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Comparative efficiency of the IT function of Western Power Distribution.

A Report for Western Power Distribution

10 June 2013

Private and Confidential

This report has been prepared on the basis of the limitations set out in the engagement letter and the matters noted in the Important Notice From Deloitte on page 1.

Contents

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Executive Summary

Benchmarking Western Power Distribution’s IT costs in the context of RIIO

Western Power Distribution group of companies (“**WPD**”) is currently undergoing a regulatory review by Ofgem under its new RIIO framework and is required by July 2013 to submit a ‘well justified business plan’ as part of that review. Typically price controls by Ofgem, and therefore the business plan, require the regulated company to increase its productivity to catch up to some benchmark representing an efficient comparator. This report provides analysis of WPD’s comparative efficiency to inform its business plan, focusing on non-operational IT costs of activities undertaken by the Information Resources (“**IR**”) department.

The IR department is responsible for IT across 70 different WPD sites and nearly 6,000 users. Reporting to the Finance Director and led by the Information Resources Manager and five members of the management team, the overall IR department consists of 81 full-time WPD staff based primarily in Plymouth with an annual budget of £25.2 million (excluding telemetry/private field network). The department aims to deliver a “no frills” service (for example there is no IT Help Desk, and no internet access from users’ desk top), but a highly resilient and available IT function based on a lean structure, without reliance on contractors or outsourcing. WPD’s IR department works closely with the business to deliver IT systems that directly contribute to WPD’s business performance.

This report provides a top-down comparative efficiency analysis of UK Distribution Network Operators (“**DNOs**”) in the period from 2007/08 to 2012/13. For much of the period covered by the analysis WPD comprised of the South Wales and South West DNO; its purchase of the two Central Networks DNOs in the Midlands occurred in 2011.

The cost data used in this study was obtained from Ofgem’s Regulatory Reporting Pack (“**RRP**”) for the years 2007/08 to 2010/11, and supplied by WPD for 2011/12 for all fourteen DNOs, and for 2012/13 for WPD only. Further, WPD provided us with an adjustment to this cost data for all fourteen DNOs, to allow for the cost of contractors used to provide non-operational IT activities, but not necessarily recorded as such in the RRP. This contractor cost adjustment estimated by WPD aims to achieve a better like-for-like comparison of costs for 2011/12 between the DNOs.

In order to maintain a degree of consistency with Ofgem’s approach in the technique employed in this study estimates a Cobb-Douglas cost function using Corrected Ordinary Least Squares regression analysis. IThese techniques suffer from a lack of data points in the context of benchmarking the DNOs that represent only six independent ownership groups. We address this by pooling data across six years, which allows us to obtain statistically valid models. Nevertheless, the available sample size in the context of non-operational IT costs restricts the use of more comprehensive sets of estimation techniques and numbers of relevant explanatory factors that can be used in the analysis. The weakness of the approach is partly reflected in the range of the efficiency estimates between DNOs.

Results

The results of the benchmarking, which are consistent across the six alternative specifications of our cost modelling, show that in 2009/10 prior to the acquisition of Central Networks, the WPD South Wales and South West DNOs are at the top quartile of the efficiency estimate across all DNOs.

The West Midlands and East Midlands DNOs that WPD acquired from Central Networks in April 2011 have costs significantly above the benchmark level in the period 2007/08 to 2010/11. Taking 2009/10 costs as the basis of comparison, the post-merger WPD comprising the four DNOs would have to reduce costs by around 30% to reach the benchmark level following the merger.

The results indicate that these cost reductions will be achieved in 2012/13, since WPD as a four DNO group is again within the top quartile of efficiency both with and without the contractor adjustment applied.

The contractor adjustment has a material impact in 2011/12 and 2012/13 on DNO's relative rankings. However, with or without the contractor adjustment WPD is on average ranked 2nd. Other DNOs rankings are not as stable On average across the six specifications presented here, including the results with and without the contractor adjustment applied, WPD is ranked first in efficiency between the ownership groups in 2012/13 as well as being well within the top-quartile efficiency boundary.

However, the estimated equations are able to explain at most roughly half the variation in the costs across the DNOs and through time, implying that the estimated values of the catch-up factors are likely to be subject to significant uncertainty. This is likely to be mainly driven by the granular nature of the benchmarked costs, as granular cost figures are more prone to be influenced by allocation rules and differences in treatment of IT support functions, notwithstanding the contractor cost adjustment across the DNOs.

Combining the insights from the different models therefore indicates that the post-merger WPD should be considered efficient with regard to non-operational IT costs.

This is confirmed by a separate bottom-up cost benchmarking undertaken by Deloitte, which also found that WPD's non-operational IT support costs were below average against DNO and non-DNO peers on a comparable basis. This analysis is not provided here because, given its bottom-up nature, it is very detailed.

1 Introduction

1.1 Background and objectives

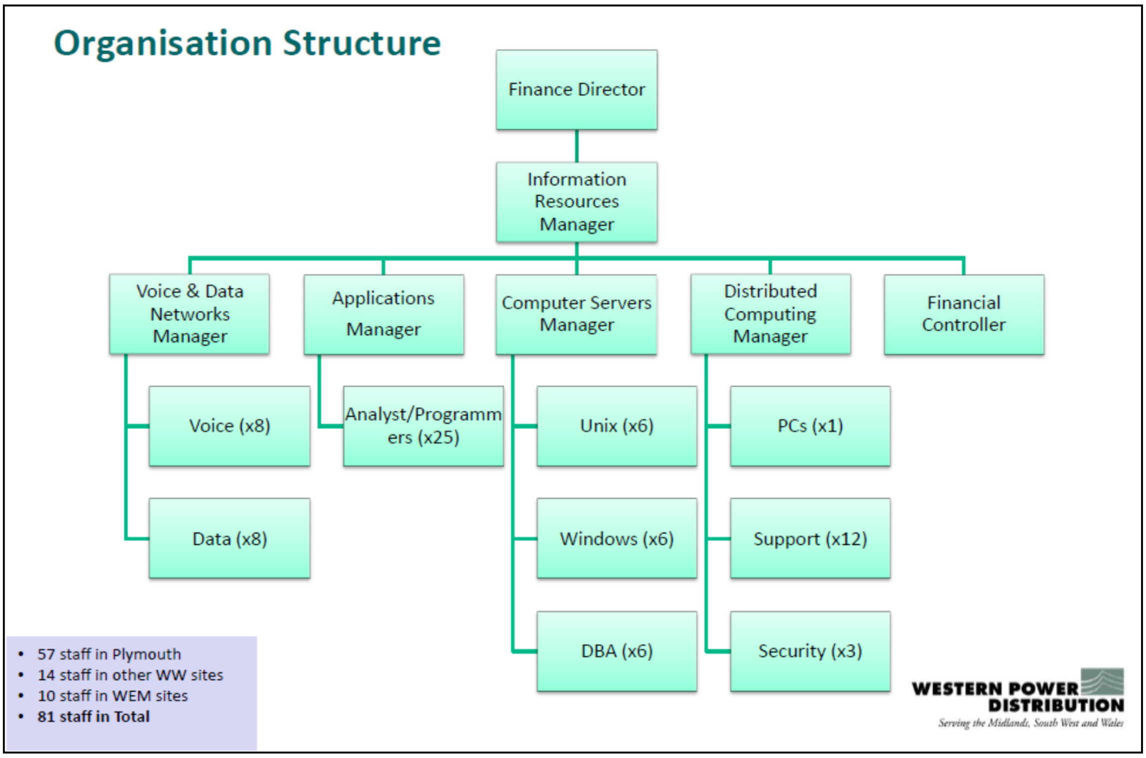
Western Power Distribution ("**WPD**") which comprises four electricity Distribution Network Operators ("**DNOs**"), covering the Midlands, the South West and South Wales, is currently undergoing a regulatory review by Ofgem for the purposes of setting new network price controls. This review is being undertaken under the new RIIO model (Revenue = Incentives + Innovation + Outputs) and its resulting price controls will commence in April 2015 for a period of eight years.

Under the RIIO-model, regulated companies are required by July 2013 to submit to Ofgem a 'well-justified business plan'. This will include cost projections for WPD supported by analysis of cost drivers and, where appropriate, cost benchmarking. Ofgem will itself assess the 'efficient costs' in the companies' business plans using a range of different levels of analysis.

In this context, the objective of this report is to provide a benchmarking assessment of the relative efficiency of WPD's non-operational IT activities undertaken by the Information Resources ("**IR**") department.

The IR department is responsible for IT across all 70 sites in the four DNOs. Headed up by the Information Resources Manager and five members of the management team as shown in Figure 1, the overall IR department consists of 81 full-time WPD staff based primarily in Plymouth, with no contractors and outsourcing, supporting 5,823 geographically-dispersed users. It has an annual budget in total of £25.2 million (excluding telemetry / PMR). WPD has set up the IR department using a relatively flat and lean structure. For example there is no traditional 'helpdesk' function within the department. However, although the scope of IR requirement has grown significantly since the merger with the two Midlands DNOs the size of the IR department has not grown proportionally.

Figure 1: WPD IR department organisation structure



Source: WPD

This report provides an assessment of the relative cost efficiency of the non-operational IT functions through a top-down econometric analysis of the comparative efficiency of the DNOs in Great Britain.

1.2 Structure of this report

This report is structured as follows:

- Section 2 sets out the methodology used for the analysis.
- Section 3 describes the data used and data limitations.
- Section 4 provides the results and findings.
- Finally, Section 5 draws conclusions on top-down benchmarking WPD's IT function.

The econometric results of the analysis undertaken are included in Appendix A.

2 Methodology

This section sets out the framework for our analysis for the top-down approach. In particular, we describe the choice of our preferred top-down comparative efficiency analysis techniques. These are similar to those that regulators have used in the past, including Ofgem for DPCR5[1].

The econometric analysis provides an assessment of WPD's historical and expected cost efficiency relative to other DNOs using established econometric techniques that have been accepted and used previously by regulators, including Ofgem. These techniques suffer from a lack of data points in the context of benchmarking the 14 DNOs against each other, particularly as those DNOs represent only six independent ownership groups[2]. We have aimed to address this by pooling data across six years, which allows us to obtain statistically valid models. Nevertheless, this does not add to the important cross-DNO dimension, and the available sample size continues to restrict the number of relevant explanatory factors that can be included in the analysis. The small sample size also restricts the use of the otherwise most suitable comparative benchmarking techniques described below. In the context of this report the issue is magnified by the granular definition of cost category, where company scale may not be a clearly dominant driver of the costs.

Subject to the above caveats, the top-down analysis produces an estimate of whether any cost reduction is needed for WPD to be considered efficient compared to its DNO peers. The weakness of the approach is partly reflected in the range of the efficiency estimates between DNOs.

2.1 Comparative efficiency analysis

This section sets out the methodological framework underlying the comparative benchmark analysis.

2.1.1 Type of analysis and interpretation of results

The analysis is used to measure the cost efficiency of the DNOs relative to each other. That is, the DNOs' ability to minimise their costs for a given level and set of outputs, taking into account the environment in which the companies operate. The approach provides an overall view on efficiency at an aggregated cost level.

The analysis is based on a function that explains costs on the basis of scale of output and environmental factors that drive costs but are outside the control of company management. An example of such a cost function is set out below.

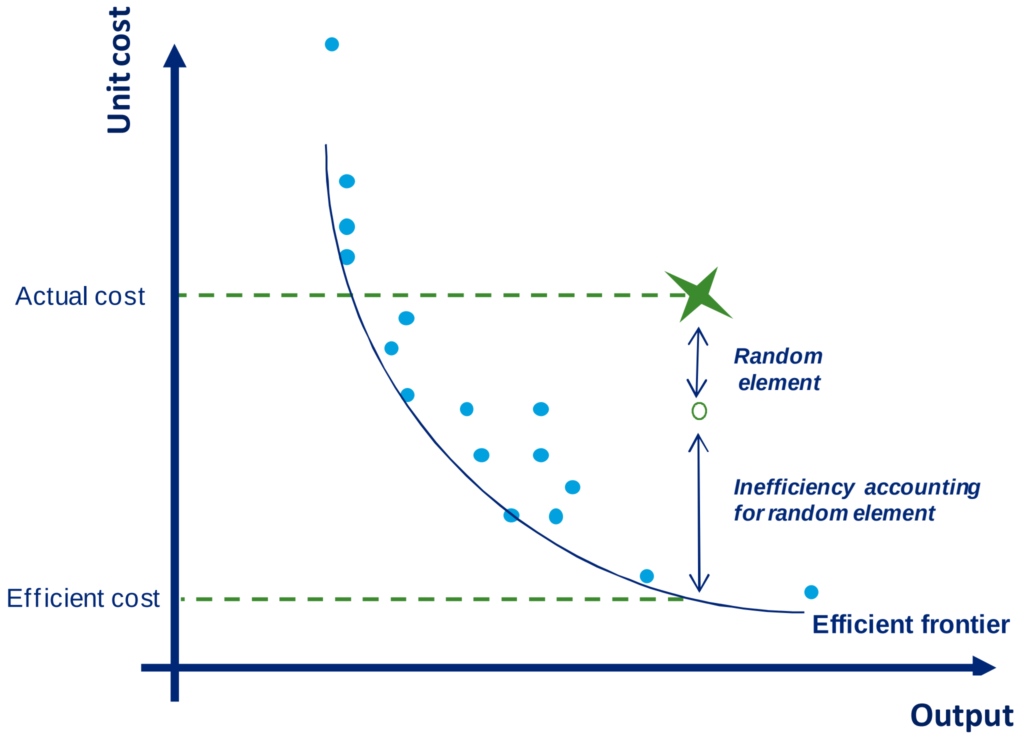
$$Cost = a + \beta^k \times Output\ factors + \alpha^l \times Environmental\ factors + u \qquad \text{(Equation 1)}$$

1 This refers to Ofgem's fifth electricity distribution price control review covering the period 1 April 2010 to 31 March 2015.

2 Typically a sample of about 30 independent data points is considered necessary for statistical reliability. More precisely, the requirement is for 30 'degrees of freedom' – calculated as the number of independent data points minus the number of variables included in the analysis.

The analysis estimates the impact of the output factors (β) and the environmental factors (α) across the DNOs. The estimated equation is then used to predict what the costs should be, given the scale of output and the operating environment of the company. The difference between the predicted costs and actual observed costs provides the measure of comparative efficiency (u in Equation 1 above). In practice, the difference will also be composed of a random element due to uncertainty in the estimation and the actual inefficiency. This is illustrated in Figure 2.

Figure 2: Top-down comparative efficiency concept



Source: Deloitte

Measuring the inefficiency as the differences between the actual costs and predicted (efficient) cost, using the estimated Equation 1, means that the methodology allows for costs that are estimated to be the result of the explanatory factors – given an estimate of the coefficient β, then the higher the output factor of a particular DNO, the higher its costs can be before they are judged inefficient. For example, if a company is particularly highly staffed and FTEs are used as the scale variable, the methodology is likely to find the company more efficient (and allow for higher costs) than on other scale variables. This makes it important that only exogenous factors (which are outside the control of management of IT operations) are included on the right hand side of the equation. Consequently, such exogenous factors are best thought of as scale and environment factors, rather than as cost drivers in a more direct sense, such as the number of servers bought.

2.1.2 Econometric techniques to estimate comparative efficiency

Given a sufficiently large number of observations[3], econometric analysis is able to model a relationship between costs and other variables by considering the differences between operators.

The multivariate regression that we model takes the following general form:

$$C_i = a + \sum_{k=1}^{K} \beta^k Y_i^k + \sum_{l=1}^{L} \alpha^l N_i^l + \varepsilon_i \qquad \text{(Equation 2)}$$

where:

subscript i represents the firm under consideration;

C_i is the total cost:

Y^k are the output variables;

N^l are environmental variables;

a represents the fixed costs;

β^k and α^l are the coefficients of the output and network variables respectively; and

ε_i is the residual that reflects relative efficiency.

We discuss below a number of econometric techniques which may be used to estimate relative efficiency and provide details of the functional form to which we have applied these techniques.

Ordinary Least Squares analysis

The major advantages of Ordinary Least Squares ("**OLS**") analysis are that it is easy to estimate and to interpret. However, it also has some drawbacks which need to be addressed in the context of this study.

- Robustness of OLS analysis depends on the assumption of independence between explanatory variables and residuals, which might not hold in efficiency studies where the residual is interpreted as the measure of inefficiency of a company. It is therefore necessary to conduct additional statistical tests of the model robustness for this concern before OLS results are interpreted. The tests undertaken to ensure robustness are discussed in Section 4.2.

- In OLS regression used for comparative efficiency analysis, the whole of the residual from the regression is interpreted as inefficiency. In practice, factors such as data errors and genuine uncertainty in measurement are likely to introduce some randomness in the error term. In other words, the residuals should be thought of as being comprised of two

3 The definition of 'sufficient' is dependent upon the number of variables in the regression and the standard deviation of the observations, as well as by the requirements of the chosen estimation technique. Theoretically this is set by the law of large numbers where the central limit theorem applies and the distribution may be determined to be normally distributed. However, in practice such variable numbers are rarely available to econometric investigations and an accepted guide of around 30 observations is typically considered sufficient to provide statistical confidence.

components; one of which is the inefficiency of the company and the other a purely random error. OLS regressions are unable to separate these two components, and therefore rely on necessarily arbitrary judgement on where to draw the line between random error and inefficiency.

- The output of an OLS regression is interpreted as inefficiency compared to a company of "average" efficiency. Generally, however, the relative efficiency compared to some measure of 'frontier' efficiency is of more interest to regulators.

The simple OLS can be improved for the analysis of comparative efficiency by using Corrected Ordinary Least Squares ("**COLS**"). COLS analysis shifts the efficiency benchmark from the average of the sample to a chosen level within the sample. This is implemented by rebasing the residuals from the regression to measure the distance from a chosen level of estimated inefficiency. The drawback is that the choice of the boundary is necessarily arbitrary, rather than determined by data.

This report uses the same strategy as Ofgem in DPCR5 by setting the efficiency boundary at the top quartile rather than at the frontier implied by the estimation residuals. This addresses the latter two of the drawbacks of OLS estimation outlined above.

We use COLS as the main technique in the study. This is the technique used by Ofgem in DPCR5.

Stochastic Frontier Analysis

Stochastic Frontier Analysis ("**SFA**") is a regression technique that is widely used in efficiency studies conducted by regulators and is extensively covered in academic literature[4]. Regulators that have used this technique include Ofcom and Oftel for BT, Comreg and ODTR for Eircom, OPTA for KPN, the Communications Commission for Telecom New Zealand and the ACCC for Telstra.

The SFA estimation procedure overcomes two of the main drawbacks of the COLS methods described above.

- *Distinguishing between two components of the error term*. SFA differentiates between an inefficiency component and a random noise component. This distinction is based on assumptions about the statistical distribution properties of the two error components.

- *Estimating a line of best fit which describes a theoretically efficient frontier*. The estimated residuals in SFA represent the distance of a DNO from its theoretical most efficient status.

SFA models can be estimated on a multi-year dataset using pooled SFA or panel data SFA. The general form of the SFA regression equation can be represented as follows:

$$\ln C_{it} = a + \sum_{k=1}^{K} \beta^k \ln Y_{it}^k + \sum_{l=1}^{L} \alpha^l \ln N_{it}^k + \delta t + u_{it} + v_{it} \quad \text{(Equation 3)}$$

4 A good academic discussion of SFA for cost efficiency estimation can be found in 'Cost Efficiency in Network Industries: Application of Stochastic Frontier Analysis' (M Kuenzle, 2005).

where:

ln is the natural logarithm;

i represents the individual company observation;

t represents the year of the observation;

u_{it} is the company specific inefficiency component (which with panel data methods can vary with time, t) ; and

v_{it} is the purely random error component.

Pooled SFA methods require the type of distribution of the inefficiency components to be specified prior to estimation. The options typically considered are half-normal distribution, exponential distribution and truncated-normal distribution. The choice of distribution can have an impact on the success of the estimation (estimations may not converge to a result, if the distribution in the data is in practice very different from the assumed distribution) and the scale of estimated efficiency differences between the companies. Moreover, the company specific inefficiency terms are not allowed to vary with time – pooled SFA estimates the company specific inefficiency on average over time.

Panel data SFA methods in principle present some advantages over single year and pooled models.

- Panel data models utilise both the between-groups and within-groups variation more efficiently, generally leading to more robust results.

- The assumptions required on the statistical properties of the error components are less strict if a panel SFA model is used.

- The company specific inefficiency components can be allowed to vary in time.

However, panel data SFA methods require substantially larger amount of data than pooled SFA, particularly in the cross-sectional dimension. For the purposes of estimating DNO relative efficiency, the fourteen observations in the cross-sectional dimension are not likely to be sufficient to provide statistical confidence in panel data SFA estimation, and therefore it is not used in this report.

Pooled SFA has two further drawbacks in the context of this report and the data available for the analysis. First, the estimated inefficiency term is constant over time for each DNO, whereas the evolution of the comparative efficiency through time is important for the purposes of setting reasonable price controls. Second, the estimated inefficiency terms from pooled SFA are susceptible to distortions from outliers in small samples, which would affect the comparative efficiency score in all years. The data used for the study has not been adjusted to ensure consistency across DNOs regarding DNO specific factors. We note that Ofgem also considered and rejected the use of pooled SFA analysis for DPCR5.

Accordingly, this report uses pooled COLS as the main estimation procedure.

2.1.3 The estimated equation

The analysis in this report uses a Cobb-Douglas (log-log) specification for the cost function. While this functional form does assume a certain type of relationship between cost and the explanatory variables, it has several advantages:

- it allows for non-constant returns to scale;
- it is linear in the explanatory variables, allowing for simpler econometric techniques;
- the coefficients on the explanatory variable can be interpreted as elasticities, so that they indicate the proportional change in costs derived from a 1% change in the explanatory variable, holding everything else constant;
- it reduces the impact of heteroskedasticity – beneficial with pooled data estimation; and
- it is consistent with previous studies into the comparative efficiency of the DNOs by Ofgem.

The form of the cost function estimated in this study is therefore:

$$\begin{aligned}\ln(cost)_{it} = {} & a \\ & +\beta^{k}\times\ln(outputfactors)_{it} \\ & +\alpha^{l}\times\ln(environmentalfactors)_{it} \\ & +\delta\times\text{Time effect}_{t} \\ & +\varepsilon_{it}\end{aligned}$$ (Equation 4)

Section 3.1 describes the variables and data used in the analysis for cost, output factors and the environmental factors. We follow Ofgem in including time effects through year specific time variables in the specifications. These capture any industry wide cost effects such as changes in input prices in each year.

This functional form is similar to that used by Ofgem in DPCR5. The type of function used by Ofgem included a scale factor and time specific effects to account for movement in average costs for DNOs through time:

$$\text{Cost} = a + \beta\times\text{Scale Factor} + \text{Time effects} + u$$ (Equation 5)

Ofgem used the above general specification to benchmark the operational costs of the DNOs at different levels of aggregation of cost, varying from total opex to just tree cutting expenditure. IT & Telecoms costs were not modelled separately, but were included as a part of a group of indirect costs covering: Network policy; HR & Non-operational training; Finance & Regulation; CEO; and IT & Property. The primary scale factor Ofgem used to explain these costs was the modern equivalent asset value ("**MEAV**") of the DNOs, with total direct costs as a secondary scale factor. The scale factors were combined into a single combined scale variable ("**CSV**") using weights determined by Ofgem through additional analyses and judgement.

The methodology used here therefore differs from Ofgem primarily in the following ways.

- IT & Telecom costs are modelled separately from other indirect cost categories.
- We attempted to improve the model specification by including an environmental factor in the analysis.
- No attempt is made to combine multiple explanatory factors into a single CSV. Results from various alternative specifications using different scale factors are presented instead. This removes an element of arbitrary judgement in obtaining the comparative efficiency results.
- Ofgem sourced the MEAV data from the Forecast Business Plan Questionnaire ("**FBPQ**"), which we do not have access to for all the DNOs. We are therefore not able to use MEAV as an additional scale variable in the analysis.

3 Data

This section provides an overview of the data and sources used in this report.

3.1 Data used in the econometric analysis

The top-down analysis uses the data collected by Ofgem in the RRP datasets and the data published in conjunction with the Electricity Distribution Annual Report for 2010/11[5]. These were supplemented by data provided to us directly by WPD for 2011/12 for all DNOs and the 2012/13 budgeted costs for the four WPD DNOs.

3.1.1 IT cost variables

The IT cost variable modelled is sourced from the Ofgem RRP datasets, provided to us by WPD from 2007/08 to 2010/11 for each of the DNOs. The cost category used in the modelling is the total business support IT & Telecoms expenditure. This covers various cost categories, the most significant of which are:

- IT/Telecoms Network Provision;
- Telecoms Telecontrol Network infrastructure and management costs;
- IT Clients Support / Services; and
- IT Applications maintenance, upgrade and running costs.

The data is sourced from the detailed cost matrix of in the RRP data. The labelling of the sheets and data changes somewhat across the years. The descriptions used through the years were:

- 2010/11 RRP: total net costs from “C1 Costs Matrix”; and
- 2009/10, 2008/09 and 2007/08 RRP: total activity costs before allocations less disallowed related party margins, from “2.2 Total Cost Matrix”.

These were supplemented by data provided to us directly by WPD for 2011/12 for all DNOs and the 2012/13 budgeted costs for the four WPD DNOs.

This provides us with a continuous series of IT & Telecoms costs to use in the estimation. It is common for Ofgem and other regulators to undertake additional adjustments for specific factors outside the control of the DNO but not reflected in the explanatory factors used prior to top-down benchmarking analysis. However, such adjustments, other than the contractor adjustment described below, were outside the scope and data available for this report. Therefore, the data is used as reported in the RRP without any further adjustments for DNO specific effects.

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5 Ofgem: “Electricity Distribution Annual Report for 2010-11”, 30 March 2012

Contractor adjustment

In addition to above reported cost data, WPD provided us with adjusted 2011/12 costs for all the DNOs, where the adjustment aims to normalise the impact of using external contractors for non-operational IT and Telecoms infrastructure or operations. The adjustment adds IT and Telecoms contractor costs back into costs as reported in the RRP. Deloitte has not reviewed the estimations to derive the contractor adjustment, but considers the principle to be valid, as the adjustment seeks to achieve a like-for-like comparison between the DNOs on the basis of how much it costs to deliver the non-operational IT and Telecoms activities.

This adjustment affects particularly the costs of CE Electric (more than doubling them) and has least impact on WPD, as shown in Table 1 below.

Table 1: Impact of the contractor adjustment on cost

Group	% change in 2011/12 cost due to contractor adjustment
Electricity North West	+20%
UK Power Networks	+43%
CE Electric	+110%
Scottish Power Distribution	+25%
Scottish and Southern Energy	+36%
Western Power Distribution	+10%

Source: WPD

3.1.2 Output and operating environment variables

Three variables providing a measure of the scale of the company are used in the analysis.

- **Circuit length.** The circuit length reflects the scale and (together with dispersion, below) geographic footprint of the DNO and therefore the scale of its direct workload. These influence many of the telecom network and data related costs in the overall IT & Telecoms cost category. Using circuit length as the scale variable, the question becomes: "How efficiently is the IT function organised for this scale of network?" This is sourced from the Electricity Distribution Annual Report for 2010/11.

- **Number of FTEs.** The number of FTEs reflects the overall scale of the company, but also has a more direct impact on the end user IT support costs and software licensing costs. Using FTEs as the scale variable the question becomes: "How efficiently is the IT function organised for this level of total FTEs?" This is also sourced from the Electricity Distribution Annual Report for 2010/11.

- **Number of customers.** The number of customers provides another measure for the overall scale of the DNO, but is not directly related to any particular aspect of the overall IT & Telecoms cost category. Using customer numbers as the scale variable, the question becomes: "How efficiently is the IT function organised for this number of customers?" This is sourced from *t*he RRP dataset tables 2.7 FTE Labour Costs.

These output variables were not available for 2011/12 and 2012/13. We have therefore used the 2010/11 levels of the variables for each of the DNOs also as the scale variable for the 2011/12 and 2012/13 costs.

We also sought to obtain measures of the geographic dispersion of the electricity networks, to include in the analysis as an environmental factor outside the control of company management. However, data on direct measures of dispersion, such as the number of support stations and the distances between them, is only available for 2010/11.

We use a proxy for measure for dispersion in the analysis, defined as the number of customers divided by the network length, using the above data. This gives a measure of the relative geographic concentration of the DNO customer base. Other things being equal, the expectation is that higher concentration leads to lower costs, mainly due to reduced telecoms resilience and service costs.

However, this proxy variable does not have the expected sign in the estimations. This implies that it does not sufficiently reflect the underlying dispersion element, and instead continues to reflect overall scale of the company or some other factors. Therefore we do not include it in the final model specifications.

3.1.3 Overall dataset

Our analysis treats the14 DNOs as separate and independent companies, though in reality the majority of them are under combined management in an ownership group. However, using the seven ownership groups over four years would not provide enough data points for reliable econometric analysis. The treatment of the DNOs as independent entities is consistent with Ofgem’s treatment of DNOs in the comparative efficiency analysis for DPCR5.

4 Results

This section discusses the results of the top-down econometric comparative efficiency analysis of WPD's IT operations. Results from six separate models are presented that allow us to determine a number of findings.

- The time effects included in the specifications are positive and significant for 2010/11 and 2011/12, indicating rising average IT costs across all the DNOs.
- Across a number of specifications, WPD taking South West and South Wales together is at or near the boundary of the top quartile of the efficiency estimates across all the DNOs in 2009/10 , with the implication that the WPD's IT operations have been efficient relative to peers prior to the acquisition of Central Networks.
- WPD as a four DNO group is within the top quartile efficiency boundary in 2012/13 with and without the contractor adjustment..
- The average rank of WPD as a four DNO group is the highest in 2012/13 across the six specifications presented here.

The findings from the top down analysis are subject to significant uncertainty. The methods and the data available are able to explain only up to 56% of the variation in costs. In context of COLS analysis this means that significant part of the implied inefficiencies may in fact be due to lack of predictive power of the model. Further, the relatively low number of data points available for the analysis means that the estimated coefficients are themselves subject to significant uncertainty. The implication of this is that the estimated efficiency factors are subject to similarly significant uncertainty, which needs to be recognised in any use that is made for regulatory decision making.

4.1 Specification

4.1.1 Output variables

As expected, the scale of the DNOs is a significant driver of their IT costs. Different measures of scale can be expected to influence different aspects of the costs that make up the IT & Telecoms cost that are modelled.

One important issue to note regarding the scale variables is that they are likely to be highly correlated with each other. This means that as one variable increases within the dataset, similar, proportionate, changes exist in all other variables. Table 2 shows the correlations between the different output variables tested for inclusion in our specifications.

Table 2: Correlations between different scale measures

	Log of number of FTEs	Log of circuit length	Log of number of customers
Log of number of FTEs	1.00		
Log of circuit length	0.68	1.00	
Log of number of customers	0.64	0.82	1.00

Source: Deloitte analysis

This issue of correlation can cause difficulties in estimation in econometric models. In particular, it may be difficult to distinguish the effects of one variable from the effects of another, commonly referred to as collinearity or multi-collinearity. This can make variables look spuriously insignificant or significant, and can affect the coefficients in regressions; potentially leading to counterintuitive magnitudes and signs on the coefficients of the correlated variables. Although this problem affects individual coefficients and their associated standard errors, making judgments over the responsiveness of costs to changes in outputs misleading, the overall model remains valid when interpreting all the affected coefficients in combination.

The presence of collinearity means that the model has to be interpreted as a whole, with less focus on the values of the coefficients on variables that are collinear between each other. There are also a number of possible remedies.

- Composite variables look at a single effect of output increasing in general. This was the approach that Ofgem followed in DPCR5. However, it requires application of necessarily arbitrary judgement on how to combine the output variables. We have therefore not pursued this approach.

- It is possible to disregard one or more variables, and assume that their impact on costs is fully reflected in the impact of another variable. However, this approach is likely to reduce the goodness of fit of the model, and will make the interpretation of coefficients of the collinear variables difficult. Further, in this specific case, each of the scale variables are likely to better reflect different parts of the costs that make up the total non-operational IT & Telecom cost, so completely disregarding one or more of the variables in the results is not an attractive option.

Our solution is to include each of the available scale variables in a separate regression, and present the results from each, as each of them provides a statistically valid model (as discussed in Section 4.2).

4.1.2 Time effects

We have included time effects in the final specifications. These are implemented as time fixed effects dummy variables. This is also how Ofgem treated time effects in the analysis for DPCR5.

4.2 Results from the benchmarking analysis

This section presents results from our preferred model specifications and estimations. We present the results from several models rather than selecting a single preferred model. Appendix A provides the raw estimation outputs for the models below, as well as for additional estimations referred to in the discussion below. The overall results on the comparative efficiency are relatively consistent across these different model specifications.

As the 2012/13 costs are not available for companies other than WPD, the 2012/13 results presented here should be interpreted as comparison of WPD DNOs in 2012/13 to other DNOs in 2011/12.

4.2.1 Circuit length as the scale variable

Equation 4 is estimated using COLS with the total circuit length as the scale variable including time fixed effects included in the equation. We estimate the model both with and without the contractor adjustment applied to allow comparison of results. Table 3 shows the estimation result, with the raw output provided in Appendix A. The interpretation of the results without contractor adjustment in Table 3 is as follows.

- The model is significant overall and explains 39% of the variation in the DNOs IT & Telecom costs. The model is therefore not able to explain the majority of the cost movements.
- The coefficient on the circuit length variable is significantly lower than one, implying increasing returns to scale. The coefficient implies that as circuit length increases by 10%, costs increase by 6.4%. This supports the choice of a log – log specification. The standard error of the coefficient estimate indicates that the model prediction is subject to some significant uncertainty. This uncertainty should be borne in mind when interpreting the efficiency results.
- The time effects are positive, but only significant for 2010/11 and 2011/12. This implies that there was an industry wide unexplained cost increase in 2010/11 and 2011/12 relative to the other years of the sample.

The model with the contractor adjustment applied in Table 4 is able to explain 52% of the variation in costs, which is substantially higher than the model estimated without the contractor adjustment.

Table 3: Regression results using circuit length as the scale variable

Explanatory variable	Coefficient	Standard error of the coefficient	Significance[6]
Log of circuit length	0.64	0.10	0.00
Year 2012/13 effect	0.15	0.10	0.14
Year 2011/12 effect	0.25	0.10	0.01
Year 2010/11 effect	0.20	0.10	0.05
Year 2009/10 effect	0.05	0.10	0.60
Year 2008/09 effect	0.03	0.10	0.78
Constant	-4.84	1.13	0.00
R-squared	**0.39**		

Source: Deloitte analysis

Table 4: Estimation results with the contractor adjustment applied

Explanatory variable	Coefficient	Standard error of the coefficient	Significance
Log of circuit length	0.65	0.12	0.00
Year 2012/13 effect	0.23	0.11	0.04
Year 2011/12 effect	0.26	0.11	0.02
Year 2010/11 effect	0.20	0.11	0.08
Year 2009/10 effect	0.05	0.11	0.64
Year 2008/09 effect	0.03	0.11	0.80
Constant	-4.90	1.27	0.00
R-squared	**0.52**		

Source: Deloitte analysis

The above models are also robust with respect to the potential concerns about OLS methodology identified in Section 2.1. Specifically, we have undertaken the Breusch-Pagan test for heteroskedasticity (a concern with pooled data), and the Shapiro-Wilk test for the normality of residuals (a concern with pooled data using OLS), and the Ramsey RESET test for misspecification of the model, which all passed. Additionally, we conduct the Hausman test for endogeneity in any of the explanatory variables, addressing the concern that the explanatory variables may be correlated with the estimated residuals. This test is also passed. The details of the tests results are provided in Appendix A.

The estimated models can then be used to predict the level of costs for the DNOs in each year, to obtain the measure of comparative efficiency as the difference between predicted and actual costs[7]. We use the top quartile boundary as the benchmark of efficiency for the COLS adjustment.

6 This is the probability of rejecting the hypothesis that the variable is insignificant when the variable is in fact significant. In this report we consider a variable significant if the probability of committing a type one error is less than or equal to 0.05.

Table 5 and Table 6 show the estimated percentage reduction in cost for the WPD DNOs to reach the top quartile boundary of efficiency in each year. As the WPD acquisition of Central Networks was not completed until April 2011, we identify Central Networks East and West Midlands DNOs separately from WPD in the results.

Table 5: DNO efficiency using circuit length as the scale variable

Group	DNO	2009/10	2010/11	2011/12	2012/13
Central Networks – East	EMID	28%	22%	23%	-6%
Central Networks – West	WMID	46%	42%	36%	4%
Western Power Distribution	S. Wales	17%	4%	2%	-37%
Western Power Distribution	S. West	-4%	24%	19%	1%
Western Power Distribution	**2 DNOs**	**6%**	**16%**	**12%**	**-13%**

Source: Deloitte analysis

Table 6: Efficiency results with the contractor adjustment applied

Group	DNO	2009/10	2010/11	2011/12	2012/13
Central Networks – East	EMID	29%	23%	8%	-45%
Central Networks – West	WMID	47%	42%	18%	-32%
Western Power Distribution	S. Wales	16%	4%	-31%	-87%
Western Power Distribution	S. West	-4%	24%	-10%	-37%
Western Power Distribution	**2 DNOs**	**6%**	**16%**	**-19%**	**-56%**

Source: Deloitte analysis

The low explanatory power of the model, the uncertainty surrounding the coefficient estimates and the limitations of the COLS approach affect the strength of conclusions that can be drawn regarding the levels of the estimated inefficiency. In particular the implied spread of efficiency, with West Midlands requiring a 36% reduction in 2011/12 to reach top quartile without the contractor adjustment and South Wales being 87% below the boundary in 2012/13 with the contractor adjustment, is likely to be exaggerated. Accepting those limitations, the results imply that:

- In 2009/10, before cost increases likely to be due to investment costs associated with the Central Networks acquisition, a 6% reduction in IT & Telecoms costs would have brought WPD as a whole within the top quartile boundary. Within the context of the limitations of the approach, the result implies that the WPD is roughly equal to the top quartile boundary. The Central Network DNOs were significantly less efficient prior to the acquisition.

[7] We also adjust the predicted costs for the tendency of log-log specification to systematically under predict when transformed from logs into a prediction in levels.

- WPD as a whole would be within the top quartile efficiency in 2012/13 without the contractor adjustment.
- WPD South Wales has improved consistently through time since 2009/10.
- The contractor adjustment has a large impact on the estimated comparative efficiency of the WPD DNOs in both 2011/12 and 2012/13. In particular, South Wales and South West move below the quartile boundary in 2011/12, and all four DNOs are clearly below the boundary on their planned 2012/13 costs compared to the 2011/12 costs of the other DNOs.

Table 7 and Table 8 show the results on a DNO ownership group basis for 2011/12 and 2012/13, including the ranking of the groups. Again accepting the above limitations, the results imply that:

- Without the contractor adjustment, WPD is ranked as the third most efficient DNO in 2011/12, and second in 2012/13, if considering only the two original WPD DNOs.
- The most efficient company without the contractor adjustment is CE Electric, but it falls to the fourth place – and significantly outside of the top quartile efficiency – when the contractor adjustment has been implemented in the data. This is consistent with Table 1 which shows that CE Electric is by far the most affected by the contractor adjustment.
- WPD as a group of four DNOs is the most efficient company in 2012/13 with the contractor adjustment applied (bearing in mind that this compares the 2011/12 costs for other companies against the 2012/13 budgeted costs for WPD).
- With the contractor adjustment, WPD considered as a group of the two original DNOs (South Wales and South West) ranks first in 2011/12 as well.
- Scottish and Southern Electricity is the second most efficient company after WPD in 2012/13 (bearing in mind that this compares the 2011/12 costs for other companies against the 2012/13 budgeted costs for WPD).
- Electricity North West is the least efficient DNO both with and without the contractor adjustment, with an implied cost reduction of 49% in 2011/12 to reach the top quartile boundary.

Table 7: Ownership group efficiency using circuit length as the scale variable

Group	DNOs	Efficiency 2011/12	Rank 2011/12	Efficiency 2012/13	Rank 2012/13
Electricity North West	All	57%	7	63%	7
UK Power Networks	All	32%	5	40%	5
CE Electric	All	-32%	1	-17%	1
Scottish Power Distribution	All	41%	6	49%	6
Scottish and Southern Energy	All	-7%	2	5%	4
Central Networks	All	29%	4	-1%	3
Western Power Distribution	2 DNOs	12%	3	-13%	2
Western Power Distribution	4 DNOs	23%	3	-6%	2

Source: Deloitte analysis

Table 8: Results with the contractor adjustment applied

Group	DNOs	Efficiency 2011/12	Rank 2011/12	Efficiency 2012/13	Rank 2012/13
Electricity North West	All	49%	7	58%	7
UK Power Networks	All	38%	6	48%	6
CE Electric	All	24%	4	36%	4
Scottish Power Distribution	All	35%	5	46%	5
Scottish and Southern Energy	All	-5%	2	10%	3
Central Networks	All	13%	3	-39%	2
Western Power Distribution	2 DNOs	-19%	1	-56%	1
Western Power Distribution	4 DNOs	1%	2	-45%	1

Source: Deloitte analysis

4.2.2 Number of customers as the scale variable

The second specification uses number of customers as the scale variable. Table 9 and Table 10 show the estimation results, with the raw output provided in Appendix A.

The results are similar to those using circuit length, though this specification performs slightly worse by explaining only 37% of the variation in the DNOs IT & Telecom costs without the contractor adjustment. With the contractor adjustment applied, the model is able to explain 56% of the variation in costs. The coefficient on the customer number variable is lower at below 0.50 for both sets of results, implying slightly stronger economies of scale on this measure compared to circuit length above. The time effects are similar to the above specification.

Table 9: Regression results using number of customers as the scale variable

Explanatory variable	Coefficient	Standard error of the coefficient	Significance[8]
Log of customer numbers	0.43	0.07	0.00
Year 2012/13 effect	0.15	0.10	0.14
Year 2011/12 effect	0.25	0.10	0.01
Year 2010/11 effect	0.20	0.10	0.05
Year 2009/10 effect	0.05	0.10	0.59
Year 2008/09 effect	0.03	0.10	0.77
Constant	-4.04	1.05	0.00
R-squared	**0.37**		

Source: Deloitte analysis

Table 10: Results with the contractor adjustment applied

Explanatory variable	Coefficient	Standard error of the coefficient	Significance[9]
Log of customer numbers	0.48	0.07	0.00
Year 2012/13 effect	0.42	0.10	0.00
Year 2011/12 effect	0.54	0.10	0.00
Year 2010/11 effect	0.20	0.10	0.04
Year 2009/10 effect	0.05	0.10	0.58
Year 2008/09 effect	0.03	0.10	0.77
Constant	-4.78	1.03	0.00
R-squared	**0.56**		

Source: Deloitte analysis

These specifications are robust with respect to the diagnostic tests as above.

Table 11 and Table 12 show the estimated percentage reduction in cost for the DNOs to reach the top quartile boundary of efficiency in each year.

8 This is the probability of rejecting the hypothesis that the variable is insignificant when the variable is in fact significant. In this report we consider a variable significant if the probability of committing a type one error is less than or equal to 0.05.

9 This is the probability of rejecting the hypothesis that the variable is insignificant when the variable is in fact significant. In this report we consider a variable significant if the probability of committing a type one error is less than or equal to 0.05.

Table 11: DNO efficiency using the number of customers as the scale variable

Group	DNO	2009/10	2010/11	2011/12	2012/13
Central Networks - East	EMID	34%	28%	29%	1%
Central Networks - West	WMID	48%	43%	37%	5%
Western Power Distribution	S. Wales	14%	0%	-2%	-42%
Western Power Distribution	S. West	3%	30%	25%	8%
Western Power Distribution	**2 DNOs**	**8%**	**18%**	**14%**	**-11%**

Source: Deloitte analysis

Table 12: Results with the contractor adjustment applied

Group	DNO	2009/10	2010/11	2011/12	2012/13
Central Networks - East	EMID	45%	33%	19%	-30%
Central Networks - West	WMID	40%	36%	9%	-47%
Western Power Distribution	S. Wales	22%	12%	-22%	-76%
Western Power Distribution	S. West	-8%	29%	-4%	-31%
Western Power Distribution	**2 DNOs**	**6%**	**22%**	**-12%**	**-48%**

Source: Deloitte analysis

The results are broadly consistent with the results using circuit length as the scale variable. The key difference is that the Central Networks East performs significantly worse under this specification. South Wales and South West also perform slightly worse on this scale variable.

Table 13 and Table 14 show the results on DNO ownership group basis for 2011/12 and 2012/13, including the ranking of the groups. The ranking of the groups is similar to the results on the previous specification, the main difference being that UK Power Networks and Scottish Power Distribution change position in the ranking with the contractor adjustment applied. This may reflect the effect of London, where UK Power Networks gains a high number of densely populated customers. However, the two companies remain similarly close to each other in terms of the distance to the top quartile boundary.

The exact distance from the top quartile boundary varies somewhat between the two specifications.

Table 13: Ownership group efficiency using number of customers as the scale variable

Group	DNOs	Efficiency 2011/12	Rank 2011/12	Efficiency 2012/13	Rank 2012/13
Electricity North West	All	54%	7	61%	7
UK Power Networks	All	26%	4	35%	5
CE Electric	All	-47%	1	-31%	1
Scottish Power Distribution	All	48%	6	55%	6
Scottish and Southern Energy	All	12%	2	23%	4
Central Networks	All	33%	5	3%	3
Western Power Distribution	2 DNOs	14%	3	-11%	2
Western Power Distribution	4 DNOs	26%	3	-2%	2

Source: Deloitte analysis

Table 14: Results with the contractor adjustment applied

Group	DNOs	Efficiency 2011/12	Rank 2011/12	Efficiency 2012/13	Rank 2012/13
Electricity North West	All	52%	7	61%	7
UK Power Networks	All	42%	5	52%	5
CE Electric	All	28%	4	40%	4
Scottish Power Distribution	All	42%	6	52%	6
Scottish and Southern Energy	All	-9%	2	7%	3
Central Networks	All	14%	3	-39%	2
Western Power Distribution	2 DNOs	-12%	1	-48%	1
Western Power Distribution	4 DNOs	5%	2	-42%	1

Source: Deloitte analysis

4.2.3 Number of FTEs as the scale variable

The third specification uses the number of FTEs as the scale variable. Table 15 and Table 16 show the estimation results, with the raw output provided in Appendix A.

The results are again similar to those using the other specifications. The coefficient on the number of FTEs variable is similar to the circuit length, and somewhat higher than the coefficient on number of customers.

Table 15: Regression results using number of FTEs as the scale variable

Explanatory variable	Coefficient	Standard error of the coefficient	Significance[10]
Log of number FTEs	0.67	0.13	0.00
Year 2012/13 effect	0.15	0.10	0.15
Year 2011/12 effect	0.25	0.09	0.01
Year 2010/11 effect	0.20	0.09	0.03
Year 2009/10 effect	0.04	0.09	0.65
Year 2008/09 effect	0.03	0.09	0.71
Constant	-2.75	0.95	0.01
R-squared	**0.34**		

Source: Deloitte analysis

Table 16: Results with the contractor adjustment applied

Explanatory variable	Coefficient	Standard error of the coefficient	Significance[11]
Log of number FTEs	0.66	0.13	0.00
Year 2012/13 effect	0.42	0.11	0.00
Year 2011/12 effect	0.54	0.11	0.00
Year 2010/11 effect	0.20	0.11	0.06
Year 2009/10 effect	0.04	0.11	0.68
Year 2008/09 effect	0.03	0.11	0.75
Constant	-2.75	0.93	0.00
R-squared	**0.49**		

Source: Deloitte analysis

This specification is also robust with respect to the diagnostic tests as above.

Table 17 and Table 18 show the estimated percentage reduction in cost for the DNOs to reach the top quartile boundary of efficiency in each year.

[10] This is the probability of rejecting the hypothesis that the variable is insignificant when the variable is in fact significant. In this report we consider a variable significant if the probability of committing a type one error is less than or equal to 0.05.

[11] This is the probability of rejecting the hypothesis that the variable is insignificant when the variable is in fact significant. In this report we consider a variable significant if the probability of committing a type one error is less than or equal to 0.05.

Table 17: DNO efficiency using the number of FTEs as the scale variable

Group	DNO	2009/10	2010/11	2011/12	2012/13
Central Networks - East	EMID	45%	33%	34%	7%
Central Networks - West	WMID	40%	36%	29%	-6%
Western Power Distribution	S. Wales	22%	12%	9%	-28%
Western Power Distribution	S. West	-8%	29%	24%	6%
Western Power Distribution	**2 DNOs**	**6%**	**22%**	**18%**	**-7%**

Source: Deloitte analysis

Table 18: Results with the contractor adjustment applied

Group	DNO	2009/10	2010/11	2011/12	2012/13
Central Networks - East	EMID	30%	24%	9%	-42%
Central Networks - West	WMID	44%	39%	14%	-36%
Western Power Distribution	S. Wales	15%	2%	-33%	-89%
Western Power Distribution	S. West	2%	28%	-3%	-28%
Western Power Distribution	**2 DNOs**	**8%**	**18%**	**-15%**	**-51%**

Source: Deloitte analysis

The results are again broadly consistent with the results from the other two specifications. The main difference is that Central Networks East performs slightly worse compared to the other two specifications without the contractor adjustment applied, but slightly better with the adjustment. These differences, however, are not likely to be meaningful within the context of the uncertainty and limitations of the approach set out above.

Table 19 and Table 20 show the results on DNO ownership group basis for 2011/12 and 2012/13, including the ranking of the groups. The results on the company rankings are nearly identical to those on estimated using circuit length as the scale variable. WPD as a four DNO group is again ranked second in 2012/13 without the contractor adjustment, and first with the contractor adjustment. However, in this case it is also ranked first in 2011/12 when the contractor adjustment is applied, compared to third without the adjustment.

Table 19: Ownership group efficiency using number of FTEs as the scale variable

Group	DNOs	Efficiency 2011/12	Rank 2011/12	Efficiency 2012/13	Rank 2012/13
Electricity North West	All	60%	7	67%	7
UK Power Networks	All	36%	5	45%	5
CE Electric	All	-28%	1	-13%	1
Scottish Power Distribution	All	48%	6	55%	6
Scottish and Southern Energy	All	-11%	2	2%	4
Central Networks	All	31%	4	0%	3
Western Power Distribution	2 DNOs	18%	3	-7%	2
Western Power Distribution	4 DNOs	26%	3	-2%	2

Source: Deloitte analysis

Table 20: Results with the contractor adjustment applied

Group	DNOs	Efficiency 2011/12	Rank 2011/12	Efficiency 2012/13	Rank 2012/13
Electricity North West	All	42%	7	51%	7
UK Power Networks	All	28%	5	39%	5
CE Electric	All	12%	4	25%	4
Scottish Power Distribution	All	41%	6	50%	6
Scottish and Southern Energy	All	12%	2	25%	3
Central Networks	All	12%	3	-39%	2
Western Power Distribution	2 DNOs	-15%	1	-51%	1
Western Power Distribution	4 DNOs	2%	1	-44%	1

Source: Deloitte analysis

4.3 Summary of the results

There is no clear way of selecting a preferred specification or a set of results from the models presented in this section. All of the models presented are statistically valid, passing the relevant diagnostic tests. Further, the specifications with the three alternative scale variables are able to explain a similar proportion of the variation in costs. Further, whereas the estimations with the contractor adjustment applied to the data explain a consistently higher proportion of the variation in costs compared to estimations without the adjustment in the data, the overall proportion explained by any one model remains around 50%.

It is prudent, therefore, to consider the overall results from the six specifications in the round. Table 21 does this, presenting the simple average of the efficiency score and ranking across the six specifications.

WPD ranks highest on average in 2012/13 across the six specifications and is the only company within the top quartile boundary. This compares WPD budgeted cost in 2012/13 to other company actuals in 2011/12. The WPD budgeted costs in 2012/13 are 35% lower compared to WPD actuals in 2011/12. Therefore, against a background of increasing costs in the industry in 2010/11 and 2011/12, the other ownership groups would have to reduce their costs also by 35% from 2011/12 to 2012/13 to maintain position relative to WPD.

Table 21: Average ownership group efficiency across the six specifications

Group	DNOs	Efficiency 2011/12	Rank 2011/12	Efficiency 2012/13	Rank 2012/13
Electricity North West	All	52%	7.0	60%	7.0
UK Power Networks	All	34%	5.0	43%	5.2
CE Electric	All	-7%	2.5	6%	2.5
Scottish Power Distribution	All	42%	5.8	51%	5.8
Scottish and Southern Energy	All	-2%	2.0	12%	3.5
Central Networks	All	22%	3.7	-19%	2.5
Western Power Distribution	2 DNOs	0%	2.0	-31%	1.5
Western Power Distribution	4 DNOs	14%	2.3	-24%	1.5

Source: Deloitte analysis

5 Discussion of the findings

The following observations can be made from the analysis and results presented here:

- The COLS models are statistically robust in that they pass the required specification and diagnostic tests. However, they can only explain roughly half or less of the variation in the IT & Telecom cost across the DNOs and through the years. This suggests that:
    - The models are missing significant variables to explain the cost movement, even though they pass the diagnostic tests. This may be the case as only company scale has been controlled for in the regressions.
    - The variation in costs is caused by random or systematic data errors. This would be the case for example if the companies had different accounting or allocation policies regarding the IT & Telecom costs, or have otherwise organised the support IT & Telecoms operations differently. This is a general weakness for using a top-down approach at a granular level of costs; the more granular the costs that are benchmarked, the more possibility there is for them to be affected by companies' individual treatment of that specific cost category.
    - The contractor cost adjustment supplied by WPD is an example of one such systematic data difference. The results here show the scale of the effect that such cost allocation differences can have on the estimation results.
    - There may be company specific factors that increase costs outside the management control for which we do not have the data to adjust the costs in order to improve the performance of the models.
- The amount of difference between the most efficient and least efficient company could therefore be a reflection of the relatively poor explanatory power of the model as opposed to measuring actual level of inefficiency.
- The implication of the low explanatory power in conjunction with the COLS methodology is that the comparative efficiency results are likely to be subject to additional uncertainty.
- Western Power Distribution as a two DNO group consisting of South West and South Wales during four of the six years under analysis, is found consistently near the top quartile boundary, and can therefore be considered efficient prior to the contractor adjustment. Further, the two DNO group was near the top quartile boundary in 2009/10, prior to incurring costs associated with the acquisition of the Central Networks DNOs.
- With the contractor adjustment applied, WPD as a two DNO group (i.e. excluding the Central Networks DNOs acquired in April 2011) ranks first among the ownership groups in 2011/12.
- The Central Networks DNOs acquired by WPD in April 2011 needed to reduce their costs by roughly 40% from their 2009/10 levels to reach the estimated top quartile efficiency

level. For WPD as a post-acquisition four DNO group, this translates to a roughly 30% reduction in costs using 2009/10 as a starting point, if no further allowance is made for the uncertainty in the results driven by the low explanatory power of the models.

- The results for 2012/13 WPD as a four DNO group show that the cost reduction has been achieved – assuming no change to IT and Telecoms costs of other companies from 2011/12 – as WPD is within the boundary of top quartile efficiency with and without the contractor adjustment applied.

- The contractor adjustment puts WPD within the top quartile boundary in both 2011/12 and 2012/13, and WPD is ranked first in 2012/13 when the contractor adjustment is taken into account.

- Taking average company rankings over the six specifications – averaging the results with and without the contractor cost adjustment – WPD has the best average rank for 2012/13.

These results suggest that WPD should be considered efficient in terms of its non-operational IT and Telecoms costs using the criteria previously applied by Ofgem.

Appendix A Econometric Results

In this appendix we provide the output from the econometrics package we used (STATA) for each of the comparative efficiency econometric models referred to in Section 4.2.

A.1 COLS regression with circuit length

Here we provide the results for the COLS model estimated with total circuit length as the scale variable. In addition, we report a suite of statistical robustness checks undertaken to assess the potential concerns that can arise with use of OLS techniques with pooled data, discussed in Section 2. The model passes all the diagnostic tests.

Without the contractor adjustment

The model estimation results:

```
. reg  ln_cost ln_lenght d1_201213 d1_201112 d1_201011 d1_200910 d1_200809

      Source |       SS       df       MS              Number of obs =      84
-------------+------------------------------           F(  6,    77) =    8.24
       Model |  3.32209917     6  .553683195           Prob > F      =  0.0000
    Residual |  5.17399944    77  .067194798           R-squared     =  0.3910
-------------+------------------------------           Adj R-squared =  0.3436
       Total |  8.49609862    83  .102362634           Root MSE      =  .25922

------------------------------------------------------------------------------
     ln_cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   ln_lenght |   .6406158   .1035444     6.19   0.000     .4344326     .846799
   d1_201213 |   .1466971   .0979878     1.50   0.138    -.0484217    .3418158
   d1_201112 |   .2466807   .0979878     2.52   0.014      .051562    .4417994
   d1_201011 |   .1992905   .0979878     2.03   0.045     .0041718    .3944092
   d1_200910 |   .0517123   .0979831     0.53   0.599    -.143397     .2468215
   d1_200809 |   .0281218   .0979778     0.29   0.775    -.1669771    .2232206
       _cons |  -4.844072   1.129799    -4.29   0.000    -7.09379    -2.594354
------------------------------------------------------------------------------
```

The model passes the Ramsey RESET test for specification error:

```
Ramsey RESET test using powers of the fitted values of ln_cost
       Ho:  model has no omitted variables
                  F(3, 74) =      1.03
                  Prob > F =      0.3865
```

The model passes the Breusch-Pagan test for heteroskedasticity:

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ln_cost

         chi2(1)      =     0.00
         Prob > chi2  =   0.9668
```

The model passes the Shapiro Wilk test for normality of the residuals:

```
                   Shapiro-Wilk W test for normal data

    Variable |    Obs       W           V         z       Prob>z
-------------+--------------------------------------------------
         res |     84    0.98265      1.239     0.471    0.31865
```

The model passes the Hausman test for endogeneity of the explanatory variables:

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     iv_full      ols_full      Difference          S.E.
-------------+----------------------------------------------------------------
   ln_lenght |      .671234     .6406158        .0306182        .0580587
   d1_201213 |     .1183084     .1466971       -.0283887        .0303249
   d1_201112 |      .218292     .2466807       -.0283887        .0303249
   d1_201011 |     .1709019     .1992905       -.0283887        .0303249
   d1_200910 |     .0234244     .0517123       -.0282879        .0303295
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from ivreg
            B = inconsistent under Ha, efficient under Ho; obtained from regress

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        1.72
                Prob>chi2 =      0.8870
```

With the contractor adjustment applied

The model estimation results:

```
. reg  ln_cost ln_lenght d1_201213 d1_201112 d1_201011 d1_200910 d1_200809

      Source |       SS       df       MS              Number of obs =      84
-------------+------------------------------           F(  6,    77) =   13.94
       Model |  6.13208663     6  1.02201444           Prob > F      =  0.0000
    Residual |  5.64579665    77  .073322034           R-squared     =  0.5206
-------------+------------------------------           Adj R-squared =  0.4833
       Total |  11.7778833    83  .141902208           Root MSE      =  .27078

------------------------------------------------------------------------------
     ln_cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   ln_lenght |   .6312214   .1081623     5.84   0.000     .4158428    .8466001
   d1_201213 |   .4149039    .102358     4.05   0.000     .2110832    .6187246
   d1_201112 |   .5400753    .102358     5.28   0.000     .3362546     .743896
   d1_201011 |   .1994299    .102358     1.95   0.055    -.0043908    .4032506
   d1_200910 |   .0518207    .102353     0.51   0.614    -.1519901    .2556316
   d1_200809 |   .0281792   .1023475     0.28   0.784    -.1756207    .2319792
       _cons |   -4.74176   1.180187    -4.02   0.000    -7.091812   -2.391708
------------------------------------------------------------------------------
```

The model passes the Ramsey RESET test for specification error:

```
Ramsey RESET test using powers of the fitted values of ln_cost
       Ho:  model has no omitted variables
                 F(3, 74) =      0.67
                 Prob > F =      0.5740
```

The model passes the Breusch-Pagan test for heteroskedasticity:

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ln_cost

         chi2(1)      =     0.17
         Prob > chi2  =   0.6844
```

The model passes the Shapiro Wilk test for normality of the residuals:

```
                 Shapiro-Wilk W test for normal data

    Variable |    Obs       W           V         z       Prob>z
-------------+--------------------------------------------------
         res |     84    0.99256      0.531    -1.389    0.91763
```

The model passes the Hausman test for endogeneity of the explanatory variables:

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |    iv_full      ols_full      Difference          S.E.
-------------+----------------------------------------------------------------
   ln_lenght |    .6599669     .6312214        .0287455        .0617602
   d1_201213 |    .3864741     .4149039       -.0284298         .033243
   d1_201112 |    .5116455     .5400753       -.0284298         .033243
   d1_201011 |    .1710001     .1994299       -.0284298         .033243
   d1_200910 |    .0234855     .0518207       -.0283352        .0332474
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from ivreg
            B = inconsistent under Ha, efficient under Ho; obtained from regress

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        1.41
                Prob>chi2 =      0.9230
```

A.2 COLS regression with customer numbers

Here we provide the results for the COLS model estimated with total customer numbers as the scale variable. In addition, we report a suite of statistical robustness checks undertaken to assess the potential concerns that can arise with use of OLS techniques with pooled data, discussed in Section 2. The model passes all the diagnostic tests.

Without the contract adjustment

The model estimation results:

```
. reg  ln_cost ln_cust d1_201213 d1_201112 d1_201011 d1_200910 d1_200809

      Source |       SS       df       MS              Number of obs =      84
-------------+------------------------------           F(  6,    77) =    7.59
       Model |  3.15868041     6  .526446735           Prob > F      =  0.0000
    Residual |  5.33741821    77   .06931712           R-squared     =  0.3718
-------------+------------------------------           Adj R-squared =  0.3228
       Total |  8.49609862    83  .102362634           Root MSE      =  .26328

------------------------------------------------------------------------------
     ln_cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     ln_cust |    .427153   .0724635     5.89   0.000     .2828597    .5714462
   d1_201213 |   .1502688   .0995161     1.51   0.135    -.0478931    .3484307
   d1_201112 |   .2502524   .0995161     2.51   0.014     .0520905    .4484143
   d1_201011 |   .2028623   .0995161     2.04   0.045     .0047004    .4010242
   d1_200910 |    .054419   .0995142     0.55   0.586    -.1437391    .2525772
   d1_200809 |   .0290208   .0995124     0.29   0.771    -.1691336    .2271752
       _cons |  -4.044789   1.050327    -3.85   0.000    -6.136257   -1.953321
------------------------------------------------------------------------------
```

The model passes the Ramsey RESET test for specification error:

```
Ramsey RESET test using powers of the fitted values of ln_cost
       Ho:  model has no omitted variables
                 F(3, 74) =      1.77
                 Prob > F =      0.1594
```

The model passes the Breusch-Pagan test for heteroskedasticity:

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ln_cost

         chi2(1)      =     0.67
         Prob > chi2  =   0.4122
```

The model passes the Shapiro Wilk test for normality of the residuals:

```
                   Shapiro-Wilk W test for normal data

    Variable |    Obs       W           V         z       Prob>z
-------------+--------------------------------------------------
         res |     84    0.98769      0.880    -0.282    0.61101
```

The model passes the Hausman test for endogeneity of the explanatory variables:

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     iv_full     ols_full       Difference          S.E.
-------------+----------------------------------------------------------------
     ln_cust |     .448353      .427153           .0212         .0408297
   d1_201213 |    .1211035     .1502688       -.0291653         .0307648
   d1_201112 |    .2210871     .2502524       -.0291653         .0307648
   d1_201011 |    .1736969     .2028623       -.0291653         .0307648
   d1_200910 |    .0253154      .054419       -.0291036         .0307675
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from ivreg
            B = inconsistent under Ha, efficient under Ho; obtained from regress

    Test:  Ho:  difference in coefficients not systematic

                 chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                         =        1.74
               Prob>chi2 =      0.8836
```

With the contract adjustment applied

The model estimation results:

```
. reg  ln_cost ln_cust d1_201213 d1_201112 d1_201011 d1_200910 d1_200809

      Source |       SS       df       MS              Number of obs =      84
-------------+------------------------------           F(  6,    77) =   16.64
       Model |  6.65030664     6  1.10838444           Prob > F      =  0.0000
    Residual |  5.12757664    77  .066591904           R-squared     =  0.5646
-------------+------------------------------           Adj R-squared =  0.5307
       Total |  11.7778833    83  .141902208           Root MSE      =  .25805

------------------------------------------------------------------------------
     ln_cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     ln_cust |   .4779362   .0710248     6.73   0.000     .3365079    .6193646
   d1_201213 |   .4176312   .0975403     4.28   0.000     .2234038    .6118587
   d1_201112 |   .5428026   .0975403     5.56   0.000     .3485752    .7370301
   d1_201011 |   .2021572   .0975403     2.07   0.042     .0079297    .3963847
   d1_200910 |   .0538617   .0975384     0.55   0.582     -.140362    .2480855
   d1_200809 |   .0286619   .0975366     0.29   0.770    -.1655582     .222882
       _cons |  -4.779217   1.029473    -4.64   0.000    -6.829159   -2.729274
------------------------------------------------------------------------------
```

The model passes the Ramsey RESET test for specification error:

```
Ramsey RESET test using powers of the fitted values of ln_cost
       Ho:  model has no omitted variables
                  F(3, 74) =      2.29
                  Prob > F =      0.0854
```

The model passes the Breusch-Pagan test for heteroskedasticity:

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ln_cost

         chi2(1)      =     0.13
         Prob > chi2  =   0.7206
```

The model passes the Shapiro Wilk test for normality of the residuals:

```
                   Shapiro-Wilk W test for normal data

    Variable |    Obs       W           V         z       Prob>z
-------------+--------------------------------------------------
         res |     84    0.98829      0.837    -0.391    0.65213
```

The model passes the Hausman test for endogeneity of the explanatory variables:

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     iv_full      ols_full      Difference          S.E.
-------------+----------------------------------------------------------------
     ln_cust |     .509418     .4779362        .0314817        .0390458
   d1_201213 |    .3887548     .4176312       -.0288765        .0280818
   d1_201112 |    .5139262     .5428026       -.0288765        .0280818
   d1_201011 |    .1732807     .2021572       -.0288765        .0280818
   d1_200910 |    .0250769     .0538617       -.0287848        .0280846
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from ivreg
          B = inconsistent under Ha, efficient under Ho; obtained from regress

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        2.41
                Prob>chi2 =      0.7906
```

A.3 COLS regression with FTEs

Here we provide the results for the COLS model estimated with total number of FTEs as the scale variable. In addition, we report a suite of statistical robustness checks undertaken to assess the potential concerns that can arise with use of OLS techniques with pooled data, discussed in Section 2. The model passes all the diagnostic tests apart from the heteroskedasticity test, which we adjust for in the estimation by using robust standard errors.

Without the contractor adjustment

The model estimation results:

```
. reg  ln_cost ln_fte d1_201213 d1_201112 d1_201011 d1_200910 d1_200809, robust

Linear regression                                      Number of obs =      84
                                                       F(  6,    77) =    7.31
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3413
                                                       Root MSE      =   .2696

------------------------------------------------------------------------------
             |               Robust
     ln_cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      ln_fte |   .6650012   .1312084     5.07   0.000     .4037318    .9262705
   d1_201213 |   .1503162   .1025346     1.47   0.147    -.0538563    .3544886
   d1_201112 |   .2502998    .093016     2.69   0.009     .0650812    .4355184
   d1_201011 |   .2029096   .0919593     2.21   0.030     .0197952     .386024
   d1_200910 |   .0431738   .0947146     0.46   0.650    -.1454271    .2317747
   d1_200809 |   .0334049   .0889369     0.38   0.708    -.1436912    .2105009
       _cons |  -2.749811   .9536137    -2.88   0.005    -4.648699   -.8509238
------------------------------------------------------------------------------
```

The model passes the Ramsey RESET test for specification error:

```
Ramsey RESET test using powers of the fitted values of ln_cost
       Ho:  model has no omitted variables
                  F(3, 74) =      2.54
                  Prob > F =      0.0632
```

The Breusch-Pagan test for heteroskedasticity is not available as robust standard errors have been used in the estimation.

The model passes the Shapiro Wilk test for normality of the residuals:

```
                   Shapiro-Wilk W test for normal data

    Variable |    Obs       W           V         z       Prob>z
-------------+--------------------------------------------------
         res |     84    0.98511      1.064     0.136    0.44591
```

The model passes the Hausman test for endogeneity of the explanatory variables:

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |    iv_full      ols_full      Difference          S.E.
-------------+----------------------------------------------------------------
      ln_fte |    .7265255     .6650012        .0615244        .0691677
   d1_201213 |    .1162407     .1503162       -.0340754        .0272822
   d1_201112 |    .2162243     .2502998       -.0340754        .0272822
   d1_201011 |    .1688342     .2029096       -.0340754        .0272822
   d1_200910 |    .0081686     .0431738       -.0350052         .027348
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from ivreg
          B = inconsistent under Ha, efficient under Ho; obtained from regress

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        3.14
                Prob>chi2 =      0.6786
```

With the contractor adjustment applied

The model estimation results:

```
. reg  ln_cost ln_fte d1_201213 d1_201112 d1_201011 d1_200910 d1_200809

      Source |       SS       df       MS              Number of obs =      84
-------------+------------------------------           F(  6,    77) =   12.38
       Model |  5.78373176     6  .963955293           Prob > F      =  0.0000
    Residual |  5.99415152    77  .077846124           R-squared     =  0.4911
-------------+------------------------------           Adj R-squared =  0.4514
       Total |  11.7778833    83  .141902208           Root MSE      =  .27901

------------------------------------------------------------------------------
     ln_cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      ln_fte |   .6648948   .1265532     5.25   0.000     .4128952    .9168943
   d1_201213 |   .4183846   .1054615     3.97   0.000     .2083839    .6283853
   d1_201112 |    .543556   .1054615     5.15   0.000     .3335553    .7535567
   d1_201011 |   .2029106   .1054615     1.92   0.058    -.0070901    .4129113
   d1_200910 |   .0431764   .1054991     0.41   0.683    -.1668992     .253252
   d1_200809 |   .0334046   .1054559     0.32   0.752    -.1765848    .2433941
       _cons |   -2.74903   .9321542    -2.95   0.004    -4.605186   -.8928738
------------------------------------------------------------------------------
```

The model passes the Ramsey RESET test for specification error:

```
Ramsey RESET test using powers of the fitted values of ln_cost
       Ho:  model has no omitted variables
                 F(3, 74) =      0.34
                 Prob > F =      0.7988
```

The model passes the Breusch-Pagan test for heteroscedasticity:

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of ln_cost

         chi2(1)      =     2.32
         Prob > chi2  =   0.1274
```

The model passes the Shapiro Wilk test for normality of the residuals:

```
                   Shapiro-Wilk W test for normal data

    Variable |    Obs       W           V         z       Prob>z
-------------+--------------------------------------------------
         res |     84    0.98985      0.725    -0.706    0.75980
```

The model passes the Hausman test for endogeneity of the explanatory variables:

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |    iv_full      ols_full      Difference          S.E.
-------------+----------------------------------------------------------------
      ln_fte |    .7263945     .6648948        .0614997        .0727768
   d1_201213 |    .3843096     .4183846        -.034075        .0299066
   d1_201112 |    .5094811      .543556        -.034075        .0299066
   d1_201011 |    .1688356     .2029106        -.034075        .0299066
   d1_200910 |     .008172     .0431764       -.0350043        .0299725
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from ivreg
          B = inconsistent under Ha, efficient under Ho; obtained from regress

    Test:  Ho:  difference in coefficients not systematic

                 chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                         =        2.67
               Prob>chi2 =      0.7509
```