variable returns of scale?

The arguments for using models with variable returns on scale (as opposed to constant returns) are more finely balanced. If the scale is fixed, then it is clearly unfair to penalise companies that are constrained to operate at levels above or below an efficient scale. However, within the regulated environment in the Netherlands, companies can determine their scale for themselves. The obvious first step to resolving the issue is to estimate DEA models under both CRS and VRS, to establish whether a problem actually exists. If a company appears to be inefficient under CRS but efficient under VRS, then this may be due either to genuine inefficiency, or to operation on an inefficiently large or small scale. Larger samples provide enough comparators to answer this question. In smaller samples, this can be far more difficult, however.

It would be useful to gather more evidence on this point. Our preliminary analysis suggests that certain companies only appear efficient if one assumes that there are substantial diseconomies of scale beyond a certain size. However, most international evidence suggests that the electricity distribution business is characterised either by constant returns on scale or moderately increasing returns on scale. If these results persist when better data becomes available, then companies will have to present DTe with extremely persuasive evidence to avoid being classified as inefficient.

We conclude that as yet, there is no reason why consumers should be asked to pay higher bills because their distributor continues to operate at an inefficient scale.

Technical or productive efficiency measurement

The choice of whether to estimate technical efficiency or productive efficiency is often determined by data considerations. The outputs of an electricity distributor consist of energy delivered, quality standards achieved, maximum demand met and consumers served, with capital and labour as inputs. The model can then be complicated by the inclusion of control variables to reflect geographical and demographic factors.

Rather than use the physical inputs for capital and labour, we could choose to use monetary measures. Using labour input, for example, omits other physical inputs used in the maintenance and operation of distribution systems and, of course, is subject to changes in contracting-out policies. Consequently, it may be preferable to use data on operating expenditure as a measure of the amount spent to maintain and operate the system. It could also be preferable to use monetary measures of capital costs (in this case, depreciation and return on capital) rather than physical measures. Physical measures do not tend to capture the real resource costs of refurbishment or replacement. Instead, movements in these inputs over time tend to reflect only the extent to which network coverage has expanded. Monetary measures of capital costs can suffer from inconsistency if one simply takes the book asset value and depreciation reported by the companies. The data we have received from the companies therefore include financial cost measures for operating and capital expenditure. In the next stage of the benchmarking analysis, attempts will be made to derive consistent measures of capital costs from the data provided

3.2.3 Identification of the inputs, outputs and environmental variables

As noted above, since model selection could not based upon econometric tests, an alternative process is required for the selection of variables. We outline the steps in such a process below:

- Evaluate DEA models to obtain estimates of inefficiency based upon inputs (costs) and outputs (kWh, number of consumers, maximum demand, quality of service).
- Encourage the industry to identify the environmental factors that may cause their efficiency score to be understated, and to provide relevant data.
- Identify whether these variables cause efficiency scores to change and try to find new comparators for those companies.
- Based on this process, isolate the factors that cause companies that emerge as inefficient in most specifications to appear efficient in one specification.

- If a number of companies define the frontier, use the procedure developed by Andersen and Petersen[2] to rank efficient companies by evaluating the extent to which inputs could be increased whilst still keeping the company on the frontier.

In this way, the regulator is assuming, as a first step, that companies should be equally efficient in producing the outputs valued by consumers and, if they are not, must provide convincing arguments as to why they may not be. These arguments can then be evaluated on data that the companies provide. It is clear that this process can encourage companies to provide more data and to justify their arguments rigorously. This comparative information, in turn, provides regulators with the opportunity to further improve regulatory policy. The efficiency analysis currently underway makes provision for such a process. These data are expected in March 2000 and should make it possible to enhance the reliability of the analysis.

3.2.4 ***Collect data on a consistent basis***

The data already received from the companies has been prepared on a reasonably consistent basis for the P_0 exercise. The preliminary analysis has revealed the most important data issues to be resolved. These have been reported to the industry, and further data will be forthcoming over the coming month. The regulator intends to collect data regularly from the companies to facilitate on-going monitoring of efficiency in the industry. Data collection costs are low in relation to the benefits of more accurate assessment of relative performance, and as the data relates to regulated natural monopolies, there is no reason why it should not be published and made available more widely for independent analysis. DTe expects regulated companies to introduce data collection systems that will ensure that the data required for benchmarking analysis are collected on a regular basis and are made available to DTe in good time. The data will be subjected to external audits.

3.2.5 Conduct the analysis

The next stage of the analysis will be undertaken with the aid of the models and variables selected in this report. Working with the industry Contact Group, DTe hopes that the analysis can be further refined and improved. The involvement of the Contact Group has certainly enhanced progress so far. By continuing in this way, a set of efficiency scores can be derived that are robust enough to employ for tariff setting purposes.

[2] A procedure for ranking efficient units in Data Envelopment Analysis, by Per Andersen and Niels Christian Petersen. *Management Science*, Vol. 39, No. 10, October 1993.

4. Distribution and retail analyses

4.1 Introduction

In this section we describe the modelling of the regional network companies. This section is structured as follows. In subsection 4.2 we describe the models for which we have produced results. Then in section 4.3 we describe the data sources, and present results in section 4.4. In section 4.5 we summarise our findings and outline the way forward for future analysis.
Due to the limitations of the data, we have chosen to benchmark distribution and supply together. Providing that reliable data can be obtained for each separate activity, these will be benchmarked individually in future.

4.2 Models

This section describes the DEA models. The various models are outlined in Table 1, and we estimate them all under both CRS and VRS specifications. Ideally, we would seek to run further models, which include variables such as peak demand together with information on quality. However, at present these data are not readily available for a sufficiently large number of companies.

Table 1: Specification of DEA models

	Inputs	**Outputs**
Model 1	Opex	Units distributed Customer numbers
Model 2	Opex	Units distributed Small customer numbers Large customer numbers
Model 3	Opex	Units distributed Small customer numbers Large customer numbers Network length Transformer numbers
Model 4	Opex	Units distributed Small customer numbers Large customer numbers Network length Transformer numbers Network density
Model 5	Opex plus tangible depreciation	Units distributed Customer numbers

For each of these models, we have produced DEA scores compared to both a CRS and VRS frontier.

Model 1 is a simple model on which to benchmark companies, including only two potential cost drivers (units and customer numbers), although these are clearly key outputs for any distribution and supply company. Model 2 is similar to Model 1, but attempts to capture differences in the composition of each company's customer base, by splitting the number of consumers into two bands, large and small.

Model 3 builds upon Model 2 by including variables that proxy the dispersion of a company's customer base and the complexity of their network - network length and number of transformers. Increases in either of these might lead us to expect higher operating expenditure.

Model 4 incorporates another variable for network dispersion - network density, defined here as network length per customer. Model 5 is analogous to Model 1, but uses operating expenditure plus tangible depreciation as input, rather than just operating expenditure. This last model moves us towards a total cost benchmark, by including a measure of capital consumption. Since the measure we have used is the companies' own reported depreciation charge, the measured efficiency scores will reflect differences in accounting policy. In the next stage of the analysis it is intended to standardise the depreciation charge and include a cost of capital to derive a total cost figure on a consistent basis.

The incorporation of mains length and transformer numbers has a number of implications. First, they could be regarded as variables for customer dispersion in the absence of any other measures. Second, the efficiency scores determined with the aid of these 'outputs' could be interpreted as the efficiency with which companies maintain their existing network. The underlying argument for the latter interpretation is that in the short term, the network configuration is given, and the companies should be judged on their ability to manage that network, regardless of how the network was created.

Whilst either of these interpretations may be valid for cross-sectional analysis in a particular year, it should be emphasised that network configuration is not an output, at least not in the sense that companies should strive to maximise either network length or the number of transformers. The key outputs of a distribution business are the quality of service it provides, the throughput of kWh to customer supply points and the provision of sufficient capacity to meet maximum demand.

The inputs that are required to meet these outputs are the costs associated with maintaining, operating and refurbishing the network - the length of mains and number of transformers are therefore inputs into this process. Companies should certainly not infer that mains length and the number of transformers represent outputs of a distribution business in any conventional sense. The July 1999 Consultation Document, the Guidelines document and Chapter 2 of this report should make it sufficiently clear to companies that in future, a yardstick mechanism will apply to prices. This will provide a very strong incentive to companies to manage their networks and other operations efficiently and also to configure their networks efficiently over time.

4.3 Data sources

The results of a benchmarking exercise will only be as reliable as the data that underpins the analysis. In December 1999, Frontier Economics received the cost data collected from the companies by DTe that informed the setting of P_0 levels for 2000. Data was available only for 1996 (data for 1999 and estimates for 2000 will become available on the same basis over the next few months), but from these figures we were able to derive the following estimates of total distribution and supply costs:

- Operating expenditure; and
- Operating expenditure plus tangible depreciation

Where operating expenditure includes the following cost items from table 2 of the 1996 P_0 data:

- Materials
- Services
- Wage costs
- Other costs.

If any of these cost categories contain cost items which are beyond the control of the companies it would be appropriate to quantify these costs in order to remove them from the benchmarking exercise. This issue will be investigated further in the next phase of the work, and DTe would welcome the views of the companies. However, since most of the uncontrollable cost items (charges to other network operators, purchases of energy and so forth) have been eliminated from the cost base we do not expect the level of uncontrollable costs in the remaining cost base to be high.

Furthermore, the cost data for some of the companies include costs incurred for the performance of transmission activities. These costs should be removed for the purpose of benchmarking distribution. DTe has asked the companies to provide information on transmission costs[3] for the next phase of the benchmarking exercise.

While there appear to some gaps in the cost data contained in these datasets, this information, together with data on the physical characteristics of each company's distribution networks, nevertheless provides the first reliable dataset from which to draw conclusions on the comparative efficiency of the companies. One should bear in mind that these data were considered reliable enough to use as a basis for price setting for 2000, implying that consumers are already paying bills calculated on the basis of this allocation of costs. We have identified some of the issues that will require further investigation, and work will continue to investigate and correct the data as appropriate.

Given the data that we have, which we describe later in this section, we have modelled distribution and retail costs in aggregate rather than separately. It is anticipated that future analysis will be on an unbundled basis once a better understanding of the underlying data has been obtained.

A further innovation for the next stage of work is to include the cost of losses as an operating expenditure, in order to construct a consistent measure of capital costs.

Furthermore, we will also seek to expand the scope of the analysis to include other external variables that might be cost drivers for the companies. DTe would welcome suggestions on which variables should be included in this expanded analysis, together with practical suggestions on how the required data can be collected.

4.4 Results

The results for Model 1[4] are shown in Figure 1. The most efficient companies have a score of 1. The figure reveals a considerable spread of relative inefficiency among the companies. MEGA and Rendo define the efficient frontier with a second group having efficiency scores between 0.900 and 0.700. Most of the larger companies are in a third group of nine companies with DEA scores below 0.700. NRE and PNEM[5] score below 0.500. While scores below 0.500 might appear implausible, such differences in efficiency have been seen in a number of investigation into the comparative efficiency of network companies[6]. On the basis of these results, one would conclude that there is considerable scope for efficiency improvement, particularly for the larger companies.

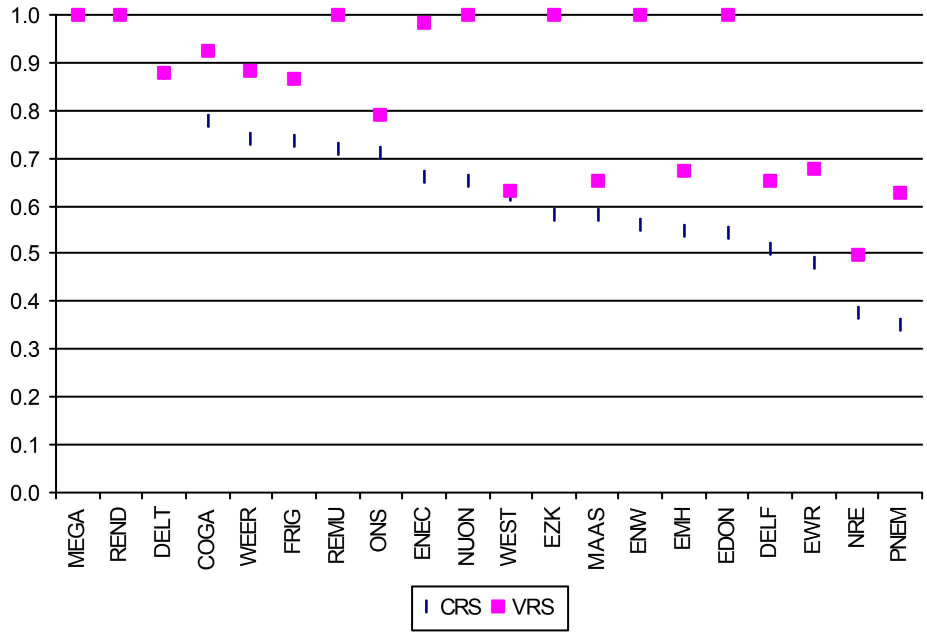
3 Operation of mains with a voltage of 110 kV or more.

4 Input: Opex; Outputs: Units, Consumers

5 The scores of some companies may depend on reporting differences. A method for dealing with this issue will be sought in the second phase of the work. PNEM, for example, does not have many cost categories in the Po tables, which implies that it may have involved cost elements in the OPEX measurements that other companies did not.

6 For example, during the 1999 Distribution Price Control Review in Great Britain, Offer presented analyses suggesting that a number of companies were only around 60% efficient.

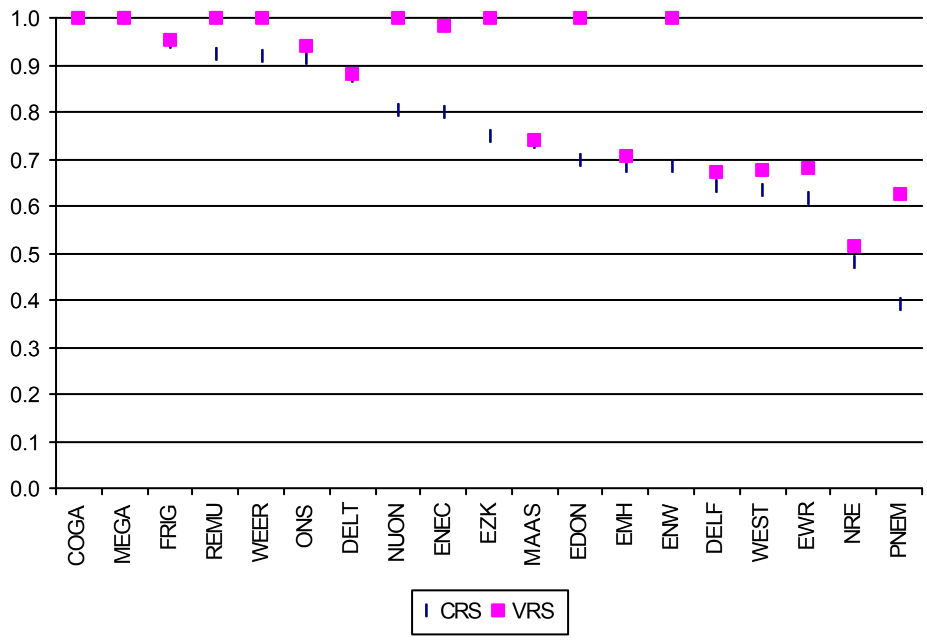
Figure 1: DEA scores for Model 1 (I: Opex; O: Units, Consumers)



Even with this simple model, seven companies from the sample of 20 define the efficient frontier under Model 1 assuming VRS. The group of efficient companies includes three of the larger companies that are shown to be inefficient under a CRS assumption (EDON, ENW and NUON). This could suggest substantial dis-economies of scale for larger companies.

Since Rendo appears to be considerably more efficient than any other company in the sample (with an Andersen-Petersen score of 1.302, implying inputs could be increased by 30% without moving this company from the frontier), we have also derived DEA scores for this sample excluding this company (see Figure 2). Removing Rendo from the dataset results in a small reduction in the spread of comparative efficiency. Since the change in DEA scores for other companies is not substantial, this suggests that Rendo is not necessarily an `outlier', and that there is a spread in operational costs, which remains to be explained.

Figure 2: DEA scores for Model 1, excluding Rendo (I: Opex O: Units, Consumers)



Source: Frontier Economics

In table 2 we report the CRS results of a number of alternative specifications that attempt to explain this wide spread in efficiency. One possible explanation for the spread identified in Model 1 is the differences between the customer base characteristics of each of the companies. For example, we would expect the costs of a company that predominantly serves large-scale (industrial or commercial) consumers to differ from one that serves small domestic consumers. Model 2 assesses relative efficiency on this basis. Under this specification, three companies define the efficient frontier (EDON, MEGA and Rendo). EDON moves to the frontier under this specification, since it supplies a relatively large proportion of high-demand consumers. However, a company primarily supplying large consumers might be expected to incur lower costs than a company primarily supplying small consumers. Therefore, these results do not necessarily imply that EDON can be regarded as efficient. In addition to moving EDON to the frontier, this model specification results in an increased spread of inefficiency compared to Model 2.

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Table 2: Summary of CRS DEA scores based on the P_0 dataset

	Model 1	Model 2	Model 3	Model 4	Model 5	Gemiddelde score
COGA	0.778	0.781	1.000	1.000	0.798	0.871
DELF	0.510	0.510	0.687	0.687	0.560	0.591
DELT	0.877	0.877	0.877	0.878	1.000	0.902
EDON	0.543	1.000	1.000	1.000	0.468	0.802
EMH	0.547	0.547	0.547	0.547	0.498	0.538
ENEC	0.662	0.663	0.663	0.663	0.741	0.678
ENW	0.561	0.561	0.561	0.561	0.590	0.567
EWR	0.480	0.483	0.533	0.533	0.498	0.505
EZK	0.583	0.588	0.588	0.855	0.728	0.669
FRIG	0.737	0.742	0.742	0.742	0.608	0.714
MAAS	0.583	0.585	0.585	0.585	0.663	0.600
MEGA	1.000	1.000	1.000	1.000	0.883	0.977
NRE	0.375	0.376	0.376	0.376	0.491	0.399
NUON	0.654	0.657	0.866	0.866	0.615	0.732
ONS	0.712	0.717	0.717	0.717	0.795	0.732
PNEM	0.352	0.353	0.389	0.389	0.563	0.409
REMU	0.721	0.721	0.721	0.721	0.553	0.687
REND	1.000	1.000	1.000	1.000	1.000	1.000
WEER	0.740	0.740	1.000	1.000	0.749	0.846
WEST	0.623	0.640	0.656	0.656	0.383	0.591

Model 3 includes additional variables to proxy the dispersion of companies' customers and the complexity of their networks. If a company's customers are dispersed or their networks unusually complex, then we might expect this company to incur higher levels of costs than others. Under this model, five companies define the frontier, although the general pattern of relative inefficiency is largely similar to that observed in Models 1 and 2. From this we draw the tentative conclusion that, while some companies can be found to be efficient by including variables which proxy customer base and network characteristics, many are shown to be inefficient under all the models presented so far.

Model 4 includes network density (defined as length of network per customer) as an explanatory factor, but this has little impact on the results. Model 5 is directly analogous to Model 1, except that the cost variable includes the companies' reported levels of depreciation. There are some significant differences in the results between the two models, particularly where PNEM and Westland are concerned. This indicates the need to establish consistent data on both the allocation between operating and investment expenditure, and on the capital cost component of total costs.

The choice of specification method (VRS or CRS) is also of some significance, as the VRS results in Table 5 clearly show. Of the five companies that define the CRS frontier in the most general operating expenditure model, three are small companies whilst two are larger ones. EDON, which can attribute its place on the CRS frontier to the inclusion of environmental variables (in particular splitting consumers into large and small categories) is also on the VRS frontier for the basic model 1. This suggests that if scale is an issue, in EDON's case it has been captured by the control variables. The same cannot be said for ENW and REMU, whose efficiency scores barely changed across the CRS specifications, but leap to the frontier on the basic VRS model. This suggests that if scale is an issue, it has not been picked up by the environmental factors. In order to maintain that these companies are indeed efficient, one must assume very substantial diseconomies of scale at large scale operation.

Other companies, such as COGAS and NUON lie between these extremes. Their CRS efficiency scores rose with the inclusion of network variables, and they are also more efficient on the basic VRS model. This, too, suggests a large unexplained size factor to justify their efficiency. One of the smallest companies is measured efficient on the VRS model, but is inefficient on the CRS model.

Table 3: Summary of VRS DEA scores based on the P_0 dataset

	Model 1	Model 2	Model 3	Model 4	Model 5	Gemiddelde score
COGA	0.923	0.925	1.000	1.000	1.000	0.970
DELF	0.652	0.652	0.798	0.798	0.766	0.733
DELT	0.878	0.878	0.878	0.879	1.000	0.903
EDON	1.000	1.000	1.000	1.000	0.919	0.984
EMH	0.674	0.674	0.682	0.682	0.640	0.670
ENEC	0.983	0.988	0.988	0.988	1.000	0.989
ENW	1.000	1.000	1.000	1.000	1.000	1.000
EWR	0.677	0.677	0.725	0.725	0.780	0.717
EZK	1.000	1.000	1.000	1.000	1.000	1.000
FRIG	0.864	0.869	0.869	0.869	0.750	0.844
MAAS	0.651	0.654	0.654	0.654	0.754	0.674
MEGA	1.000	1.000	1.000	1.000	1.000	1.000
NRE	0.498	0.499	0.499	0.499	0.712	0.542
NUON	1.000	1.000	1.000	1.000	0.976	0.995
ONS	0.792	0.797	0.797	0.797	0.916	0.820
PNEM	0.626	0.628	1.000	1.000	0.952	0.841
REMU	1.000	1.000	1.000	1.000	0.856	0.971
REND	1.000	1.000	1.000	1.000	1.000	1.000
WEER	0.884	0.884	1.000	1.000	0.849	0.923
WEST	0.632	0.645	0.749	0.848	0.384	0.652

4.5 Summary of benchmarking analysis and the way forward

We have presented DEA scores for the Dutch distribution and supply companies based on the P_0 dataset. Whilst these data are preliminary it should not be forgotten that this dataset informed the set of tariffs now being charged in the Netherlands. The analysis has been useful, both in defining new data requirements and in informing model selection. The following requirements have been identified for the data as such:

- To establish a consistent allocation of costs between operating and capital expenditure.
- To provide for a consistent measure of capital costs.
- To obtain a cost allocation between the transmission and distribution activities for those companies that undertake both.
- To extend the data to include figures for 1999 and (estimates for) 2000.
- To identify the need for further control variables to capture network characteristics, of which perhaps the most important may be the split between underground and overhead cables.

On the methodological issues the following comments are appropriate for defining the next stage of the analysis, to enable the analysis to make a useful contribution to the regulatory system:

- Where consistent arguments can be made for the inclusion of new control variables, and the data can be collected, these will be included in the model to evaluate their importance.

- CRS models are more appropriate than VRS models, given that we intend to continue to evaluate the importance of control variables. If a company is consistently inefficient in models where control variables are explicitly included, but efficient on VRS models, this suggests the presence of unexplained scale effects. It would simply be unacceptable for the consumers to pay for these when neither the regulator nor the company concerned can objectively justify to them why these effects exist.

Representatives of the companies in the Contact Group have stated that the dataset should attempt to capture all relevant information about each company's existing position. This should enable DTe to establish price controls that do not unfairly penalise companies for high costs attributable to factors that are beyond the company's control. DTe would welcome the views of the companies on the additional data required to make this judgement.

In summary, DTe is keen to ensure that the benchmarking process is regarded as transparent and inclusive. To this end, DTe hopes to receive submissions from the companies suggesting potential improvements to the analysis, in particular focussing on suggestions for environmental factors that should be included in the next stage. Such submissions would be helpful in highlighting any omissions in our analysis and should lead to a fair and well-understood set of conclusions.

5. Transmission efficiency analysis

5.1 Introduction

In this section we describe the modelling of the transmission companies. This section is structured as follows: in subsection 5.2 we describe the models we estimate, then in section 5.3 we describe the data sources, and present results in section 5.4. In section 5.5 we report some preliminary evidence of productivity growth over time, and in section 5.6 we summarise our findings and outline the way forward for future analysis.

It also describes how the analysis for the Dutch TSOs requires further analysis.

5.2 Models

In this section we outline the main assumptions underlying our comparative international analysis of TSOs (e.g. TenneT and TZH).[7] Further details are provided in Annex 1.

Table 4 identifies broad data requirements for the benchmarking of transmission companies. The intention of DTe is to benchmark the efficiency of transmission system operation while a separate benchmark is to be applied to the purchasing of ancillary services (for voltage and frequency control, black start capability). The ancillary services benchmark is not part of this study

Table 4: Preferred DEA model specification for electricity transmission

Inputs	**Outputs**	**Proxies for environmental factors or control variables**
Cost	Units transmitted [GWh/a]	Area
	Maximum demand [MW]	Population density
	Generation capacity connected [MW]	Mains length [km]
	Quality of service	Transformer capacity [MW] Transformers [no], Grid connection points [no]
		Share of underground cables [%]

In our analysis we use information on selected TSOs from Europe and the US. We employ a simple model that uses cost (as defined below) as input and units transmitted and maximum demand as the key output variables. Mains length (measured in terms of circuit km) and the number of transformers (where available) are used as criteria for environmental conditions and network complexity.[8]

Formally we treat mains length and number of transformers as additional output variables. However, mains length and the number of transformers must be modelled with care. After all, these are not outputs that ought to be maximised, as this could give adverse incentives to TSOs to inefficiently expand these assets.

7 TZH was originally classified as a network company, but at its own request, was ultimately benchmarked as a TSO, alongside TenneT.

8 In this regard network length and transformer numbers capture network complexity both in terms of geographical conditions (longer circuit length indicates more complex geographical conditions) and in terms of likely quality (that is, a grid with high redundancies is likely to be more reliable).

5.3 Data

5.3.1 Costs

Two major issues arise in definition of cost:

- The identification of transmission related activities and consequently transmission cost
- The valuation of cost identified as being transmission related.

TSO cost base

In the cost base to be benchmarked we include:

- The cost for transport in a broad sense, comprising:
  - Provision of system services relating to transmission use (transmission in a narrow sense) for energy/load including the `transmission' of ancillary services
  - Connection of power plants (`capacity'), distribution systems and large consumers (`loads')
  - Interconnection with neighbouring transport systems
  - Metering and information management for use of system.

- Cost of system control (dispatch of generation/ancillary services)[9]

This implies that we explicitly exclude:

- The cost of energy losses
- The purchase cost of ancillary services
- The cost of services to power exchanges.

Cost valuation issues

Cost valuation issues in an international comparison arise in a number of ways. We summarise the assumptions used below. For a more detailed explanation, we refer to Annex 2.

Exchange rates

To convert cost from national currencies into Dutch Guilders [NLG] we used foreign exchange rates prevailing in October 1999. (Are shown in Annex 2).

Wage rates

We have corrected personnel costs for wage rate differentials where possible, to take account of the fact that labour costs tend to be higher in the Netherlands than elsewhere. The re-scaling factors applied to labour cost are shown in Annex 2. As all correction factors are at or below 1.0, we nominally increased the labour cost of foreign companies. We have not re-scaled the wage cost of German TSOs (these would have to be scaled down) which favours the relative efficiency position of Dutch companies. We have also refrained from applying the wage cost adjustment to the US data, as transparent re-scaling of labour costs for US companies was not possible.

Capital cost

Current cost depreciation and a return of 6.5% on the net current cost asset base together constitute the cost of capital. As described more fully in Annex 2, we have estimated capital cost in current cost terms in a consistent format for all companies, on the basis of historic cost information.

Allocation of overhead costs

For European TSOs, we eliminated only the direct cost (and not the overhead cost) for the benchmark analysis. This implies that all overhead cost is left in the cost base to be benchmarked.

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9 The US peers are important members of their regional reliability council and therefore also offer system/ancillary services. For US TSOs we include cost of "System Control and Load Dispatching" which falls in the category of "1.E. (556) Power Production Expenses-Other Power Supply Expenses" in FERC form 1 statements.

US companies, on the other hand, are vertically integrated and activities to be excluded - such as generation and in some cases also distribution – constitute a significant part of the cost base. We therefore allocated part of the overhead cost to the excluded activities by:

- Allocating overhead operating cost (excluding depreciation) according to the share of operating cost of transmission activities in total operating cost; and
- Allocating overhead capital cost according to the share of capital cost of transmission activities in total capital cost.

5.3.2 Output data

TSOs carry out two very distinct functions:

- Connecting power plants with regional networks and connecting regional networks with each other.
- Transporting energy/facilitating loads across the network.

At first glance, this could have two consequences for the measurement of TSO output (which are not, however, relevant for our analysis, as explained below):

- The transportation of energy or the facilitation of loads can be measured in terms of units transmitted per year [MWh/a] or maximum demand [MW] while there is no equally clear-cut measure for connecting power plants with regional networks and connecting regional networks with each other.

- Most companies report loads and energy transported within their control area, rather than loads/energy physically transmitted across their network. Differences between these figures arise if generators feed in power at the distribution level where the energy is consumed within the distribution system. In this case the energy/load is not transported on the transmission system although statistics show it as load/energy transported within the control area.

In practice, the former problem – the lack of an output measure for connecting plants and distribution networks – appears to be of little relevance to regional networks and to connecting regional networks with each other. Beyond a certain critical size of the transmission system (that is reached by all TSOs we consider) and a substantial share of generation connected to the transmission system, loads (and units transmitted) are the major cost drivers. The latter problem – ring fencing those loads and units that can be attributed to a TSO as its outputs - requires a refinement of the data which we outline below. In the Netherlands, the transmission function is split between TenneT and nine regional companies (EDON, Continuon, ENBU, Nord West Net, TZH, ENECO, Delta, PNEM, MEGA - with TenneT operating the 220/380kV network and regional companies operating up to 150 kV). A number of major plants are connected to the transmission grids of the regional companies. For our analysis this implies that we must be very specific about the definition of outputs provided by TenneT (in terms of MWh transported, maximum load facilitated etc.) as opposed to the outputs attributable to the entirety of the Dutch transmission networks.

More specifically, if we attributed the Dutch system load and gross demand in the Netherlands to TenneT, then TenneT would appear as highly cost efficient. This result would be misleading and would be the consequence of choosing an incorrect `denominator value' in the efficiency analysis. We applied two distinct methods to the Dutch data in order to address this problem:

1. Clearly define outputs attributable to TenneT (i.e. exclude energy transmitted and load served that is catered for by the Dutch regional companies). We label this company `TenneT (company output)' as opposed to `TenneT (national output)', where we assign national system outputs (load, units) to TenneT.

2. Combine DTe data with data on the complementary regional transmission systems to reconstruct cost and output of the Dutch national transmission system. As ring-fenced transmission data was available for only one of the regional companies we had to rely on data for TZH, a regional

transmission company formed after the recent separation of EZH into a generation and a networks company. We extrapolated the cost of regional transmission systems from this information. TZH accounts for some 19% of national public system peak load and national distribution. We therefore estimate Dutch national public 110/150kV cost and output as five times the respective TZH data. We added these data to the TenneT data, correcting for double counting of outputs. We label the resulting virtual company `TenneT + TZH'. Future analysis should include information on other regional TSOs.

Similar problems of comparability of output data exist – although to a much lesser extent than for TenneT – for the international comparator companies. This is to say that TenneT has much more of an interconnection function than other TSOs included in the analysis.

This implies that we tend to underestimate the efficiency of TenneT in its `company output' specification, while we definitely overestimate its efficiency in the `national output' specification. Our analysis at this stage shows that TenneT's efficiency lies between 50% and 100%. In variations to the analysis by manipulation of international output data (e.g. re-scaling outputs measured within the control areas by indicators for decentralised generation), we aim to narrow down the range of TenneT's efficiency position. In the next stage of the efficiency analysis, more accurate output data must be obtained for the international TSOs we identify as peers to Dutch transmissionsystem operation.

It has also been argued that, although TenneT is only responsible for parts of national transportation, it is responsible for management of ancillary services on the entire system. This would imply that the `tenet (national output)' specification would be more appropriate than the `tenet (company output)' specification (although it was acknowledged that the `tenet (national output)' overstates the true efficiency. However, we would expect system control cost to be largely of a fixed nature and independent of the exact volume of generation capacities that are within tenet's control. This suggests, therefore, that the volume of controlled generation capacity (within a reasonable range) is not a cost driver, but we would estimate the model under both CRS and VRS to establish whether this fixed effect is a significant one for TenneT.

The availability of output data largely limits the variable specification for our DEA model, as we see from table 5.

Table 5: Data availability for DEA of TSOs				
Variables	**Nether-lands**	**Europe**	**USA**	**Common**
Cost	X	X	X	X
Units transmitted [GWh/a]	X	X	X	X
Maximum demand [MW]	X	X	X	X
Generation capacity connected [MW]	X	(X)*	(X)*	
Generation output from plant connected [MWh/a]	X			
Quality of service (including losses)	(X)*	(X)*		
Grid connection points [no]	X			
Area	X	X		
Population density	X	X		
Mains length [km]	X	X	X	X
Transformers [no]	X		X	
Transformer capacity [MW]	X		X	

(X)*: not available in a comparable format

5.3.3 Outline of the sample

Comparators for TenneT and other regional TSOs were only included in the sample if they perform both of the following activities:

- System control/load dispatch – this was to be indicated either by the explicit nomination as TSO in accordance with the EU Electricity Directive or, in the case of US companies, by membership of the National Electricity Reliability Council (NERC).
- Distance transportation of load/energy – indicated by the operation of transmission lines at or above 220kV.

Apart from the three specifications of TenneT as outlined earlier (company output, national output and `TenneT + TZH') we included seven other TSOs from Europe in the analysis:

- PreussenElektra (Germany)
- NGC (UK)
- Scottish Power (UK)
- Svenska Kraftnät (Sweden)
- Statnet (Norway)
- Fingrid (Finland)
- Red Electrica (Spain).

We further include 44 US TSOs that fulfil the above criteria.

We were not able to assess the efficiency of other Dutch regional TSOs, as data on these companies was not available at the time when the quantitative analysis was undertaken. DTe will include this assessment in a second phase of analysis.

In all cases, we used financial information in historic cost format - processed into current cost format where required - and physical statistical information (circuit km, transformer numbers etc). All foreign information was drawn from company accounts. In the case for the US companies, these accounts were prepared for the Federal Energy Regulatory Commission (FERC) and in the case of Scottish Power, for the Office of Electricity Regulation (OFFER). Data for other European companies was drawn from annual reports. All reports used - except for TenneT's – were examined by external auditors.

In all cases, we used data for the year 1998 (in the case of UK companies, for the financial year ending 30 March 1999). Financial data for TenneT was only provided for 1996 and 2000 (forecast). We interpolated to obtain comparable data for 1998.

5.4 **Results of the international efficiency comparison**

In this section, we report the DEA results for a base model and model variants (under both CRS and VRS) that take account of environmental conditions in different ways. All models use total cost: that is, the sum of operating expenditure (excluding depreciation) and a measure of capital cost – depreciation and return on capital, as follows:

Model 1:
- Units and maximum demand as outputs
- No account of environmental condition
- Largest sample of 55 TSOs.

Model 2:
- Units and maximum demand as outputs (as in the Base Model)
- 220kV+ circuit km as proxy for network complexity
- Sample of 39 TSOs.

Model 3:
- Model 2 with 110kV-220kV circuit km as additional proxy for network complexity
- Potentially efficient companies such as Svenska Kraftnät, Fingrid, Red Electrica must be omitted as they do not operate 110/150kV lines (sample is reduced to 21 TSOs).

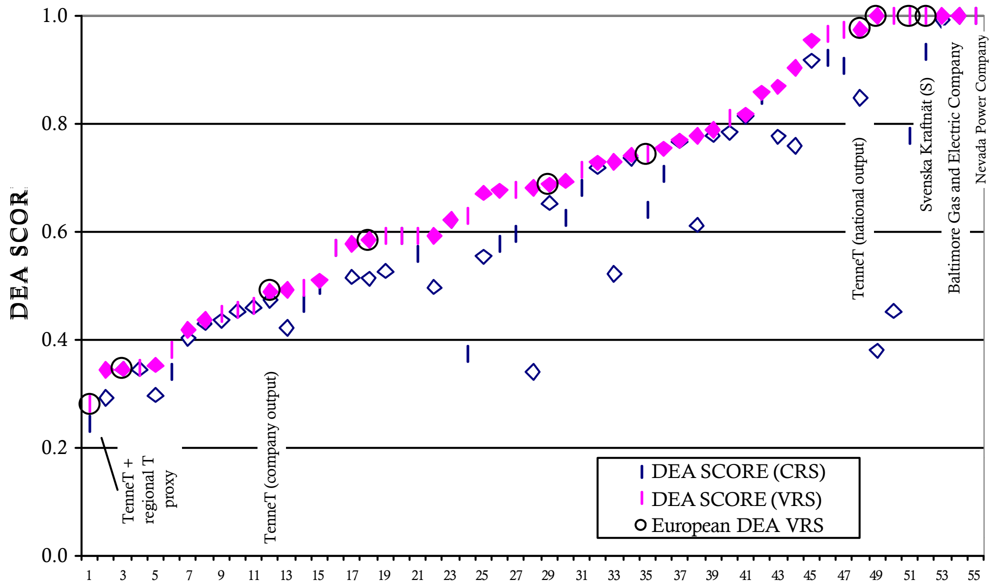
Model 4:
- Model 2 with transformer numbers as additional proxy for network complexity (and potentially also as proxy for the quality or reliability of transmission system operation)
- Potentially efficient companies such as Svenska Kraftnät, Fingrid, Red Electrica must be omitted due to lack of data on transformer numbers (sample of 28 TSOs).

Model 1

Model 1 comprises all TSOs on which data has been collected, including European TSOs such as Statnet, Svenska Kraftnät and Fingrid. Due to lack of information on transmission quality for the entire sample, we restrict output variables to the number of units transported (via the national/regional system) and the maximum load (on the national/regional system).

In the VRS specification, the frontier peers to Dutch transmission system operation include the US companies Baltimore Gas and Electric Company and Nevada Power Company, and the European TSO Svenska Kraftnät . We note that only Baltimore Gas and Electric Company and Nevada Power Company constitute the frontier in a CRS specification of the model.

Figure 4: DEA-scores in Base model



Input: total costs T (x NLG 1 million)
Output: annual output (GWh) and monthly peak (MW).

In this model, Baltimore Gas and Electric and Nevada Power Company emerge as frontier peers to different specifications of Dutch transmission system operation in the CRS specification. Baltimore Gas and Electric and Svenska Kraftnät represent respective peers in a VRS specification.

Table 6: Peers to Dutch transmission system operation

Input Total T costs [m NLG].
Outputs: Annual output (GWh), Monthly peak (MW).

Specification of Dutch transmission operation	**TenneT + TZH**		**TenneT (company output)**		**TenneT (national output)**	
Model	CRS	VRS	CRS	VRS	CRS	VRS
Baltimore Gas and Electric Company	X	X	X	X	X	X
Svenska Kraftnät (Zweden)		X		X		X
Nevada Power Company	X		X		X	

The DEA scores under different characterisations of Dutch transmission system operation are shown in Table 7. `TenneT + regional T proxy' is assigned the lowest DEA scores among the different specifications of Dutch TSO operation, while TenneT with national output variables achieves the highest scores. These scores are summarised in the table below:

Table 7: DEA Scores of Dutch transmission system – Base Model		
Specification	**DEA Score (CRS)**	**DEA Score (VRS)**
TenneT + regional T proxy	0.244	0.281
TenneT (company output)	0.474	0.490
TenneT (national output)	0.849	0.976

Our analysis may tend to understate the true efficiency of TenneT when examining `TenneT (company output)'. As outlined above, this is because load and unit throughput are attributed to the comparator companies in the national/regional system, while we only use the outputs actually measured for TenneT. On the other hand, our analysis will tend to overstate the true efficiency of TenneT when examining `TenneT (national output)'. This is because TenneT only physically transports only part (some 56%) of the units/load in its area across its system. Attributing national outputs to TenneT will particularly favour the efficiency position of TenneT. TenneT's true efficiency will therefore lie within the range of 49% and 98%[10].

Summary of Models 2,3 and 4

Analysis using our alternative models, which take account of environmental variables by applying alternative proxy variables, does not reveal any significant shift in the efficiency ranking of Dutch transmission system operation.

Although we included 200kV+ circuit length as environmental proxies in Model 2, the DEA scores for `TenneT + regional T proxy' and `TenneT (national output)' do not change (in the VRS specification) in comparison with the base model. The efficiency score for `TenneT (company output)' only improves marginally, from 0.490 to 0.495, in comparison with base model 1.

Model 3 takes account of the 110kV-220kV networks as an additional proxy for network complexity. We omit TenneT from the analysis for technical reasons, as TenneT does not operate at the 110kV level. This model variant takes more account of structural characteristics of `TenneT + regional T proxy' than the base model 1. Although we were working on a reduced sample in this model, DEA scores for `TenneT + regional T proxy' only improve marginally, from 28% to 31% (in the VRS specification and in comparison to Model Variant 1), since the peers – including the new peer Indianapolis Power & Light Company - also have extensive 110kV networks.

Model 4 incorporates transformer numbers as an additional proxy for network complexity. This can only be achieved at the expense of a reduced dataset, as information on transformer numbers is not available for other European TSOs apart from TenneT.

The exclusion of European TSOs (previously identified as peers to TenneT) and the inclusion of transformer numbers as another variable do not change the relative efficiency position of Dutch TSOs substantially. The (VRS) DEA score of TenneT improves marginally under both output specifications.

A summary of the DEA scores under the range of model specifications is presented in table 8. In these models, we account for environmental conditions through a number of model variations. In essence, we find that although efficiency scores do change significantly for some companies when

10 We have also been advised that the efficiency position of Svenska Kraftnät may be overstated. Svenska Kraftnät does not own the transformers at its interface with distribution companies so that the costs of these transformers are not shown in its accounts. This will be investigated in an extension of the analysis in phase 2. We do not expect a correction for the cost of transformers to significantly change the efficiency position of Dutch transmission operations. This can be deduced from the results of a number of model variations. Excluding Svenska Kraftnät from the sample does not lead to a significant increase in the efficiency position of Dutch companies. The efficiency of Svenska Kraftnät is backed up by other efficient TSOs.

correcting for environmental conditions, the relative efficiency positions of Dutch TSOs are not altered significantly. We note again that the inclusion of additional variables in the model will not reduce efficiency scores for any individual company.

Table 8: **Summary of DEA scores of the Dutch transmission system**

Specification	DEA-score (CRS-)	DEA-score (VRS-)
Model 1		
TenneT + regional T-proxy	0,244	0,281
TenneT (company output)	0,474	0,490
TenneT (national output)	0,849	0,976
Model 2		
TenneT + regional T-proxy	0,247	0,281
TenneT (company output)	0,493	0,495
TenneT (national output)	0,857	0,976
Model 3		
TenneT + regional T-proxy	0,275	0,307
TenneT (company output)	-	-
TenneT (national output)	-	-
Model 4		
TenneT + regional T-proxy	0,260	0,298
TenneT (company output)	0,530	0,534
TenneT (national output)	0,874	1,000

5.4.1 Efficiency analysis with corrected output data

Given that the output data (units transmitted, maximum demand) from different countries are not necessarily comparable, we made some preliminary attempts to correct the international data. At this stage, this could only be achieved in a rather crude manner for the US data. More accurate data should be sought in the next stage of the analysis.

We corrected international output data by scaling down the outputs of foreign companies. This was based on the assumption that any hydro generation by these companies, and any generation from plants with a gross capacity below 100 MW, feeds into the network locally with the energy being consumed locally. This would imply that power from plants so specified is not transported across the transmission network. We therefore scale down load and units transmitted by the ratio of decentralised generation relative to units transmitted. Note that after the output re-scaling `TenneT (national output)' is no longer a relevant comparator and can therefore be excluded from the comparison.

At this stage, we were only able to gather reliable data for the correction from US companies. Outputs for US companies were scaled down by factors between 0% and 20%. Peer companies to Dutch transmission system operation proved to have little decentralised generation, so that the output re-scaling had no major impact on the efficiency scores of Dutch transmission system operation.

The efficiency scores in the VRS specification of our revised analysis improve (relative to the base case) from 0.281 to 0.350 for `TenneT + regional T proxy' and from 0.490 to 0.515 for `TenneT (company output)' (Table 9) This is to be expected, given that the peer companies for Dutch TSO hardly have any decentralised generation. Also note that our re-scaling approach may unduly favour `TenneT + regional T proxy', as in other countries `decentralised plant' could well be connected to 110kV, just as in the Netherlands. This analysis indicates that the true efficiency score for TenneT lies more towards the low efficiency score of `TenneT (company output)' than the high score of `TenneT

Table 9: DEA Scores of Dutch transmission system using corrected output data		
Specification	**DEA Score (CRS)**	**DEA Score (VRS)**
TenneT + regional T proxy	0.244	0.350
TenneT (company output)	0.474	0.515
TenneT (national output)	-	-

5.4.2 Summary of efficiency analysis

As the efficiency scores of TenneT do not change substantially when the model is modified, we conclude that model specification – at least with the available data – is not a critical issue.

All analysis that included both TenneT and TZH showed extremely low efficiency scores for Dutch transmission system operation. This suggests that TZH, the data of which were used to simulate a regional transmission company, is significantly less efficient than TenneT. The efficiency of TZH should be considered in detail as soon as the final data are available, when the other eight transmission companies must also be included in the dataset. The position of TZH relative to the other regional companies can then be considered here.

There are notably wide variations between the efficiency scores for different output specifications for TenneT (`company' versus `national' outputs), with the efficiency score in the range of 50% to 100%. We undertook some preliminary adjustment to the outputs for the international comparator companies, in order to provide further information on where in this wide range TenneT's efficiency might lie. Our analysis suggests that TenneT's efficiency is closer to the lower end of the range, since these adjustments had little affect on the results. In the next stage of the benchmarking analysis, the output variables for comparator companies should be tracked down more accurately; to correct for any outputs not actually provided by respective TSOs.

It should be emphasised here that the score determined for TenneT is based on the data provided by TenneT to date. The values for TenneT used in the analysis were construed on the basis of interpolation from historical data for 1996 and a forecast for the year 2000. As electricity imports can vary considerably from one year to the next, TenneT's efficiency is sensitive to the fact that the average for data for only two years is used (and one dataset is a TenneT projection). Possibilities for assessing TenneT on the basis of less unreliable data in the future (e.g. an average for more years) must therefore be considered.

5.5 Productivity growth

Future productivity growth can be informed by examining historical productivity growth. As we do not have a reliable time-series of Dutch data, we try to assess productivity growth potential by examining some historical experience from the UK, where NGC and Scottish Power may have started from an efficiency position comparable to that of TenneT.

We used current cost data for years ending 1993 to 1999 from regulatory accounts and estimated productivity improvement in a dynamic DEA model including units transported, maximum demand and network circuit length (as proxy for network complexity)[11].

Applying sequential DEA we find that productivity has grown at an annual rate of 6.8% for NGC and 3.6% for Scottish Power over the seven-year period under review (Table 10). During this period, the

[11] For NGC we excluded the cost of an investment incentive programme known as the Transmission Services Scheme (TSS) for the years 1998 and 1999

UK regulator (OFFER) imposed an average X-factor adjustment of 6.2 (%) on NGC and of 1.0 (%) on Scottish Power.

Table 10: **Base-weighted productivity growth and X-factors Model** Input: Current cost at 1993 prices Output: units transported, max demand, circuit km		
	Base-weighted productivity growth p.a. (92/93 – 98/99)	Average X-factors p.a.(92/93 – 98/99)
NGC	6.8%	6.2%
Scottish Power	3.6%	1.0%

5.6 Summary and the way forward for further analysis

We can summarise our conclusions are follows. First, we have found evidence for inefficiencies in transmission system operation in the Netherlands. In order to draw final conclusions, however, we need to do more analysis based on more accurate data (in as far as these can be provided).

Second, we find that the inclusion of proxies for the environmental conditions under which TSOs operate do not significantly alter the efficiency positions of Dutch transmission operation.

Third, the gradual exclusion of efficient peers in the modelling process did not affect the efficiency results. In other words, the efficiency position of TenneT and TZH is not due to their being compared with an unusually efficient business.

Fourth, we acknowledge that, due to the lack of data, not all-potential cost drivers could be considered. So far, we had to leave out explicit measures of transmission quality due to lack of comparability and non-availability of data. However, the environmental proxies we used may capture some quality information. This is because a TSO with more extensive network assets (lines, transformers) is less likely to face transmission disruptions. Furthermore, we have highlighted problems in making outputs comparable between TSOs.

Finally, we note that there is a wide variation of the results for TenneT (between 50% and 100% efficient) depending on whether its own company output or national output is used as the output variable. We made some preliminary corrections to the output data of the other businesses, to put these on the same basis as TenneT's company output data. An efficiency analysis of these data shows that TenneT's efficiency remains at around 50%. This investigation should be followed up by more detailed investigations into the output and quality variables of peers, particularly of those excluded from the analysis in favour of Dutch TSOs.

The limitations to our analysis that we have noted can potentially be overcome upon the collection and use of more data that is not available in the public domain:

- Quality of TS operations – further sources of quality information are to be sought.
- Measures of outputs – Actual maximum demand and units on the transmission systems (and not respective national figures) should be used in the analysis.
- Ownership of transformers at the interface to distribution. Transformers at this interface are typically owned by the TSO, with very few exceptions. One such exception is Svenska Kraftnät. We would either have to omit Svenska Kraftnät from the sample (the least preferred choice) or add an uplift for transformers to Svenska Kraftnät’s cost base.

- Capital cost valuation. Once the peer companies have been identified capital, cost evaluation should be refined. Greater account should be taken of the company-specific historical investment paths.

We anticipate that these adjustments will be carried forward into the next stage of the efficiency analysis.

6. Conclusions and way forward

This report develops DTe's position as outlined in its July 1999 Consultation Document. In that document, DTe identified a number of methodologies for benchmarking. The constructive involvement of the industry Contact Group (representing the distributors), TenneT and TZH has assisted in taking the process to this stage.

At the most general level, we have restricted our modelling to Data Envelopment Analysis (DEA), for reasons described in Chapter 3. We have gathered data for the transmission and distribution businesses in the Netherlands and for international transmission companies. We anticipate, at this stage, that international data on distributors will be required to explain certain outlying points in the Dutch dataset.

Using the data on Dutch distribution and supply companies, we have derived a set of efficiency scores on the basis of the dataset for charges in 2000. In some cases, these efficiency scores have simply been useful in identifying particularly obvious data issues that should be resolved in the next stage. However, whilst the data are preliminary and in need of refinement and extension, the analysis has been useful both in defining new data requirements and in informing model selection.

On the methodological issues, we noted from the analysis that the choice of control variables had some impact on the efficiency position of particular companies, and also whether the model should be based on constant or variable returns to scale. Consequently, the choice of model and the choice of variable could have a major impact on the efficiency score of the companies. It would be inappropriate to 'set in stone' a particular approach to variable and model choice, particularly when data on certain variables has yet to be supplied. However, in Chapter 5 we provided an indication of our approach, which we repeat here:

- Where consistent arguments can be made for the inclusion of new control variables, and the data can be collected, these will be included in the model to evaluate their importance.

- CRS models are more appropriate than VRS models, given that we intend to continue to evaluate the importance of control variables. If a company is consistently inefficient in models where control variables are explicitly included, but efficient in VRS models, this suggests the presence of unexplained scale effects. It would simply be unacceptable for the consumers to pay for these, when neither DTe nor the company concerned can objectively justify to them why these effects exist.

In the efficiency analysis of the transmission businesses we have found evidence of inefficiency at TZH and TenneT. It should be noted, however, that there is a wide variation in the results for TenneT (between 50% and 100% efficient) depending on whether its own company output or national output is used as the output variable. Neither the choice of CRS or VRS specification, nor the inclusion of particular environmental control variables, had much influence on the results.

In section 5.6, we identified a number of data needs, but the principle issue to be resolved is ensuring that TenneT's output data are comparable to that of the other businesses. We made some preliminary corrections to the output data of the other businesses, to put these on the same basis as TenneT's company output data. An efficiency analysis of these data shows that TenneT's efficiency remained at around 50%. As already mentioned, variations in electricity imports from one year to the next mean that TenneT's efficiency is sensitive to the fact that the average of data for only two years was used (and one of the two datasets was a forecast provided by TenneT itself).

This investigation should be extended by a more detailed research of output variables and quality variables of peers, particularly of those peers excluded from the analysis in favour of Dutch TSOs.

Representatives of the companies in the Contact Group, and of TenneT and TZH, have stated that ideally, the dataset should capture all relevant information about each company's existing position. This should enable DTe to set price controls that do not unfairly penalise companies for high costs attributable to factors that, in the short term, are beyond their control. DTe would welcome the views of the companies on the additional data required to make this judgement.

In summary, DTe is keen to ensure that the benchmarking process to be regarded as transparent and comprehensive. To this end, DTe hopes to receive submissions from the companies suggesting potential improvements to the analysis, in particular focussing on suggestions for environmental factors that should be included in the next stage. Such submissions would be helpful in highlighting any omissions in our analysis and should lead to a fair and well-understood set of conclusions.

To conclude, the outstanding issues to take forward are:

Distribution

- To establish a measure of consistency between operating and capital costs
- To provide a consistent measure of capital costs
- To provide for cost allocation between the transmission and distribution activities for those companies that undertake both
- To extend the data to include the years 1999 and (forecasts for) 2000
- To identify the need for further control variables to capture network characteristics, of which perhaps the most important may be the split between underground and overhead cables.

Transmission

- Data on the quality of transmission operations – further sources of quality information must be sought.
- Measures of output – actual maximum demand and units with the transmission systems (not the national figures) should be used in the analysis.
- Information on the ownership of transformers at the interface to distribution – with very few exceptions, transformers at this interface are typically owned by the TSO. Svenska Kraftnät is one such exception. We should either omit Svenska Kraftnät from the sample (the least preferred choice) or add an uplift for transformers to Svenska Kraftnät's cost base.
- Capital cost valuation - once peer companies have been identified, capital cost evaluation should be refined further, taking greater account of the company-specific historical investment paths.

Annex 1: Characteristics of TSO's

TSOs perform two very distinct functions:

- Connecting power plants with regional networks and connecting regional networks with each other; and
- Transporting energy/facilitating loads across the network.

In one extreme scenario power production could be decentralised to the extent that regional networks may be self-sufficient, in which case a transmission network would only be required to provide transportation capacity when the regional generation systems failed. This would entail maintaining a network of substantial size, on which little transmission would actually occur. Such a network operator could be described as an `interconnection TSO'.

In another extreme scenario, all generation plants could be centrally connected and all power consumed in the regional grids would physically have to flow across the transportation network. A large volume of energy would be transported on this network in relation to its size. Such a TSO could be describes as a `transportation TSO'.

The key question is how to compare these two types of TSOs. If one used regional loads/units consumed as outputs of these TSOs, the efficiency of interconnection TSOs would be largely overstated. Interconnection TSOs would be attributed outputs that they do not actually provide. If, on the other hand, only those units/loads that physically run across the network are considered as outputs, then the efficiency of an interconnection TSO may be understated in comparison with a `transportation TSO'. Part of the cost of an `interconnection' network might be incurred for reserve purposes, which would have to be spread over a relatively small number of output units (units transported/load). The latter approach – using outputs measured on the system – seems less critical than the former, in which total regional output would be regarded as the output of the TSOs.

In a regulatory context, this problem seems to be less of an issue, as we do not observe any TSO that has either purely an interconnection or purely a transportation function. Once the transmission network reaches a critical size, we do not expect that the extent to which a network is an `interconnecting' rather than a `transportation' network will have a serious impact on cost. It is critical, however, to identify physical outputs that are genuinely transported via the transmission system. Such data are typically not available in the public domain. We could only collect information for the Dutch transmission operations. For foreign TSO operations, we had to use information on regional or national `throughput', without knowing to what extent these outputs were actually transported across the transmission system. This is not critical for TSOs with a high number of production units connected to the transmission system (as is the case for most TSOs), but may be critical for those that service areas with a significant degree of decentralised generation that feeds into local networks.

For our analysis, we also exclude metropolitan TSOs that only service a restricted, though densely populated area (for example, companies such as HEW or Bewag in Germany). Metropolitan TSOs in the US sample are identified as having a relatively high ratio of units transported per circuit km.

Implications of characteristics for modelling

For a meaningful international comparison of TSOs, we must ensure that we compare like with like: i.e. that we compare equivalent functions of TSOs. TSOs typically take responsibility for a number of tasks:

Transport (in a broad sense)
Provision of transport services (`transportation' in a narrow sense) for energy/load, including `transportation' of ancillary services.
- Connection of power plants (`capacity'), distribution systems and large consumers (`loads').
- Interconnections with neighbouring transport systems.
- Metering and information management for the use of system.

System control/deployment of production units and ancillary services.

Procurement of ancillary services.

Other optional services, such as:
- Purchase of energy to offset transmission losses;
- Metering and information management for power exchange (e.g. NGC in the UK)
- Promotion/facilitation of environmentally friendly generation (e.g. connection of renewable energy generation facilities under favourable conditions (Denmark), marketing of energy from these sources (Germany) etc).

We see transport (in a broad sense) and system control as core activities to be included in the benchmark analysis. On the other hand we exclude the cost of purchasing/providing ancillary services as well as the other services.

We also considered whether to include energy losses in the benchmarking analysis of TSOs. The problem is that costs of such losses lie only partially within the TSO's control. Whilst the company can control the quantity of losses, the value is determined by the market or by a regulator. The cost of energy losses has, therefore, been excluded from TSO costs.

It has been brought to our attention that international TSOs operate their grids at different voltage levels and that this could have an impact on observed cost. This is clearly true, but the choice of the transmission voltage level is made by the TSO itself. If a TSO turns out to be high-cost because it has not invested in the voltage levels that would allow for lowest-cost transmission, then this would be the sort of inefficiency we aim to identify with our analysis. We therefore prefer to focus on the function of transmission (i.e. the transportation of energy over greater distances etc.), without prejudging which voltage level transmission networks should be operated at.

We do note that cost splits between different functions that we include or exclude for the purpose of our analysis may not be identical for all countries. Examples are:
Inclusion of the costs of managing ancillary services which are typically not separated in company accounts, and exclusion of the procurement costs of ancillary services.
The segregation of overhead costs where a TSO carries out a range of functions not undertaken by TSOs in other countries (e.g. marketing of renewable energy or provision of in-house ancillary services).

In many cases, overhead costs are not allocated to any particular functions. If we eliminate the direct cost of some activity, therefore, the company's overhead cost company may still contain some share of cost that is attributable to the excluded activity (e.g. purchasing of ancillary services or energy to compensate for power losses). We note, however, that the degree of arbitrariness that this introduces is limited.

To summarise, we include in the benchmark analysis:

- Transport costs, in a broad sense
- The costs of system control (operation of generation/ancillary services)

and explicitly exclude:

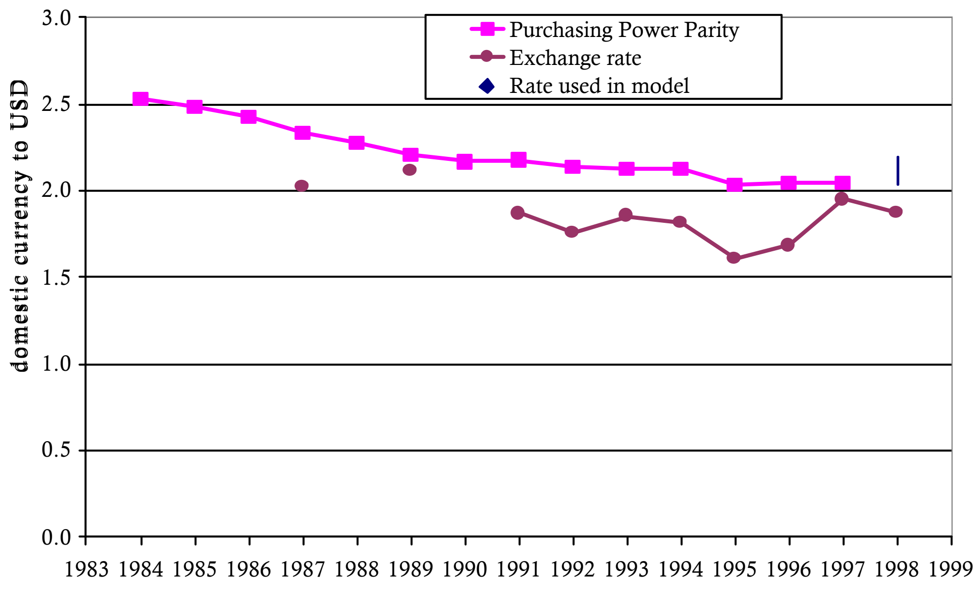
- The costs of energy losses;
- The purchasing costs of ancillary services
- The costs of services to power exchanges.

Annex 2: Derivation of cost data

Cost valuation issues in an international comparison arise in a number of ways:
- Exchange rates
- Wage rates;
- Cost of capital; and
- Allocation of overhead costs.

Exchange rates
The cost conversion from national currencies into NLG is based on exchange rates prevailing in October 1999 (figure 5). We have been advised the decision to convert all cost values into NLG may be ambiguous. The fundamental arguments for this are that exchange rates exhibit short-term fluctuations driven by actions in the capital markets (that are beyond the companies' control). We note that these fluctuations can be all but eliminated by annually averaging exchange rates. Furthermore, exchange rates correspond with commercial practices (i.e. what companies actually have to pay when converting cash). One alternative would be to use Purchasing Power Parities (PPP, defined as the relative value service bundles bought in two different countries at domestic prices). PPPs tend to be more stable than exchange rates, as domestic goods prices fluctuate only marginally. However, in this case the issue is of minor practical relevance, as PPPs and the exchange rates of the NLG against the USD have converged over the last few years. In 1997, PPP stood at 2.05 NLG/USD and the exchange rate at 1.95. We use a 1999 exchange rate of NLG 2.12, which tends to favour the Dutch efficiency position.

Figure 5: Exchange Rates and Purchasing Power against the USD



Source of data: OESO

The use of European exchange rates should not give rise to any controversy, as inter-European exchange rates are either fixed within the Euro-zone or vary within narrow bands. The use of an NLG/USD exchange rate of 2.12 is more critical to the following analysis, since this rate is relatively volatile and US companies represent the peergroup for Dutch TSOs in a number of model specifications. A rate of 2.12 is rather high in view of movements over the last two years. This means that US companies will appear more inefficient and their European counterparts more efficient.

Table 11: **Country codes and conversion factors**

Country	Country code	Currency	Exchange rate [NLG/foreign currency]	Wage rate adjustment factor (NL=1.00)
Finland	FIN	[FIM]	0.3710	0.68
Germany	D	[DEM]	1.1000	1.00
Netherlands	NL	[NLG]	1.0000	1.00
Norway	N	[NKR]	0.2640	0.98
Spain	E	[ESP]	0.0132	0.52
Sweden	S	[SKR]	0.2520	0.71
United Kingdom	UK	[GBP]	3.3800	0.63
United States of America	USA	[USD]	2.1200	#

Wage rate adjustment has not been applied to US data
Source of Data: FT, United Nations

Wage rates

Wages paid by TSOs are determined largely by labour market conditions and, therefore, lie outside the control of companies. As wage rates or staff cost in general may vary strongly between countries, we may be identifying (labour cost) inefficiencies of some companies that are not within their control. We therefore correct for wage rate differentials where possible, by re-scaling personnel costs by the ratio of Dutch to foreign wage rates. The scaling factors applied are shown in 11. As all correction factors are at or below 1.0, we nominally increase the labour cost of foreign companies. We have not re-scaled the wage cost of German TSOs (downward), which favours the relative efficiency position of Dutch companies. Labour cost adjustment has been applied in this manner for European companies. The costs of US TSOs is reported in a way that does not allow for the separation and isolated re-scaling of labour cost. We have therefore refrained from applying the wage cost adjustment to the US data.

We acknowledge that labour cost re-scaling only partially alleviates problems of data comparability, since if companies had been faced by corrected wage rates they might have chosen a different capital cost/wage ratio. A company where personnel costs are scaled up would have chosen to employ fewer people and operate more capital-intensively. Correcting for this effect would be arbitrary however, so we did not attempt it. We note that this omission tends to favour the relative efficiency position of Dutch TSOs.

Allocation of overhead costs

For European TSOs we have eliminated only the direct cost of activities which we exclude for our benchmark analysis. This implies that all overhead cost is left in the cost base to be benchmarked. We consider this a reasonable simplification, as the European TSOs that we include in the benchmark analysis are legally unbundled from other activities (such as generation) and the excluded activities only account for a minor part of their overall activities.

US companies on the other hand are vertically integrated and activities to be excluded - such as generation and in some cases also distribution – constitute a significant part of the cost base. We, therefore, allocate part of the overhead cost to the excluded activities.

Capital costs

Depreciation and a rate of return on investment of the asset base together constitute the capital costs of the business.

In company accounts, depreciation and asset values are usually based on historic cost rather than current cost. Capital cost evaluation for regulatory purposes should ideally be based on current cost. We normalise capital cost by allowing a standardised depreciation and rate of return on an asset base. The current cost of the asset base is estimated on the basis of the historic cost and average life of the assets. A simple model to standardise capital cost is outlined below.

Procedure for normalising capital costs

of comparison between companies. While the relevant assets should be shown at current cost, most of our data are based on historic cost. We outline a brief model that can be used to convert the gross asset base (i.e. without accumulated depreciation) at historic cost to the net asset base (i.e. after depreciation) at current cost. The current cost net asset base is the asset base we will use in the model.

As little information is available on historic investment paths for power company assets over their entire life, we assume a stable investment path over time that allows for investment growth (ω) in line with demand growth. We further assume constant annual inflation rates (r) for electrical assets. We also simplify by assuming a standard life for all assets.[12] We assume linear depreciation.

The gross asset value in historical cost terms (for which we hold information) then equals the sum of investments in nominal terms over time. Annual nominal investment outlays are estimated by escalating investment for each year with investment growth and inflation. Formally, the gross asset value in historic cost terms is expressed as

$$GAV(hca) = \sum_{i=t-t+1}^{t} I_0 (1+w)^i (1+r)^i \quad . \qquad (1)$$

where

I_i: investment in period i

t: current period [year]

τ: asset life time [years]

ω: rate of annual growth in investment

r: annual inflation rate for electrical assets

[12] The transformation of asset values may easily be detailed by looking at assets of different life-times in separate calculations.

Estimating gross asset value in current cost terms

The gross asset value in current cost terms is determined by revaluing the entire asset base each year, on the basis of the current inflation index:

$$GAV(cca) = (1+r)^t \sum_{i=t-t+1}^{t} I_0 (1+w)^i \ . \qquad (2)$$

Upon solving (1) for I0 and substituting into (2) we obtain:

$$GAV(cca) = GAV(hca) \frac{(1+r)^t \sum_{i=t-t+1}^{t} (1+w)^i}{\sum_{i=t-t+1}^{t} (1+w)^i (1+r)^i} \ .$$

This provides a factor to scale the gross asset base from historic to current cost.

Estimating annual current cost depreciation

Depreciation on assets in current cost terms from one vintage period (year) are calculated by spreading the investment outlays $I_t = I_0(1 + w)^t(1 + r)^t$ across the life of these assets. Annual depreciation in any given year is then the sum of write-downs on assets from different vintage periods (years):

$$d(cca)_t = (1+r)^t \sum_{i=t-t+1}^{t} \frac{I_0 (1+w)^i}{t} \ .$$

Upon substituting in (2) we obtain

$$d(cca)_t = \frac{GAV(cca)}{t} \ .$$

Annual depreciation in current cost terms is, therefore, estimated simply by dividing the gross asset value in current cost terms by the average life of the asset.

Estimating netasset values in current cost terms

Net asset values are defined as gross asset values reduced by the accumulated depreciation (Ad(current cost)):

$$NAV(cca)_t = GAV(cca)_t - Ad_t \ . \qquad (3)$$

Note that accumulated depreciation only comprises depreciation on assets still contained in the asset base (that is, the life of which has not expired). Accumulated depreciation will be higher for older assets than for newer ones. Specifically, assets of vintage $t - n$ will have been depreciated over $t - n$ periods. We also note that in current cost accounting, the inflation correction factor $(1 + r)^t$ is identical for assets of any vintage. We therefore express accumulated depreciation as:

$$Ad(cca)_t = (1+r)^t \sum_{i=t-t+1}^{t} I_0 (1+w)^i \frac{t - i + (t - t + 1)}{t} \qquad (4)$$

Substituting this into (3) gives

$$NAV(cca)_t = GAV(cca)_t - (1+r)^t \sum_{i=t-t+1}^{t} I_0 (1+w)^i \left(1 - \frac{i - (t - t + 1)}{t}\right).$$

After substituting in from (2) we can simplify this to

$$NAV(cca)_t = (1+r)^t \sum_{i=t-t+1}^{t} I_0 (1+w)^i \left(\frac{i - (t - t + 1)}{t}\right).$$

The ratio of net over gross asset value gives an indication of the degree of asset write-down:

$$\frac{NAV(cca)_t}{GAV(cca)_t} = \frac{\sum_{i=t-t+1}^{t} I_0 (1+w)^i \left(\frac{i-(t-t+1)}{t} \right)}{\sum_{i=t-t+1}^{t} I_0 (1+w)^i}$$

The following parameters are used to standardise capital cost. We assume an average asset life of 40 years. We further assume that investments have historically grown at a steady rate of 3% per year, and that the prices of typical assets purchased by aTSO inflate at rate of 3% per year. To calculate the return on the net asset base, we assume a (real) rate of return of 6.5%. This figure is a reasonable estimate for regulated utilities in the UK.[13]
This parameterisation is by no means intended to pre-judge any rate of return to be established by DTe during ongoing regulatory proceedings.

13 For example, Ofgem (1999): Reviews of Public Electricity, Suppliers 1998 to 2000 - Distribution Price Control Review, Final Proposals, December 1999, p. 68.

Annex 3: Description of transmission company data

European TSOs

Statnett
Statnett is the Norwegian TSO. Whilst it has overall technical control of the Norwegian transmission system, some 25% of the system (in terms of cost) is owned by regional companies. Statnett pays a fee to the owners, so that the total cost of the system is reflected in Stanett's accounts.

We used the accounts of the Statnett parent company. Statnett costs can be split into grid operations (including administration share), system operation, engineering and construction, power exchange services and general administration. For our purposes we exclude power exchange services, but allocate administration to the TSO. TSO costs will therefore tend to be overstated. Statnett also publishes alternative accounts (giving lower cost figures), showing cost as incurred under the Main Grid Commercial Arrangement. These accounts have not been used as they are not sufficiently detailed to allow for a correction of personnel and capital cost.

Statnett does not provide further details on quality indices.

Svenska Kraftnät
Svenska Kraftnät is the Swedish TSO that owns and operates the Swedish national grid. The national transmission system is mainly operated at 220 kV and 400 kV.

We use the accounts of Svenska Kraftnät Utility. These show the costs and revenues of transmission system operation, system control and power losses. Apart from core transmission and system control functions, Svenska Kraftnät is involved in telecommunications (including fibre-optics) and consulting activities. The company also receives an allowance for `power preparedness activities'.[14] The cost of these unrelated businesses, including the allowance for power preparedness, were deducted from the operating costs for the purpose of the cost benchmarking analysis.

Fingrid
Fingrid operates some 97% of the Finnish national transmission grid and all major international interconnectors. Fingrid was formed in September 1997 through the merger of the transmission operations of major, vertically integrated power companies (IVO and PVO). Fingrid operates the transmission system at the 110 kV, 220 kV and 400 kV levels.

We use financial data for the Fingrid parent company.

Fingrid maintains and operates the transmission system, maintains system balance,purchases energy to offset transmission losses and procures reserve generation capacity. It also owns generation capacity to control power failures. The isolation ofthe costs of power purchases and of maintaining generation reserves are ambiguous,we included these costs in Fingrid's cost base, implying that we will underestimateFingrid's efficiency.

14 "Svenska Kraftnät's goal in connection with electricity preparedness is to ensure that operations in connection with electricity supply are carried out in such a way that the power requirements of the overall defence forces and society as a whole can be satisfied during times of emergency. The goal also includes efforts to ensure that the risks of heavy strains on society as a result of extensive disruptions in the electricity system or a dam collapse are reduced." (Svenska Kraftnät (1998), Annual Report, p. 7).

National Grid Company (NGC)
NGC operates the Transmission System in England and Wales at 275 and 380 kV. NGC undertakes a number of optional functions such as metering and information services for the Electricity Pool of England and Wales. We excluded these costs, aswell as costs recently incurred in a short term investment boost known as the Transmission Services Scheme (TSS).

Scottish Power
Scottish Power is an electric utility with vertically integrated generation, transmission and distribution in the South of Scotland. Scottish Power merged with PacifiCorp of the US in 1998.

Unlike its Scottish counterpart Scottish Hydro, which services sparsely populatedareas, Scottish Power has a service area that is broadly comparable to that of other European TSOs. We use financial data from Scottish Power's ring fenced regulatory HCA accounts.

PreussenElektra
PreussenElektra is a vertically-integrated generation and transmission company in the North of Germany. PreussenElektra has legally separated generation and transmission operations and we focus on the transmission activities of the PreussenElektra Netz subsidiary.

Red Electrica
Red Electrica is a vertically separated TSO servicing the largest part of the Spanish mainland. We have excluded the purchase cost of energy from Red Electrica's accounts.

Us peers

All data on US companies was drawn from FERC (Federal Energy Regulatory Commission) form 1 statements.

Baltimore Gas and Electric Company (BG&E)
BG&E is a major vertically integrated electricity and gas company in Maryland and the subsidiary of the Baltimore based Constellation Energy Group that has operation in the US and Latin America. BG&E is a major generator/trader in the Pennsylvania-New Jersey-Maryland Power Pool (PJM Pool) and a provider of transmission services in this market.

Carolina Power & Light Company
Carolina Power & Light Company (CP&L) is a vertically integrated generation, transmission and distribution company that services the smaller part of North and South Carolina. CP&L is currently in the process of merging with the Florida Progress Corporation. CP&L is member of the Southeastern Electric Reliability Council (SERC).

Duke Energy Corporation
Duke Energy Corporation, based in Charlotte, North Carolina holds its Transmission activities in the subsidiary Duke Energy Transmission. Duke Energy Transmission operates the transmission system that covers the largest parts of North and South Carolina. The parent company, Duke Energy corporation has US wide internationalenergy activities. Duke is a member of the Southeastern Electric Reliability Council (SERC).

Gulf Power Company
The Gulf Power Company is a major vertically integrated electricity company servingthe North-West Mainland of Florida with headquarters in Pensacola Florida. The Gulf Company is a subsidiary of the Southern Company, an energy Group with world-wide activities. The Gulf Power Company is member of the Florida Reliability Co-ordinating Council (FRCC).

Nevada Power Company (peer only in the CRS model)
Nevada Power Company is a vertically integrated electricity company with its core activities in the South of Nevada. The transmission system covers most of Nevadaincluding the city of Las Vegas. Nevada Power Company is a member of the Western Systems Co-ordinating Council (WSCC).

Indianapolis Power & Light Company
Indianapolis Power & Light Company is a vertically integrated electricity company servicing the cities of Indianapolis, Indiana and communities in Central Indiana. Indianapolis Power & Light Company is a member of the East Central Area Reliability Co-ordination Agreement (ECAR).

Dayton Power and Light Company
Dayton Power and Light Company (DPL) is a vertically-integrated electricitycompany servicing West Central Ohio. DPL is a member of the East Central Area Reliability Co-ordination Agreement (ECAR).

Public Service Corporation of Colorado
The Public Service Corporation of Colorado (PSCO), based in Denver CO, services some 70% of the State of Colorado. It is a subsidiary of New Century Energies, a holding company with major energy interests throughout the US and also the parent company of Yorkshire Electricity in the UK. PSCO is member of the Western Systems Co-ordinating Council (WSCC).

Wisconsin Power & Light Company
Wisconsin Power & Light Company (WPL) is a vertically-integrated generation, transmission and distribution company. WPL is the largest TSO in Wisconsin and hasnow merged with IES Industries and Interstate Power Co. to form Alliant Utilities.WP&L is member of the Mid-Continent Area Power Pool (MAPP).

MidWest Energy Corp
MidWest Energy Corp is a small vertically-integrated generation, transmission anddistribution company in Kansas.

Annex 4: DEA and Malmquist linear programming

DEA-optimisation programme

Given that the industry is characterised by constant returns on scale, by DEA techniques we may establish:

- Which company produces the highest output(s) with the least input(s) (by identifying the `frontier' companies)
- How much should inefficient companies decrease their input(s), given their level of output(s), in order to reach the efficiency levels already demonstrated to be achievable by the frontier companies.

We now proceed to generalise the geometric derivation of DEA explained in the main proposal, to a multi-dimensional input-output space.

Suppose there are k companies in an industry. Each company i, i = 1,...,k, uses n inputs,, $\left(X_1^i, \mathrm{K}\ , X_n^i\right)$ to produce m outputs, $\left(Y_1^i, \mathrm{K}\ , Y_m^i\right)$. We make the following notational definitions:

$$\mathbf{X}^i = \left(X_1^i, \mathrm{K}\ , X_n^i\right), \mathbf{Y}^i = \left(Y_1^i, \mathrm{K}\ , Y_m^i\right),$$
$$\mathbf{X} = \left(\mathbf{X}^1 \quad \Lambda \quad \mathbf{X}^k\right), \mathbf{Y} = \left(\mathbf{Y}^1 \quad \Lambda \quad \mathbf{Y}^k\right).$$

Efficiencies are calculated comparatively, relative to other (frontier) companies. The DEA approach calculates the proportion by which inputs need to be decreased (or outputs increased) in order to achieve demonstrated efficiency. We wish to obtain θ^i such that ($\theta^i X^i, Y^i$) is at the efficiency frontier. The linear programme we solve is:

(1) $\forall$ firm i, Minimise q^i mits

(2)

(3) $q^i \mathbf{X}^i \geq \mathbf{X} l$, $\quad i = 1, \mathrm{K}\ , k$,
$\mathbf{Y}^i \leq \mathbf{Y} l$, $\quad i = 1, \mathrm{K}\ , k$,

among all possible (non-negative) entries of the vector of weights, λ, and subject to, of course, θ^i being positive. The parameters θ^i, i = 1,...,k, are precisely the DEA relative efficiency scores for the given model inputs and outputs.

This specification, which derives the optimal input levels for given outputs, is called input-oriented ranking. An output-oriented model could be implemented instead, although under our constant returns to scale assumption this has no effect on the resulting scores. Only under more general scale assumptions would one find any differences. Throughout this report we have calculated input-oriented DEA scores. This seems the appropriate specification given that the companies' outputs are essentially given to them, while their inputs are controllable.

Malmquist-productivity indices

From our analysis of DEA estimation, we can generalise to compare an industry in two different time periods. Let us first suppose that we have derived, at each of the points in time, t = 1,2, the (static) DEA efficiency scores which we shall denote by θ_t^i and θ_{t+1}^i for each company i in the industry of k companies. At each point in time we have different input-output combinations, which we denote thus:

$$\mathbf{X}_t^i = \left(x_{1,t}^i, \ldots, x_{n,t}^i\right), \mathbf{Y}_t^i = \left(y_{1,t}^i, \ldots, y_{m,t}^i\right),$$
$$\mathbf{X}_t = \left(\mathbf{X}_t^1 \cdots \mathbf{X}_t^k\right), \mathbf{Y}_t = \left(\mathbf{Y}_t^1 \cdots \mathbf{Y}_t^k\right), \qquad t = 1,2.$$

Now, as well as the usual DEA, we can perform the following comparative benchmarks:

(3) $\forall$ firm i, Minimise $q_{t,t+1}^i$ subject to

$$q_{t,t+1}^i \mathbf{X}_t^i \geq \mathbf{X}_{t+1} l, \quad i = 1, \ldots, k,$$
$$\mathbf{Y}_t^i \leq \mathbf{Y}_{t+1} l, \qquad i = 1, \ldots, k,$$

(4) $\forall$ firm i, Minimise $q_{t+1,t}^i$ subject to

$$q_{t+1,t}^i \mathbf{X}_{t+1}^i \geq \mathbf{X}_t l, \quad i = 1, \ldots, k,$$
$$\mathbf{Y}_{t+1}^i \leq \mathbf{Y}_t l, \qquad i = 1, \ldots, k,$$

where, of course, the usual non-negativity constraints apply.

Table 12 describes the resulting efficiency scores for a two-period model.

Table 12: Efficiency scores obtained from a two-period Malmquist linear programming approach

Score	Observations
θ_t^i	Efficiency score for company *i* in period *t* relative to the efficiency frontier in period *t*.
θ_{t+1}^i	Efficiency score for company *i* in period *t* + 1 relative to the efficiency frontier in period *t* + 1.
$\theta_{t,t+1}^i$	Efficiency score for company *i* in period *t* relative to the efficiency frontier in period *t* + 1.
$\theta_{t+1,t}^i$	Efficiency score for company *i* in period *t* + 1 relative to the efficiency frontier in period *t*.

From these scores we can construct Malmquist indices of productivity as follows

Table 13: Malmquist-indices - definition

	Productivity	Catch-up	Frontier shift
Base-weighted	$p_i^b(t,t+1) = q_{t+1,t}^i / q_t^i$	$cu_i(t,t+1) = q_{t+1}^i / q_t^i$	$fs_i^b(t,t+1) = q_{t+1,t}^i / q_{t+1}^i$
Current-weighted	$p_i^c(t,t+1) = q_{t+1}^i / q_{t,t+1}^i$	$cu_i(t,t+1) = q_{t+1}^i / q_t^i$	$fs_i^c(t,t+1) = q_t^i / q_{t,t+1}^i$
Remarks	Measures the actual improvements of each company through time	Measures comparative improvements of the company relative to others	Measures improvements of all other companies relative to those of company *i*.

In this way, we parameterise industrial improvements in a meaningful manner. If the number of time periods under study exceeds two, then we still compare improvements over a longer period.

References

Andersen, P. en Niels Christian Petersen (1993), A procedure for the ranking of efficient units. *Management Science*, Vol. 39, No. 10, oktober 1993.

Dienst Toezicht en uitvoering Elektriciteitswet, *Price cap*-regulering in de elektriciteitssector. Informatie- en consultatiedocument, juli 1999.

Dienst Toezicht en uitvoering Elektriciteitswet, Richtsnoeren inzake *price cap*-regulering in de Nederlandse elektriciteitssector voor de periode *2000-2003*, februari 2000.

OFGEM (1999), *Reviews of Public Electricity, Suppliers 1998 to 2000 – Distribution Price Control Review, Final Proposals*, december 1999.

Unipede/Eurelectric (1999), Network Voltage Responsibilities, verslag van de werkgroep "Netwerkvraagstukken", Brussel, oktober 1999.

Utilities Journal, *The Final Frontier*, September 1999.