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RIIO-ED1 business plan expenditure assessment - methodology and results

Supplementary annex

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Overview:

This document summarises our methodology and results for the assessment of the expenditures proposed in the electricity distribution companies' business plans for the next distribution price control (RIIO-ED1). We have published this supplementary annex to provide further detail to that set out in our 'Assessment of the RIIO-ED1 business plans' document.

Associated documents

Assessment of RIIO-ED1 business plans and fast-tracking (letter)

- Assessment of the RIIO-ED1 business plans
- Initial Assessment of the RIIO-ED1 innovation strategies
- RIIO-ED1 Glossary

The assessment letter and supplementary annexes can be found on our website at the following link:
https://www.ofgem.gov.uk/publications-and-updates/riio-ed1-business-plan-assessment-and-fast-tracked-consultation

RIIO-ED1: Draft Determinations for Western Power Distribution Ltd

- RIIO-ED1 Fast-Track Draft Determination Financial Model (Excel)
- RIIO-ED1 Fast-Track Draft Determination Financial Model Audit Letter

The Draft Determinations and supplementary annexes can be found on our website at the following link:
https://www.ofgem.gov.uk/network-regulation-%E2%80%93-riio-model/riio-ed1-price-control

Strategy Decision for RIIO-ED1 – Overview
https://www.ofgem.gov.uk/publications-and-updates/strategy-decision-riio-ed1-overview

Open letter consultation on RIIO-ED1 Business Plans
https://www.ofgem.gov.uk/ofgem-publications/75338/riioed1bppublicationseekingviews.pdf

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1. Introduction and overview

Chapter Summary

A summary of the purpose and structure of this document and an overview of the methodology for our fast-track assessment of the expenditures set out in the business plans.

Introduction

1.1. A key part of the RIIO (Revenue = Incentives + Innovation + Outputs) model is for companies to develop a well-justified business plan. This should be informed by enhanced stakeholder engagement. The 14 distribution network operators (DNOs) submitted and published their business plans for the next electricity distribution price control (RIIO-ED1) by 1 July 2013.

1.2. DNOs that have stepped up to the challenge of submitting realistic and well-justified business plans that provide demonstrable value to consumers may benefit from proportionate treatment. Proportionate treatment is a mechanism within RIIO where we subject particularly high quality elements of a company's plan to lighter touch regulatory scrutiny. If a plan is of sufficiently high quality and good value overall, we may consider it for fast-tracking. Fast-tracking means we accept the business plan as submitted and conclude the company's price control review early.

1.3. We have published a letter setting out a summary of our assessment of DNOs' business plans for RIIO-ED1.[1] The letter also sets out:

- our proposal to conditionally fast-track the four DNOs owned by Western Power Distribution (WPD)
- our decision that the DNOs owned by Electricity North West (ENWL), Northern Powergrid (NPg), UK Power Networks (UKPN), SP Energy Networks (SPEN) and SSE Power Distribution (SSEPD) will not be fast-tracked, and will therefore now follow the slow-track process.

1.4. Our proposal to fast-track WPD is subject to the outcome of a consultation and the consultation on our methodology for assessing equity market returns. Further details can be found in our RIIO-ED1 Business plan assessment and fast-tracked consultation publication.[1]

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[1] https://www.ofgem.gov.uk/publications-and-updates/riio-ed1-business-plan-assessment-and-fast-tracked-consultation

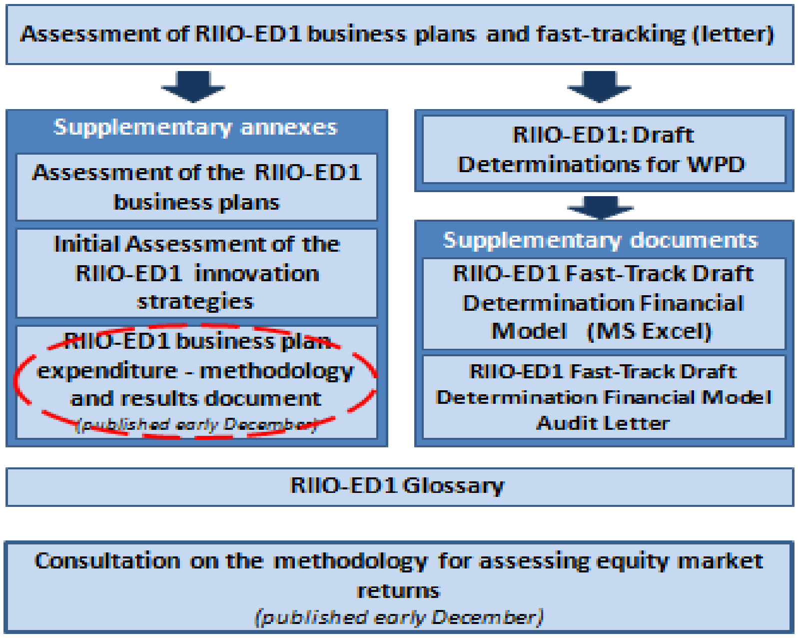
Purpose of this document

1.5. The purpose of this supplementary annex is to set out how we assessed the 'Resources (efficient expenditure)' criterion for the purpose of the fast-track assessment. This is one of five criteria we used to assess the DNOs' business plans.

1.6. This supplementary annex contains technical detail of our approach to cost assessment for the RIIO-ED1 fast-track assessment and the key results from our analysis. We may make further refinements and changes to our methodology for the purpose of slow-tracking but this will not impact on our fast-track proposals.

1.7. A high-level explanation of our efficient expenditure assessment can be found in Appendix 2 of our supplementary annex 'Assessment of the RIIO-ED1 business plans.[2] Figure 1.1 shows a map of the RIIO-ED1 business plan assessment and draft determination documents.

Figure 1.1: Map of the RIIO-ED1 business plan assessment and draft determination documents



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[2] https://www.ofgem.gov.uk/ofgem-publications/84606/assessmentoftheriio-ed1businessplans.pdf

Efficient expenditure: Requirements of a well-justified plan

1.8. Under the RIIO framework, the onus is on the DNOs to demonstrate the cost-efficiency and long-term value for money of their business plans. As part of this we expected DNOs to set out:

- the costs of delivering the outputs and secondary deliverables that their plans will deliver
- cost projections in the context of historical performance
- a proportionate degree of cost-benefit analysis and other justification for their expenditure
- the processes and tools they used to determine their efficiency; external benchmarking evidence; evidence of market testing and clear demonstration of consideration of their longer-term cost and output requirements.

1.9. The DNOs were required to set out forecast expenditures and volumes against the four scenarios for future low carbon penetration developed by the Department of Energy and Climate Change (DECC) including additional detail on a reference scenario.[3] We expected DNOs to justify how they had determined the scenario on which they had based their plans. We also set out in the Strategy decision that we expected the DNOs to demonstrate how they would manage the transition from one scenario to another.

1.10. Smart grid solutions and innovation are important tools for DNOs to drive cost efficiency. The DNOs were required to demonstrate that smart grid solutions and learning from innovation projects have been embedded into their core business. We required DNOs to provide a clearly articulated strategy for the deployment of smart grids and innovation, including how the maximum benefits for customers can be realised. We expected to see clear efficiencies resulting from innovation and smart grids in the DNOs' business plans to ensure potential savings are passed on to customers.

1.11. We expected DNOs to have considered ways in which smart meter data could be used to improve output delivery and cost efficiency through enabling smart technologies. In particular we expected the benefits DNOs realise from the use of this data to outweigh the costs of the data.

Overview of our expenditure assessment methodology

1.12. As set out in our Strategy decision, and building on our approach from DPCR5 and RIIO-GD1, we have applied a broad toolkit approach to our cost assessment. We use this to build up a picture of whether a company is efficient. The approach makes good use of the rich information that is now available under the RIIO framework to differentiate the quality of DNOs' business plans. We have made use of

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[3] The reference scenario was DECC's Scenario 1 (high abatement in low carbon heat) and was used for context for and comparison against the DNOs' core forecast.

quantitative and qualitative assessment, DNOs' narrative and supporting evidence, historical costs and performance data and company forecasts.

1.13. We have carried out a qualitative assessment of smart grids and innovation in the DNOs' business plans. We also assess whether the DNOs' strategies are making best use of smart metering data and the benefits they believe they can achieve compared to the costs. In conducting our assessment of efficient costs we implicitly consider the costs and benefits from smart grids, smart meters and innovation.

1.14. The DNOs' scenarios forecasts were used to provide context for the assessment of the low carbon technology forecasts and to support the assessment of DNOs' narratives on uncertainty and risk.[4] Our assessment of this information formed part of the qualitative assessment of business plans.

1.15. We have carried out comparative analysis for both totex[5] as a whole and on a cost activity-level basis.[6] This ensures that no single approach is deterministic in reaching our view on the efficiency of expenditure in the DNOs' plans. We have used specific technical and economic expertise to inform and assist us in carrying out our assessment and to provide assurance on the robustness of our approach.

1.16. We estimate cost models using historical data and then roll these forward to take account of forecast real price effects (RPEs) and changes in volumes and outputs.

1.17. We have benchmarked the efficient level of totex for each DNO using the upper quartile (UQ) rather than the frontier to allow for other factors that may influence the DNOs' costs. The upper quartile level of efficiency (lower quartile level of costs) is the first quartile in the distribution of efficiency scores. While, on any one measure of efficient totex, it is only possible for four out of 14 DNOs to outperform this, we also have given regard to the spread of efficiency scores. Had most of the DNOs been tightly banded we would have considered DNOs close to the upper quartile as being efficient. We have made an adjustment to the upper quartile level of efficiency to take account of instances where DNOs have offered up tighter customer interruptions (CI) and customer minutes lost (CML) targets than our benchmarking methodology has produced. These differences have been valued at the relevant CI and CML incentive rates. We have adjusted the efficiency level to ensure our testing is robust to downside cost of equity scenarios.

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[4] For details on our assessment of uncertainty and risk in the DNOs' business plans, see the Assessment of RIIO-ED1 business plans and fast-tracking document: https://www.ofgem.gov.uk/publications-and-updates/riio-ed1-business-plan-assessment-and-fast-tracked-consultation

[5] Totex represents total expenditure submitted by companies; it includes all activity-level costs including network investment, network operating costs, closely associated indirects and non-operational capex.

[6] Activity-level costs represent expenditure at a disaggregated level of detail for example tree cutting, asset replacement or reinforcement activity.

1.18. For our activity-level analysis we sum forecast and modelled costs back up to totex level and calculate an overall efficiency for each DNO before calculating the upper quartile benchmark. This reduces the risk of cherry-picking between activities.

1.19. We have decided that it is appropriate to place a significantly greater weight on our activity-level analysis in reaching our conclusions for fast-tracking. This is because our activity-level analysis enables a richer model specification, ie we can take into account a greater number of potential factors that explain costs, including the efficiency of both volumes and unit costs. It also enables us to take into account the qualitative work carried out by our technical consultants, DNV KEMA, and economic consultants, CEPA, in reviewing the plans and the associated cost-benefit analysis (CBA) assessments submitted by the companies. This analysis gives greater clarity on where companies' forecasts are better or worse than our benchmarks.

1.20. We consider that our different assessments of totex have provided significant value in helping us to challenge the results of our activity-level analysis and understand the key drivers of differences in performance. However, we consider it is important to recognise the limitations of the top-down totex approaches. We are concerned that some DNOs appear to have submitted over-optimistic forecasts of the cost drivers used in our totex analysis. This would favour them in the efficiency results. Given the limited number of data points it is only realistic to use a small number of cost drivers in the totex benchmarking. We also consider that the totex assessment approach may not sufficiently address differences in sparsity for SSEH and SWEST, the uptake of distributed generation (DG) or differences in the asset replacement cycle.

1.21. We have also carried out a range of sensitivity analyses in our quantitative work to ensure the robustness of our assessment. These include:

- varying the regional labour and company-specific factors
- using common allocation of indirects
- dropping SPEN's data from the benchmarking as SPEN is an outlier in our cost assessment, largely driven by the scale of expenditure requirements it has put forward for SPMW
- applying a fixed cost adjustment for each DNO based on the work that was carried out by KPMG on behalf of ENWL
- carrying out regressions using 13 years of data rather than just the historical years
- using Random Effects rather than our main pooled ordinary least squares (OLS) methodology.

1.22. These sensitivities give us confidence that the overall conclusions drawn using our toolkit approach are robust.

1.23. We have circulated an early version of our models to the DNOs in order for them to check normalisations, linkages between workbooks and internal calculations. We appointed an academic advisor, and an external auditor, to minimise the risk of inaccuracies in our modelling. We have completed our cost assessment for fast-tracking and we do not intend to make any further corrections to this assessment for any points that may be subsequently identified by the DNOs. Our approach of applying the upper quartile, and using a broad toolkit including quantitative and qualitative analysis and a range of sensitivities, takes into account the possibility of inaccuracies in the modelling and we are therefore confident that our overall assessment is robust.

1.24. Throughout this document we make reference to our three totex assessment approaches:

- activity-level analysis – our disaggregated activity-level assessments are combined to form a view of totex. For example tree cutting expenditure is assessed separately and the results from our analysis are combined with the assessment of other cost activity areas to form view of activity-level totex (see Chapter 7 for further detail)

- totex high-level drivers – totex is assessed using high-level drivers: customer numbers, network length and units distributed (see Chapter 8 for further detail)

- totex activity-level drivers – totex is assessed using a combination of drivers based on our activity-level analysis (see Chapter 8 for further detail).

1.25. This document is structured as follows:

- Chapter 2 sets out the Headline results of our cost assessment of the RIIO-ED1 business plans
- Chapter 3 sets out an explanation of the key data we have used in our cost assessment including the key characteristics of the data.
- Chapter 4 explains the normalisation and other adjustments we have applied to the cost data prior to carrying out our benchmarking
- Chapter 5 sets out our approach to econometric benchmarking
- Chapter 6 sets out our approach to Real Price Effects and ongoing efficiency
- Chapter 7 explains our disaggregated activity-level benchmarking
- Chapter 8 explains our totex benchmarking
- Chapter 9 discusses bringing our results together and sensitivity analysis
- Appendix 1 sets out further detail on statistical tests
- Appendix 2 sets out totex for individual DNOs
- Appendix 3 sets out the data terms used in regression
- Appendix 4 sets out the characteristics of data used in our analysis
- Appendix 5 sets out the regression results.

2. Headline results

Chapter Summary

The high level results of our benchmarking and expenditure assessment.

Results of our expenditure assessment

2.1. Figures 2.1 and 2.2 set out our overall assessment of efficient expenditure for the DNOs and DNO groups. Our view of totex brings together the different elements of our toolkit approach. These comprise our three totex assessment models, two of which are based on assessments of totex as a whole (‘top-down’), and one derived from an activity-level assessment.

2.2. Our benchmarked efficient level of expenditure for each DNO uses the upper quartile (UQ), and is shown as the blue dotted, 100 per cent, line in the graphs. We set out in our November document[7] that we have tested the DNOs’ business plans against a range of realistic downside cost of equity scenarios. This is to ensure that any fast-tracked company remains sufficiently efficient overall to represent value for money for consumers. The orange dotted lines in Figures 2.1 and 2.2 represent our central reference point for this.

2.3. In addition we have also factored in instances where DNOs have offered up tighter customer interruptions (CI) and customer minutes lost (CML) targets than our benchmarking methodology has produced. This produces the red line on Figures 2.1 and 2.2 below which shows our final adjusted efficiency benchmarks.

2.4. As shown in the charts, WPD is the only group better than the upper quartile benchmark with an adjustment to take into account cost of equity and CI and CML targets, the red line in Figure 2.1 and all four of its DNOs are either better than, or closest to the red line in Figure 2.2.

2.5. Overall, we are satisfied that the four WPD companies are robust to our testing of efficient costs. We do not have the same degree of satisfaction in respect of the next closest DNOs – ENWL and SSEPD.

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[7] https://www.ofgem.gov.uk/ofgem-publications/84945/assessmentoftheriio-ed1businessplans.pdf

Figure 2.1: Graph of submitted total expenditure versus our view[1, 2] of the efficient level, by DNO group

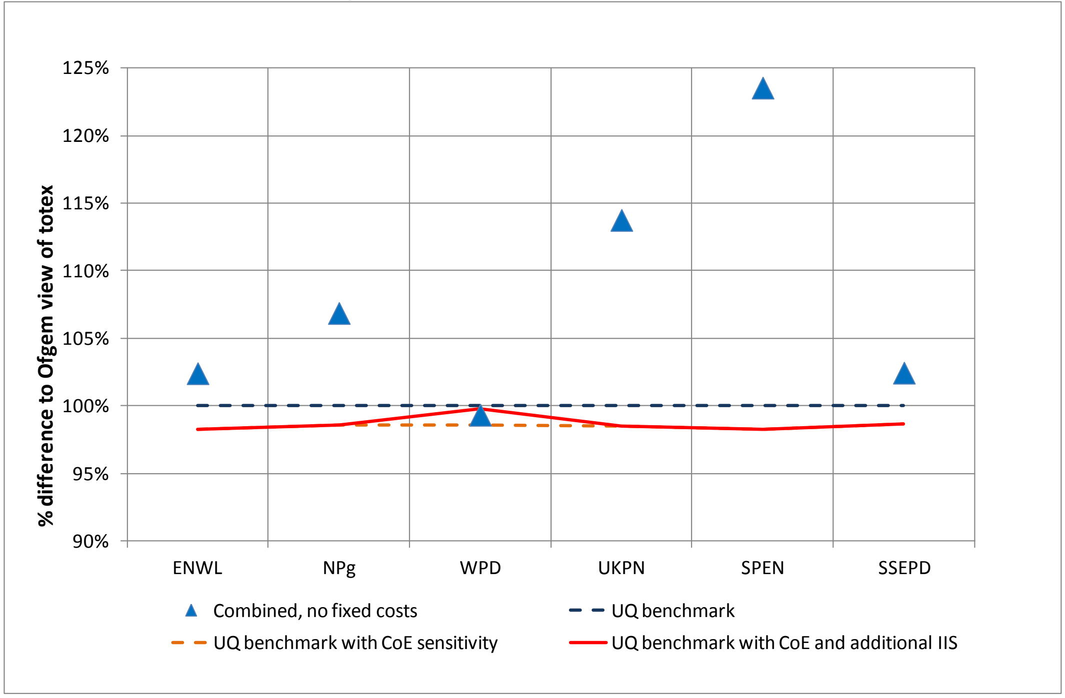
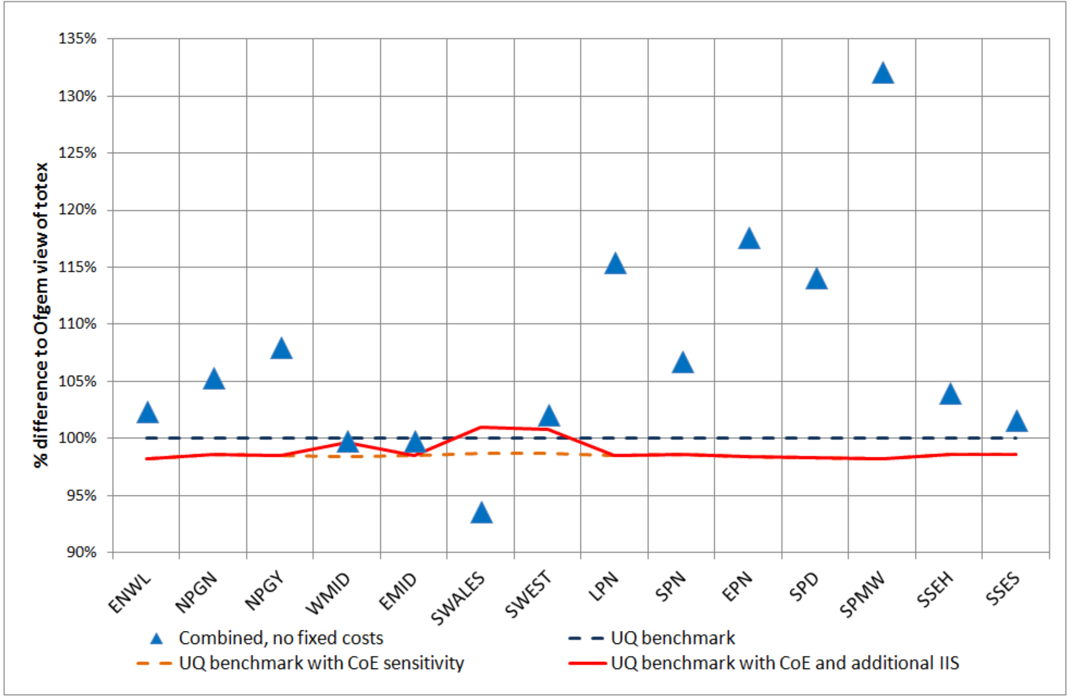


Figure 2.2: Graph of submitted total expenditure versus our view[1, 2] of the efficient level, by DNO



[1] Ofgem view, combined assessment weightings: 75% activity-level analysis, 12.5% totex activity-level drivers, 12.5% totex high-level drivers. There has been a minor adjustment to this chart relative to the version presented in the November fast-track assessment document as we identified an issue with the CI/CML monetisation. This slightly improves the position for WPD

[2] IIS - the interruption incentive scheme. Adjustment to take account of higher CI/CML targets offered by some DNOs

2.6. In Table 2.1 and Table 2.2 we set out efficiency scores for each DNO and DNO group for the three models[8] of totex, prior to any adjustment to take into account cost of equity or CI and CML targets.

2.7. While we carried out our three assessment approaches separately, we have come to the view that we should place significantly greater weight on our activity-level analysis than on the analysis of totex as a whole and so have also considered the scoring expressed on a combined basis. Chapter 9 explains why we have come to this view and how we have combined the models as a result.

Table 2.1: Efficiency scores[1,2] DNO level

DNO	Activity-level analysis	Totex activity-level drivers	Totex high-level drivers	Combined assessment[1]
ENWL	103.4%	98.2%	100.8%	102.4%
NPGN	106.8%	102.4%	99.8%	105.3%
NPGY	111.0%	97.9%	102.4%	108.0%
WMID	98.0%	108.8%	102.5%	99.8%
EMID	100.2%	99.8%	97.5%	99.8%
SWALES	92.7%	100.6%	93.3%	93.7%
SWEST	97.7%	117.7%	118.2%	102.1%
LPN	121.0%	102.2%	100.5%	115.4%
SPN	106.7%	109.2%	104.8%	106.7%
EPN	121.7%	109.4%	104.8%	117.7%
SPD	115.6%	116.3%	103.7%	114.1%
SPMW	126.2%	149.5%	158.6%	132.1%
SSEH	99.9%	115.5%	122.3%	104.1%
SSES	103.3%	94.3%	99.8%	101.7%

[1] Combined assessment weightings: 75% activity-level analysis, 12.5% Totex activity-level drivers, 12.5% Totex high-level drivers

[2] Excludes costs associated with Network Rail's electrification programme submitted by WPD. See Chapter 4 for further detail on our assessment of rail electrification costs.

Table 2.2: Efficiency scores[1,2] DNO group

DNO group	Activity-level analysis	Totex activity-level drivers	Totex high-level drivers	Combined assessment[1]
ENWL	103.4%	98.2%	100.8%	102.4%
NPg	109.2%	99.7%	101.3%	106.9%
WPD	97.7%	106.5%	102.6%	99.3%
UKPN	116.9%	107.1%	103.5%	113.7%
SPEN	121.3%	132.8%	128.6%	123.5%
SSEPD	102.2%	100.4%	106.4%	102.4%

[1] Combined assessment weightings: 75% activity-level analysis, 12.5% Totex activity-level drivers, 12.5% Totex high-level drivers

[2] Excludes costs associated with Network Rail's electrification programme submitted by WPD. See Chapter 4 for further detail on our assessment of rail electrification costs.

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[8] See paragraph 1.24 for detailed description of our assessment approaches.

3. Data used in our analysis

Chapter Summary

Explains the key data we have used in our cost benchmarking analysis including expenditure data, volume information, network characteristics and output information. We also describe some key characteristics of the data we have used, which are important for our analytical approach, as described in later chapters.

Overview

3.1. The data that we have used for the RIIO-ED1 fast-track cost assessment is drawn from the Business Plans submitted by the 14 DNOs by 1 July 2013 including the Business Plan Data Templates (BPDTs), narrative, table commentaries, Cost-Benefit Assessments and scheme papers together with further clarifications provided in response to our supplementary questions. The BPDTs are based on the Regulatory Instructions and Guidance (RIGs) data templates for DPCR5 with some information requirements reduced and others added for the purposes of the RIIO-ED1 assessment.

3.2. The BPDTs are designed to provide suitable data for benchmarking the DNOs' historical performance and future cost requirements on a like-for-like basis and to enable both high-level and detailed scrutiny of the DNOs' proposed costs for RIIO-ED1. They also provide sufficient information to review their performance to date on primary outputs and secondary deliverables.

3.3. The BPDTs include data on each DNO's historical expenditure, volumes of work, network characteristics and outputs for the first three years of DPCR5 (2010-11 to 2012-13), forecast information for the remainder of DPCR5 (2013-14 to 2014-15) and for the RIIO-ED1 period (2015-16 to 2022-23).

Expenditure information

Summary of the data

3.4. Table 3.1 below sets out the actual and forecast expenditure for each DNO and the industry as a whole. It shows actual expenditure for 2010-11 to 2012-13, forecast expenditure for the remainder of DPCR5 (2013-14 to 2014-15) and the whole of RIIO-ED1 (2015-16 to 2022-23). This data is also shown graphically in Figure 3.1.

Table 3.1: Annual average submitted net totex[1, 2] including RPEs (£m, 2012-13 prices)

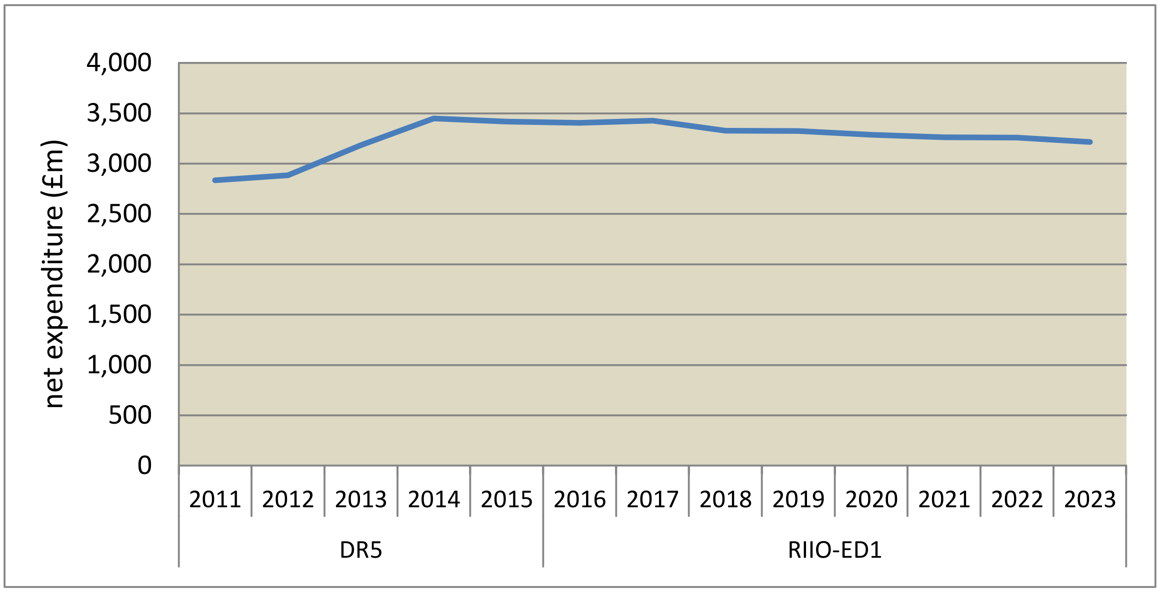
DNO	DPCR5 (actuals)	DPCR5 (forecast)	RIIO-ED1
	2010-11 to 2012-13	2013-14 to 2014-15	2015-16 to 2022-23
ENWL	242.7	264.3	237.5
NPGN	147.7	190.8	170.6
NPGY	202.1	252.5	232.4
WMID	259.3	307.3	260.8
EMID	255.4	280.1	261.6
SWALES	128.2	125.4	135.4
SWEST	178.5	195.1	212.0
LPN	198.1	259.2	246.0
SPN	229.0	232.3	237.1
EPN	335.8	361.5	357.6
SPD	189.2	222.6	217.5
SPMW	217.8	278.6	277.5
SSEH	122.1	134.9	155.5
SSES	261.6	328.5	311.2
Industry	**2,967.5**	**3,433.1**	**3,312.9**

[1] Table excludes costs associated with Network Rail's electrification programme submitted by WPD. See Chapter 4 for further detail on our assessment of rail electrification costs.
[2] May be rounding differences compared to the November publications due to data sourced from disaggregated activity-level business plan data template tables (the cost and volumes tables CV).

3.5. Industry totex has increased for the first three years of DPCR5. DNOs forecast further increases over the remainder of DPCR5 and then a fall in expenditure during RIIO-ED1. The forecast reduction is based on efficiency savings the DNOs expect to make during the RIIO-ED1 period, movements in the investment cycle and innovative use of technology, amongst other factors.

3.6. Given that efficiencies should take account of both catch-up efficiencies (inefficient DNOs catching up with the efficiency frontier) and frontier shift (the best performers continuing to improve), we consider that overall, DNOs have significantly underestimated the levels of efficiency that can be achieved over the RIIO-ED1 period. This is underlined by the results of our efficiency analysis. As highlighted in Chapter 2, some DNOs have put forward significantly more challenging forecasts than others. Our cost analysis, explained in this document, is designed to differentiate between DNOs to reveal such differences.

Figure 3.1 Industry totex for 2010-11 to 2022-23 (£m, 2012-13 prices)



Key characteristics

3.7. One of the key characteristics of the totex data is that there is much greater variation across DNOs than over time. This feature has been observed before in efficiency analysis for price controls such as that of NATS.[9] This has important implications for our choice of cost benchmarking techniques and was a key factor in our decision to use Ordinary Least Squares (OLS) rather than Random Effects analysis, as set out in Chapter 5. Further technical details on the characteristics of the data are set out in Appendix 4.

3.8. We have questions over the credibility of the forecast rise in costs up to the end of DPCR5 before costs then fall again from the beginning of RIIO-ED1. We would not expect a break in costs to line up so clearly with the break between price control periods. If companies are able to achieve efficiencies in RIIO-ED1 we would expect them to start to achieve this under the existing price control.

Cost drivers

Summary of the data

3.9. We use a broad range of cost drivers for our toolkit approach including high-level variables such as network length, customer numbers, units distributed, scale variables such as Modern Equivalent Asset Value (MEAV which is the cost of replacing

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[9] National Air Traffic Services
http://www.caa.co.uk/default.aspx??catid=5&pagetype=90&pageid=585

the existing network at current replacement unit costs) and activity drivers such as the number of faults and spans cut.

Key characteristics

3.10. A number of these variables, particularly the high level drivers, again show very little variation over time as they are essentially scale variables which pick up significant differences in size between DNOs but change very slowly. Further detail is set out in Appendix 3.

Outputs

Summary of the data

3.11. In line with the principles of RIIO we have assessed the efficiency of costs proposed to deliver an acceptable level of outputs. We have made extensive use of output as well as input data in our cost assessment methodology.

3.12. While some DNOs stated ambitions for performance under the Broad Measure of Customer Satisfaction, we have consulted on the target setting approach for this output, and therefore do not intend to bind the DNOs to their plan commitments in this area. For reliability, the target setting methodology is clear – and one DNO group (WPD) has chosen to set out tighter targets than under our methodology. We have considered the CI (customer interruptions) and CML (customer minutes lost) targets being put forward for RIIO-ED1 as part of our overall assessment of cost efficiency.

3.13. We have made significant use of Load Index (LI) information to test the robustness of the DNOs' reinforcement expenditure, and Health Index (HI) and Criticality Information (C) to inform our assessment of asset replacement requirements. The data on LIs is provided by each DNO for each primary substation and substation group together with detailed information on demand growth and expenditure. The HI and C information is provided for over 20 asset categories and covers the current state of the network, the forecast for the end of DPCR5, the middle of RIIO-ED1 and the end of RIIO-ED1 with and without investment.

Key characteristics

3.14. While the submission of asset health and criticality information represents a significant step forwards from previous price controls, there are some clear differences in the quality of DNOs' business plan submissions and there is limited comparability of the health indices between DNOs because of differences in assessment. We expect significant improvements from some DNOs in the information that is provided as part of their slow-track submissions.

4. Normalisation and other adjustments

Chapter Summary

The normalisations and other adjustments we have applied to ensure that our benchmarking of the DNOs' expenditure is robust and can be compared on a like-for-like basis.

Overview

4.1. As part of our assessment we have considered whether DNOs' submitted data requires adjustment to ensure that the comparisons for our benchmarking are on a robust like-for-like basis. Adjustments are made to company submitted totex which are then incorporated in both our totex and activity-level assessments. A key reason for making such adjustments prior to the benchmarking (outside the econometric models) is the nature of the data, as discussed in Chapter 3. As there is a relatively short time series of historical data and there is limited variation over time it is impractical to include variables to account for factors such as regional labour cost differences and company specific effects as part of the cost drivers in our regressions.

4.2. Our adjustments fall into the following categories:

- **regional labour cost adjustments** on the basis that operating in certain parts of the country attracts significantly higher labour costs
- **company specific factors** – additional costs associated with operating particular DNO networks
- **other adjustments** where we have concerns with the robustness of the data or to bring DNOs onto a consistent basis (eg changes to forecast data for network length, customer numbers and asset data where it impacted on MEAV)
- **exclusion of costs that are inappropriate for comparative benchmarking** because they are only incurred for a small number of DNOs
- **exclusion of costs from our main benchmarking** as they are assessed through separate bespoke analysis and then added back to our final results. For example, the assessment of streetworks costs associated with the Traffic Management Act (2004) and the Transport (Scotland) Act (2005)
- **exclusion of costs outside the price control** where the costs relate to activities that should not be funded through the price control. For example,

any forecast reinforcement expenditure relating to the optimism bias within the Transform model[10] was excluded from benchmarking and not funded.

4.3. We highlighted in our Strategy decision that we would be applying a higher hurdle for regional labour adjustments and company specific factors in RIIO-ED1 compared to previous network price controls. Companies would have to provide appropriate quantitative evidence of cost differentials as part of their Well Justified Business Plans and explain what steps they were taking to mitigate these costs differences.

4.4. The remainder of this chapter provides a summary of the normalisations and other adjustments we considered.

Adjustments

4.5. Table 4.1 sets out a summary of the normalisations and adjustments we have applied to company submitted data as part of our core analysis.

Table 4.1: Summary of normalisations and cost adjustments made to company submitted data prior to benchmarking assessment

	Adjustments made to company submitted costs (£m gross, 2012-13 prices)				
	Regional cost adjustments		Costs excluded for separate assessment[2]	Total adjustments over RIIO-ED1	Average annual adjustments
	Labour costs adjustments	Other company specific factors[1]			
ENWL	28.3	0.0	-19.6	8.7	1.1
NPGN	23.4	0.0	-47.8	-24.4	-3.0
NPGY	33.6	0.0	-43.6	-10.0	-1.2
WMID	23.8	0.0	-69.2	-45.4	-5.7
EMID	23.1	0.0	-61.1	-38.0	-4.7
SWALES	12.7	0.0	-38.7	-26.1	-3.3
SWEST	19.9	0.0	-54.2	-34.3	-4.3
LPN	-185.8	-71.1	-40.1	-297.0	-37.1
SPN	-78.2	0.0	-37.5	-115.7	-14.5
EPN	-36.8	0.0	-58.0	-94.8	-11.8
SPD	29.1	0.0	-51.8	-22.6	-2.8
SPMW	37.6	0.0	-56.8	-19.3	-2.4
SSEH	17.0	-35.9	-31.5	-50.5	-6.3
SSES	-63.4	0.0	-33.4	-96.8	-12.1

[1] Includes company specific factors discussed in paragraphs 4.8 to 4.17

[2] Includes for example streetworks costs, wayleave payments associated with closely associated indirects

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[10] The Transform model is a spreadsheet model commissioned by the DNOs under Work Stream 3 of the Smart Grid Forum. Further information can be found at: http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=47&refer=Networks/SGF/Publications

Regional labour cost adjustments

4.6. We have considered the analysis presented by UKPN, SSEPD and our own internal analysis on regional labour cost adjustments and decided that, for these particular DNOs, it is reasonable to make such adjustments prior to carrying out our cost benchmarking.

4.7. We recognise that there are labour cost differentials between London, the South East and elsewhere in Great Britain. We have calculated labour indices using the Office of National Statistics (ONS) Annual Survey of Hourly Earnings (ASHE)[11] data. We took into account the additional labour costs associated with working in London and the South East and considered the proportion of work that is done in these areas and elsewhere. These adjustments affect all DNOs.

Company specific factors

4.8. Three companies put forward cases for additional company specific factors that should be taken into account prior to our benchmarking.

4.9. SSEPD provides evidence of additional costs associated with working in remote Highland and Island areas of Scotland. This includes additional costs associated with staffing remote depots on a number of the Scottish Islands, additional transport and communication costs. We consider that SSEPD's submission on the Highlands and Islands regional factor is concise, generally well-documented and evidenced and we have therefore included 92 per cent of their proposed adjustments in our benchmarking analysis.

4.10. UKPN includes additional costs associated with working in London. These costs are divided into a number of distinct areas:

- **transport and travel** – UKPN argues that there are significant additional costs associated with London Congestion Charging and the application of parking fines in Central London. They suggest that there are significantly increased costs associated with servicing vehicles in London. They indicate there are additional costs associated with delivery of large items of plant in London
- **excavation** – UKPN suggests that there are significantly higher costs associated with excavations in the London area. This includes the impact of congestion under roads and footpaths, the impact of lane rental and permitting and environmental restrictions on work. It sets out additional costs associated with their underground network including maintaining keys for access to buildings, additional costs associated with ventilating substations, work in confined spaces, pumping out contaminated water and maintaining pipes and ducts

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[11] http://www.ons.gov.uk/ons/taxonomy/index.html?nscl=Earnings

- **security** – UKPN argues that there are significant additional costs associated with preparation of major events and that planned work often has to be rescheduled at a cost because of such events
- **property** – UKPN identifies additional insurance required for its properties in the London area
- **resourcing and contracting** – UKPN suggests that there are significant additional costs of working in the London area including different labour rates, transport, travel costs and standby charges.

4.11. The quality of UKPN's submission on company specific factors is more varied than that of SSEPD. Some areas such as transport and travel costs are reasonably well documented. However, it is unclear how it has quantified a number of the incremental costs associated with excavation, security and properties in London. In some cases, such as the environmental restrictions on streetworks in London, it has accepted that it is not able to quantify the impact on costs.

4.12. We have accepted 30 per cent of UKPN's proposed adjustment for LPN, taking into account limitations in the evidence that they have provided and overlaps with other adjustments. The additional direct and contract labour costs associated with working in London have been separately addressed as part of the regional labour adjustment. We have also assessed streetwork costs separately.

4.13. SPEN has indicated that there are additional costs associated with operating and maintaining the interconnected network in its SP Manweb (SPMW) licence area. SPEN notes that SPMW has smaller transformers than the industry standard, which are run constantly interconnected at all voltages. It also notes that standard cable sizes are used throughout. It notes that around 55 per cent of the SPMW network is designed and run as an 'X-Type' network, solidly interconnected at 33kV, 11kV and LV, rather than the more conventional 'Y-Type' network.

4.14. SPEN states that the SPMW network has greater complexity, involves more components and is more expensive to construct and maintain than the standard industry network design.

4.15. It suggests that its network is 30 per cent more costly to run than a standard design but does not put forward sufficient quantitative evidence to show how this figure has been calculated or how they will mitigate it. We have also disaggregated the asset categories further for RIIO-ED1 than DPCR5 to take account of differences between networks. This enables us to separately identify those asset types that are specific to SPMW and ensure that we assess costs and volumes separately.

4.16. On this basis we have decided not to apply a company specific factor at this stage for SPMW as they have presented insufficient information. We will review this as part of the slow-track assessment based on the information SPEN submits in its revised plan.

4.17. ENWL is the only DNO operating a single licence and has suggested that we should make an adjustment for fixed costs associated with running a network as part of our analysis. It proposes that single licensees are unable to obtain economies of scale and as such fixed costs may be higher than those for groups with multiple licensees. Work they commissioned by KPMG suggested that the impact of such fixed costs is £11m p.a. Single DNO status is not an inherent characteristic and ENWL proposed no means of protecting their customers should their status change. However, we have undertaken sensitivity analysis on the basis of ENWL's view of 'fixed costs' as part of our overall benchmarking. ENWL remains above our benchmark under these sensitivities. The evidence that ENWL presented for our fast-track assessment was not sufficiently compelling for us to incorporate it at this stage.

Indirect cost allocations

4.18. A number of cost activities are carried out at a group level rather than by individual DNOs, for example business support and closely associated indirect activities. Each company has its own methodology and preferred cost allocation drivers for allocating such costs between its DNOs and other companies within the same group. We have considered whether companies using different drivers to allocate these costs might distort our totex or disaggregated activity analysis.

4.19. We have concluded that it is appropriate to continue to use the companies' own allocations for the purposes of our cost benchmarking as at fast-track we are considering whether or not to consider accepting a DNO's plan. However, we have run sensitivity analysis with common allocation drivers for all groups. We will carry out further analysis of indirect allocation as part of our slow-track assessment.

Excluded costs

4.20. We have excluded certain costs in DNOs' submissions from our main benchmarking analysis either because they are only incurred by a small number of DNOs or are subject to different treatment.

4.21. WPD's forecast costs of £96m for diverting lines associated with Network Rail's electrification programme fall within this category and we have assessed them separately to be efficient The DNOs have met with government and Network Rail, and this has raised questions as to where these costs should lie. We consider that, from a public policy perspective, they should not be borne by energy consumers. We have concluded that we will allow the costs in WPD's business plans, but, should it be decided that another party will fund them, we will include a mechanism in WPD's licence to remove them from the settlement.

4.22. The following costs have been excluded from our benchmarking and an efficient view of costs associated with these activities has been added back to our benchmarked expenditure assessment:

- streetworks
- insurance costs associated with business support
- ETR 132[12] tree cutting activity
- wayleave payments from closely associated indirect activities.

Adjustments to Low Carbon Technology related secondary reinforcement expenditure

4.23. In order to ensure comparability of low carbon technology (LCT)-related secondary reinforcement benchmarking we had to make adjustments to some DNOs' costs.

4.24. Most DNOs have used the Transform model[13] to assist forecasting the LCT-related reinforcement requirements. This model estimates the most efficient combination of conventional and smart interventions for LCT-related reinforcement for a specified level of load growth. The Transform model applies a 110 per cent optimism bias[14] to conventional intervention unit costs. Those DNOs who used the Transform model retained the optimism bias. We believe DNOs should be able to accurately forecast the cost of LCT-related reinforcement interventions and that DNOs may have overstated costs of conventional reinforcement.

4.25. We ran the Transform models provided by the DNOs to calculate the expenditure forecasts for RIIO-ED1 with optimism bias removed. Each DNO's forecast expenditure has been adjusted to the lower of either the amount submitted by the DNO or the results of our run of its Transform model (excluding optimism bias) scaled by the ratio between the Transform model output as used by the DNOs and the total cost for LCT-related reinforcement. We use the adjusted forecasts in our assessment of LCT-secondary reinforcement. Further details of our assessment of this activity area can be found in Chapter 7.

4.26. We have excluded NPg's expenditure for unbundling of shared services and assessed this separately as they were the only DNO to forecast expenditure in this

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[12] ETR 132 tree cutting activity is that undertaken in line with the principles of the ENA's Engineering Technical Report 132: 'Improving network performance under abnormal weather conditions by use of a risk based approach to vegetation management near overhead electric lines'.

[13] The Transform model is a spreadsheet model commissioned by the DNOs under Work Stream 3 of the Smart Grid Forum. Further information can be found at: http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=47&refer=Networks/SGF/Publications

[14] The optimism bias factor is applied to costs which are uncertain in order to counteract a common bias towards forecasting unit costs lower than they will turn out to be. In the case of smart solutions, this may be appropriate as these costs are still uncertain. However, conventional solution unit costs should be well understood.

area. Our technical consultants advised that while unbundling could be driven by heat pumps and electric vehicles, it is unlikely to be driven by installation of photovoltaics (PV) as forecast by NPg. We used NPg's unit cost and applied this to the total volume of heat pumps and electric vehicles multiplied by a diversity factor of 0.6. This diversity factor is applied to account for customers who have both low carbon technologies. We defined the diversity factor with the advice of our technical consultants and using evidence from other DNOs' business plans.

4.27. UKPN has not forecast volumes for conventional solutions. In order for the benchmarking not to be affected, we used the industry average unit cost for conventional interventions to derive a modelled volume for inclusion in our benchmarking.

Non-controllable costs

4.28. We have excluded costs that are subject to cost pass-through mechanisms from our cost benchmarking as there are separate arrangements in place to fund DNOs for these costs.

Reversal of adjustments

4.29. Once we have estimated modelled costs for each activity and for totex, we reverse an efficient view of those cost items excluded from our benchmarking analysis for separate assessment. We also reverse an efficient view of regional labour adjustments and company specific factor adjustments. This determines the total modelled costs for each DNO. Further detail can be found in Chapters 7 and 8.

5. Approach to econometric benchmarking

Chapter Summary

An overview of our approach to econometric benchmarking for both our totex and activity-level regression analyses.

Overview

5.1. This chapter discusses the main issues involved in both the totex and activity-level econometric benchmarking. We discuss the form of the cost driver(s) we are using, the choice of estimator, choice of data for the model estimation, the choice of cost driver and statistical testing.

Cost function

5.2. We have used one of the most common cost functions employed in empirical cost research, the Cobb-Douglas function, in line with our approach to both DPCR5 and RIIO-GD1. Its simplest form is:

$$\mathrm{Log}(Y) = C + \beta * \mathrm{Log}(X) + \varepsilon$$

5.3. Where: Y is the measure of costs – eg totex or tree cutting expenditure; X is the cost driver(s) – eg network length; β is the slope parameter; ε is the error term, C is the intercept, and log is the natural logarithm.

5.4. This function accounts for economies of scale, and also transforms the distribution of the data to approximate the normal distribution better than when the data are in their level format. We have utilised the above functional form on all our regression cost activities.

Estimation technique

5.5. The main estimation technique we have adopted is Corrected Pooled Ordinary Least Squares (CPOLS) estimator, consistent with DPCR5 and RIIO-GD1. Ordinary Least Squares (OLS) estimates the line of best fit (the cost function) through our data points. The Pooling term means that all the relevant years of the data for the 14 DNOs have been combined into a single data set for the regressions and a single slope parameter is derived for all years. The OLS regression line is an average benchmark which we do not consider sets a sufficiently challenging cost benchmark. Therefore we use the corrected ordinary least squares approach in order to estimate benchmark efficiency. The OLS regressions line is shifted down until it passes through the upper quartile level of efficiency. The upper quartile level of efficiency (lower quartile level of costs) is the first quartile in the distribution of efficiency scores. Out of 14 DNOs, it is only possible for four DNOs to outperform this based on any one measure of efficient totex. However, if most DNOs were tightly banded we would also consider those close to our benchmark as being efficient.

5.6. The differences between the DNOs' actual data and the cost function (or the DNO forecasts and our modelled costs based on forecast cost drivers) are the error terms or residuals. The treatment of the error terms as inefficiency is dependent on the model capturing all the determinants of costs. There are essentially two ways of separating out inefficiency from other components within the residuals:

- using regulatory knowledge and judgment to capture other factors that may influence costs. This is achieved through the use of appropriate adjustments to company data prior to benchmarking and the application of the upper quartile benchmark after the modelling has been carried out

- using more 'advanced' econometric techniques to split out the residual or error term into a number of components such as random noise and inefficiency and unobserved differences (heterogeneity) between companies. These techniques include the Random Effects (RE) estimator and Stochastic Frontier Analysis (SFA).

5.7. Frontier Economics[15],[16] in its initial work for Ofgem and the DNOs for RIIO-ED1 advocated the use of the RE estimator. Oxera[17] has advocated the use of RE or one of a number of different SFA estimators. By contrast, Gibbens and Zachary[18] on behalf of WPD strongly criticise the use of these more advanced estimators suggesting that they are unlikely to be meaningful given the type of data we are using. While some of their criticism falls on benchmarking in general they have particular concerns regarding RE and SFA. They suggest that anyone who proposes such models must appropriately defend the associated distributional assumptions.

5.8. We have considered the use of pooled OLS and other benchmarking techniques. Given the characteristics of the expenditure and cost driver data discussed in Chapter 3, we consider that the use of pooled OLS together with appropriate regional and company specific adjustments and the application of the upper quartile is the most suitable approach for RIIO-ED1. As there is very limited time-series variation compared to cross sectional variation in the data we do not consider that the use of RE or SFA techniques would be appropriate in our case. We have explored the use of time dummies and trends in our regressions and found them to be insignificant.

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[15] *Total cost benchmarking at RIIO-ED1, Phase 2 report*, Vol 1. May 2013. Report prepared for Ofgem by Frontier Economics Ltd.

[16] *Total cost benchmarking at RIIO-ED1, Phase* 2 report, Vol 2. May 2013. Report prepared for Ofgem by Frontier Economics Ltd.

[17] *Recommendations on cost assessment approached for RIIO-ED1*, February 2013. Report prepared for Ofgem by Oxera in association with Professor Subal Kambhakar.

[18] Gibbens, RJ and Zachary, S, May 2013, *Commentary on the report by Frontier Economics to Ofgem on the feasibility of econometric benchmarking in DNO cost regulation*. Report prepared for Ofgem by Gibbens and Zachary on behalf of WPD.

Choice of data for the model estimation

5.9. We have used three years of historical cost data in estimating our fast-track cost models for RIIO-ED1. We consider that it is appropriate to base the estimation of cost functions using actual historical data and then use estimated parameters to forecast modelled costs for RIIO-ED1 using our view of forecast cost drivers. We also considered using the RIIO-ED1 cost data or full 13 year historical and forecast cost data to run the regressions. However, the model diagnostics were poor for both of these alternatives. By inspecting data plots of the time profiles we had concerns that some of the forecast data was unreliable and showed very little variability. As a result we took the view that it is inappropriate to base our estimation of cost models using this information.

Choice of cost drivers

5.10. We have used a balance of engineering knowledge and quantitative analysis to determine the final cost drivers for each of our totex and activity-level regressions. We carried out initial preparatory work with the DNOs to identify a suitable set of drivers and have refined this as we have completed our analysis. The detailed cost drivers are set out in Chapters 7 and 8.

Statistical testing

5.11. We have developed a group of statistical tests which we apply to all of our regression analysis based on the approach we used at DPCR5 and RIIO-GD1. Further details of these tests are set out in Appendix 1. The results of the models are presented in Appendix 5. All the models that we have used in our regression have passed the diagnostic tests, with the exception of one of the closely associated indirect activities (call centre). Using our prior knowledge of this cost activity however, we feel that we have selected the most appropriate drivers to assess this activity.

6. Real Price Effects and ongoing efficiency

Chapter Summary

Our approach to the assessment of real input price growth and ongoing efficiency for our cost assessment.

Overview

6.1. As set out in our Strategy decision, allowed revenues are indexed by the Retail Prices Index (RPI) as part of the price control framework. It is expected that the price of several inputs, most notably labour, will not change in line with the RPI measure of inflation. To account for this differential we have estimated appropriate RPEs for each DNO to support the fast-track assessment. This is based on forecast differences between economy-wide inflation, as measured by the RPI, and input price inflation. These are known as the real price effect (RPE) assumptions.

6.2. We expect even the most efficient DNO to make productivity improvements over the price control period, for example by employing new technologies. These improvements are captured by the ongoing efficiency assumption. This assumption represents the potential reduction in input volumes that can be achieved whilst delivering the same outputs.

RPEs

6.3. We have based our modelled RPEs for each DNO on common assumptions for the path of input prices weighted together, based on the notional structure of a DNO. The notional structure was based on the average structure of all DNOs as submitted in their business plans. This was the approach taken for DPCR5 and RIIO-GD1.[19] The reason to apply a notional structure is to ensure we are not rewarding potentially inefficient company structures.

6.4. Our approach to deriving a view of appropriate RPE assumptions has drawn on the methodology used for RIIO-T1 and GD1.[19] We have also considered further evidence submitted as part of the DNOs' business plans.

6.5. We have used a RPE assumption for labour, materials, equipment and plant, transport and other inputs. For each of these assumptions, we have calculated the long-term real trend in historical data from a range of widely available cost indices. This is calculated based on input indices that are comparable to the inputs used by DNOs. For all cost types apart from labour, this long-term trend is used for all forecast years.

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[19] See RIIO-T1/GD1: Final Proposals – Real price effects and ongoing efficiency (December 2012): https://www.ofgem.gov.uk/sites/default/files/docs/2012/12/5_riiogd1_fp_rpe_dec12.pdf

6.6. A short-term forecast is calculated for labour as this is the only input type where reliable, independent data is widely available. This data is used for forecasts up to 2017-18. Forecast indices revert to long term trend from 2018-19 onwards.

6.7. Transport inputs and ‘other’ inputs (those that do not fit into the specified activity categories) are both assigned zero per cent growth. Key inputs for transport (eg fuel) are included in RPI and we expect little movement in prices relative to RPI. We consider that price growth in other inputs is largely covered by RPI.

6.8. The RPE assumptions are weighted together based on proportions of the input types in each work area (there are six work areas). The weights are based on an average of the DNOs’ business plan submissions.

6.9. We apply the RPE indices to our modelled views of totex for both the high-level totex and disaggregated activity-level analysis prior to the calculation of the upper quartile. This avoids any risk of cherry-picking between unit cost efficiencies and RPEs.

Ongoing efficiency

6.10. We have not applied a separate assumption for ongoing efficiency for our cost assessment as efficiency assumptions are already included in the DNOs’ forecasts that form part of the upper quartile calculation. We will apply a common ongoing efficiency assumption to all non-fast tracked companies’ costs.

7. Disaggregated activity- level analysis

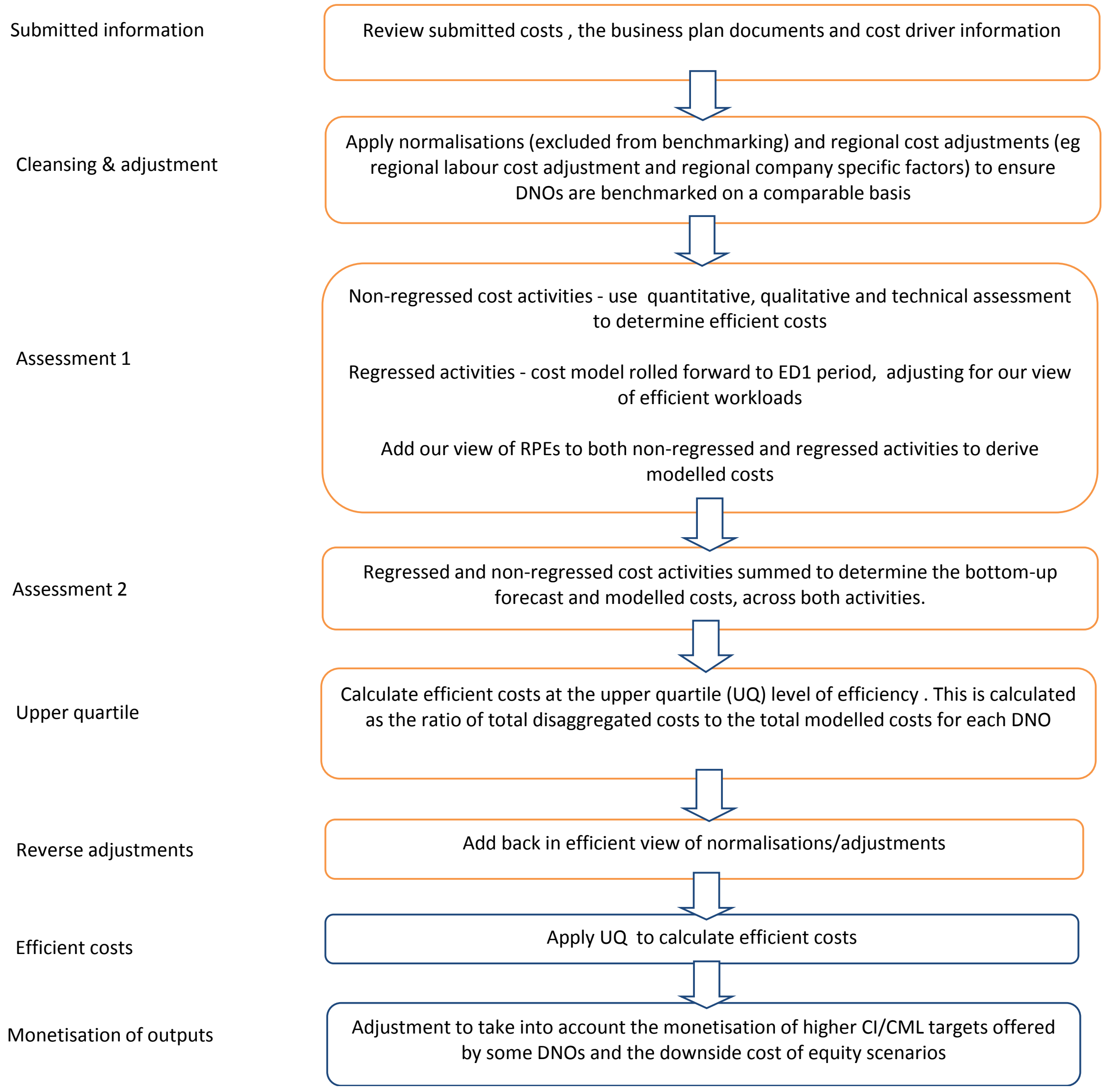
Chapter Summary

Detailed activity-level analysis that we have carried out for the RIIO-ED1 fast-track assessment.

Overview

7.1. As part of our overall toolkit approach we have carried out activity-level analysis. This builds on the work carried out at DPCR5, preparatory work for RIIO-ED1 and work developed by the industry. Our approach is summarised in Figure 7.1 below.

Figure 7.1: Summary of activity-level cost assessment methodology



Submitted information

Review submitted costs , the business plan documents and cost driver information

Cleansing & adjustment

Apply normalisations (excluded from benchmarking) and regional cost adjustments (eg regional labour cost adjustment and regional company specific factors) to ensure DNOs are benchmarked on a comparable basis

Assessment 1

Non-regressed cost activities - use quantitative, qualitative and technical assessment to determine efficient costs

Regressed activities - cost model rolled forward to ED1 period, adjusting for our view of efficient workloads

Add our view of RPEs to both non-regressed and regressed activities to derive modelled costs

Assessment 2

Regressed and non-regressed cost activities summed to determine the bottom-up forecast and modelled costs, across both activities.

Upper quartile

Calculate efficient costs at the upper quartile (UQ) level of efficiency . This is calculated as the ratio of total disaggregated costs to the total modelled costs for each DNO

Reverse adjustments

Add back in efficient view of normalisations/adjustments

Efficient costs

Apply UQ to calculate efficient costs

Monetisation of outputs

Adjustment to take into account the monetisation of higher CI/CML targets offered by some DNOs and the downside cost of equity scenarios

7.2. Our activity-level analysis incorporates a mixture of cost assessment techniques:

- regression analysis where appropriate cost drivers exist
- other assessment techniques including ratio or trend analysis where robust cost drivers are either not available or where a technical assessment of cost efficiency is more appropriate.

7.3. We have developed tailor-made approaches for asset replacement and reinforcement.

7.4. Our asset replacement work makes use of age-based asset replacement modelling and ratio analysis for assessing volumes. We used expert views on the appropriate unit costs and volumes for each asset category.

7.5. For load related reinforcement we use a mixture of ratio benchmarking on the amount of capacity being added and unit costs, as well as more detailed analysis looking at load indices and, in particular, the pattern of proposed expenditure relative to load-growth. Both of these areas of work have been informed by technical advice from our consultants DNV KEMA, who have worked as part of our team.

7.6. For the other activities we used either regression techniques similar to our approach for totex, used ratio benchmarking of volumes and/or unit costs or used run-rates for volumes or expenditure based on DPCR5 data.

7.7. We summed up both forecast costs and our modelled costs across all the activities before calculating the upper quartile level of efficiency. We then reversed our normalisations and other adjustments before applying the upper quartile benchmark. We have adjusted the final upper quartile efficiency scores to take into account cases where companies have offered up tighter CI and /or CML targets than our benchmarking methodology process. These differences have been valued at the relevant CI and CML incentive rates. As set out in our November document on the assessment of the RIIO-ED1 business plans we have also tested the DNOs’ business plans against a range of realistic downside cost of equity scenarios.

7.8. This Chapter sets out our assessment approach for the key activity-level areas:

- reinforcement
- asset replacement/intervention
- high value projects (HVPs)
- business support
- activities assessed using regression analysis
- other activities assessed using ratio benchmarking or trend analysis.

Reinforcement

7.9. The DNOs' business plans include a range of measures to accommodate and account for any forecast changes in demand patterns within the RIIO-ED1 period. In line with our Strategy decision, we have broken down our reinforcement by the technical nature of the work undertaken. This ensures that each area is assessed consistently against common expenditure drivers. We have also carried out more aggregated analysis to ensure that the boundaries between different categories do not unfairly impact on the result for specific DNOs. We have broken down reinforcement expenditure into the following categories:

- primary reinforcement schemes
- modelled assessment of reinforcement at primary substations
- transmission connection point (TCP) charges
- low carbon technology (LCT) driven reinforcement
- secondary reinforcement (non-LCT).

Primary network reinforcement

7.10. DNOs were required to provide a list of asset installations and disposals for each proposed primary network reinforcement scheme in RIIO-ED1. The costs of these schemes were also split across asset types. We assessed the unit costs of assets using the same approach as for asset replacement, described later in this chapter. Across each of the reinforcement schemes, the submitted unit costs were compared to Ofgem's expert unit costs for asset replacement. Comparing the total costs across each DNO scheme using their own unit costs and the equivalent total using Ofgem's expert unit cost, we applied a percentage adjustment (positive or negative) to each DNO's submitted costs covering all primary network reinforcement.

7.11. Alongside this assessment, we reviewed the accompanying scheme papers provided to give a qualitative assessment of the rationale presented for the needs case for the network intervention, the appropriateness of the solutions considered and the forecast costs.

N-1 primary reinforcement

7.12. We modelled expenditure relating to n-1 primary reinforcement and other work captured in the Load Index secondary using bespoke assessment including the following elements:

- **unit cost adjustments** – the eight-year RIIO-ED1 forecast for reinforcement work covered by the Load Index was adjusted by the average percentage adjustment from the following calculations:
    - percentage adjustment from difference between DNO view on unit cost in scheme papers and Ofgem expert view of relevant unit costs
    - percentage adjustment for industry median unit cost of delivering one MVA of capacity from Primary network n-1 reinforcement schemes

  - percentage adjustment for median ratio of DNO forecast cost of additional capacity relevant to their historical unit cost of delivering capacity:
    - the DNO forecast cost of additional capacity is set by deriving the unit cost for an additional MVA of capacity forecast
    - the historical unit cost of delivering capacity is set by deriving a unit cost from DNO MEAV for EHV+ assets divided by the firm capacity currently present on the network

- **volume adjustment** - across the relevant schemes included within each DNO's business plan, the ratio of forecast capacity added, relevant to the forecast increase in demand above firm capacity was benchmarked at the median across the industry. Where DNOs forecast a ratio above the industry median, we adjusted submitted costs in line with the industry median ratio divided by the DNO submitted ratio. Where DNOs forecast a ratio below the industry median, no adjustment was made.

Transmission Connection Point (TCP) charges

7.13. We carried out an initial review of expenditure on TCP charges with the support of DNV KEMA. As there was insufficient detail to analyse the plans effectively, we decided that these costs should be included in the n-1 modelling.

7.14. We considered that the inclusion of these costs in the primary network n-1 modelling was appropriate given that TCP expenditure has the potential to offset the need for expenditure on primary network reinforcement subject to the n-1 modelling. We consider that this boundary issue would mean that those DNOs that included a significant level of TCP expenditure would otherwise potentially benefit unfairly in the n-1 modelling relative to DNOs that do not forecast significant levels of TCP expenditure.

Low carbon technology reinforcement

7.15. We have modelled low carbon technology (LCT) related secondary network reinforcement having made a number of adjustments to the forecasts to ensure they are on a comparable basis. These adjustments are discussed in Chapter 4. We have considered both the efficiency of volumes and unit costs.

7.16. We have adjusted each DNO's eight-year RIIO-ED1 forecast of network interventions per MW of LCTs connected to the industry median. We have also adjusted their unit costs for LCT-related intervention to the industry median. The unit cost and volume adjustments are made to the total normalised expenditure.

7.17. In our assessment of business plans for fast-track, we have not made adjustments to DNOs' forecast LCT volumes. However we may change this approach when assessing the resubmitted business plans if forecast LCT volumes are not well justified.

Secondary reinforcement

7.18. In the case of reinforcement of the secondary network that is not attributable to LCTs, the volume of interventions and capacity released are difficult to capture, therefore benchmarking unit costs is not appropriate. Our starting point is to apply the median DNO forecast to each DNO and then apply an adjustment factor based on the network characteristics of each DNO. This adjustment factor is based on the following factors :

- DNO HV/LV MEAV as a percentage of the industry median HV/LV MEAV. This reduces our modelled allowance where a DNO has smaller than median secondary network MEAV and increases our modelled allowance where a DNO has a larger than median secondary network MEAV

- percentage of DNO MEAV that relates to HV/LV assets as a percentage of the industry median figure for this. This reduces our modelled allowance where a DNO has smaller than median percentage of their overall MEAV made up of secondary network assets, and increases our modelled allowance where a DNO has a larger than median percentage of their overall MEAV made up of secondary network assets.

Connections

7.19. Given data issues for some of the DNOs we have adopted a simple approach for the connections assessment. For our fast-tracking assessment we have accepted the DNOs’ connection volumes for RIIO-ED1 but applied the median industry unit costs. We may change this approach when assessing resubmitted business plans, if forecast volumes are not well justified.

Asset replacement/intervention

7.20. We set out our latest thinking on the methodology for the assessment of asset replacement/intervention in the Strategy decision. We have applied a number of analytical techniques to assess asset replacement costs and volumes. We used the following techniques:

- an age based asset replacement model (survivor model) based on asset age profiles and the probability of assets of different ages failing
- run-rate and trend analysis - asset replacement volumes assessed as a proportion of total asset base
- review of asset health and criticality information and narrative explanation
- unit cost benchmarking.

Age based model

7.21. We have used an aged-based asset replacement model based on survivor model principles. The model is designed around the assumption that industry asset lives can either be maintained at the levels achieved in the past or longer lives can be achieved in the future through improved asset management. For this reason, the model calculates the highest of the lives achieved across the industry that are implied by historical asset replacement volumes in DPCR5 or forecast volumes from 2013-14 to the end of RIIO-ED1. This benchmark set of asset lives is then combined with each DNO's individual asset age profile to give a DNO modelled volume.

7.22. The main inputs to the model are the current age profile and life assumptions based on a normal distribution. The current age profile is the number of assets that remain in service from the years in which they were installed. The life assumptions or asset lives indicate the likelihood of asset failure based on age.

7.23. The model first calculates implied asset lives from actual or forecast replacement using a normal distribution for the cumulative probability of failure. The model calculates the lives by matching actual or forecast volumes against the calculated asset life.

7.24. We understand that such modelling has limitations and will not fully take account of all relevant factors. Where a company has provided robust evidence to support higher numbers than suggested in the model, we have made adjustments. This work has been supported by our technical consultants, DNV KEMA, who have provided specialist knowledge to our team. Where the evidence provided is not considered to be of a high enough standard we have placed more weight on the output of the model. The types of supporting evidence we have considered for departures from model outputs are:

- business cases and other supporting narratives for named schemes and high value assets
- asset specific condition information
- relationships to health indices
- evidence of poor or worsening performance
- evidence of type faults, failure modes and safety issues, and
- reports from specialist external consultants.

Non-modelled volumes

7.25. In our Strategy decision we stated that significant improvements have been made during DPCR5 to improve asset data and therefore we would aim to assess most asset replacement volumes using the age-based asset replacement model. We have still needed to use trend analysis to review the DNO submitted forecast volumes for a number of asset categories where there were issues over data or the spread of implied asset lives was very large. In such cases we used replacement run-rates based on submitted disposal volumes as a proportion of DNO assets in service. In most cases we applied the industry median benchmark to represent efficient replacement volumes. Due to the variable quality of the asset replacement data submitted by DNOs we applied an expert view of benchmark replacement volumes for some asset categories taking into account the industry median and other supporting information.

Unit costs

7.26. We reviewed evidence on asset replacement unit costs and calculated an expert view of unit costs based upon inputs from technical consultants and industry historical and forecast asset replacement costs. We used this expert view of unit costs as an input to determine our overall replacement baselines together with modelled volumes.

Substitution of assets

7.27. Within asset replacement there are many instances where DNOs may dispose of an asset but then replace it with a similar but not identical asset. An example of this would be for LV underground cable replacement where old LV main Consac cables and LV main paper cables are being disposed of and replaced with LV main plastic cables. We have grouped assets where we believe this substitution takes place and we have applied a blended unit cost to account for this aggregation. The blended unit cost was calculated using the proportions of asset replacement volumes to calculate an industry average weighted unit cost. We allowed for substitution between assets for the following asset categories:

- LV cables
- LV board (WM) with LV pillar (ID)
- HV cables
- 6.6/11kV switch (GM) with 6.6/11kV RMU
- HV transformers
- EHV cable
- EHV switchgear
- EHV transformers
- 132kV cables; and
- 132kV switchgear.

Conversion of modelled asset disposal to asset addition volumes

7.28. The drivers for asset replacement are predominantly asset condition, obsolescence and safety, but environmental factors may also influence the activity. For these reasons the volumes in both our modelled and non-modelled assessment are derived from asset disposals. However, our expert view of unit costs is derived from asset additions. In order to ensure that we are combining consistent units to calculate overall expenditure we have applied the ratio of submitted additions against disposals to give a view of modelled additions.

Qualitative adjustments

7.29. We have applied qualitative adjustments to modelled asset replacement volumes based on a technical assessment of the business plan narrative. For example, where a DNO has provided appropriate evidence to support asset replacement volumes, despite our quantitative analysis suggesting volumes were inefficient, we considered a qualitative adjustment to our analysis.

High value projects (HVPs)

7.30. External consultants have assessed the HVP scheme papers submitted by DNOs. A number of scheme papers do not provide sufficient detail to enable to us to adequately assess efficient costs of carrying out the work. Therefore we used cost efficiency assessment from our asset replacement and primary network reinforcement analysis combined with the qualitative assessment from our technical consultants.

7.31. In several cases DNOs have submitted HVP costs covering projects that were also included in their DPCR5 business plans. We have made an adjustment for the feasibility of these projects being completed over the RIIO-ED1 period. We have done this by looking at the ratio of the expected expenditure on these projects against the DPCR5 final settlement allowance and have factored this into our adjustments for submitted costs. This modelled view will not impact on the final assessment of the DPCR5 HVP re-opener mechanism.

Business support

Ratio benchmarking

7.32. For our assessment of business support expenditure we have used ratio benchmarking of gross costs for aggregated business support activities (finance & regulation, HR & non-operational training, IT & telecoms, property management, CEO & group management) against a composite size metric. We carried out the benchmarking at DNO ownership group level, using a comparator group of the six DNO groups (ENWL, NPg, WPD, UKPN, SPEN and SSEPD). We did not utilise external benchmarking data in our fast-track assessment but we may do so for our slow-track assessment. We benchmarked the RIIO-ED1 cost ratios against the median value to give efficient cost baselines for each group. These efficient cost baselines were allocated to individual DNOs within a group in proportion to their submitted forecasts. As noted in Chapter 3 we have also carried out sensitivity analysis including a fixed cost adjustment depending on the size of the DNO group.

Construction of composite size metric

7.33. We constructed a composite driver the same way as described in RIIO-T1 and GD1 final proposals.[20] We identified an appropriate activity size metric for each business support activity and then weighted the drivers based on the contribution of the activity to overall costs. The relevant drivers are set out in Table 7.1 below. The

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[20] Ofgem (2012), 'RIIO-T1: Final Proposals for NGET and NGGT - Cost assessment and uncertainty', pg 123: https://www.ofgem.gov.uk/sites/default/files/docs/2012/12/3_riiot1_fp_uncertainty_dec12.pdf

activity size metrics used were those outlined in the Strategy decision. We also examined a sensitivity using an alternative set of size metrics. The choice of metrics made little difference to our overall rankings of the companies in respect to their business support costs and reinforces our confidence in the suitability of the selected size metrics.

Table 7.1: Business support drivers

Business support Activity	Size metric used	Alternate size metric
Finance and regulation [split into three components]		
Finance	Revenue	MEAV
Procurement	Total spend	MEAV
Insurance	*Excluded from benchmarking*	*Excluded from benchmarking*
HR & non-op training	Employees	Employees
IT & telecoms	IT end-users	IT end-users
Property management	Revenue	Network length
CEO & group management	Revenue	MEAV

Monte Carlo Assessment

7.34. Our view of business support efficiency was arrived at by using Monte Carlo simulation. This involved applying the benchmarking methodology described above a number of times with varying input parameters in order to produce a range of results for each DNO group. The use of Monte Carlo simulation adds to the robustness of our benchmarking assessment as it allows for some consideration of uncertainty embedded in the DNOs forecasts and in our methodology. Our final view, for input into the totex models, was the average of all results in the range and was based on one thousand simulations with varying composite size.

Assessment of narrative justification

7.35. Where DNOs looked inefficient based on our quantitative assessment we reviewed the DNO narratives to see whether justification was provided for high business support expenditure. None of the companies that we assessed as being inefficient based on our quantitative assessment provided sufficient justification to materially affect our view of their efficiency.

Activities assessed using regression analysis

Overview of approach

7.36. We have used regression analysis for four disaggregated cost activities:

- tree cutting
- troublecall (including LV/HV overhead faults and LV and HV plant and equipment)
- occurrences not incentivised (ONIs) such as repairing faults on street lighting and other street furniture

- closely associated indirects (excluding operational training and vehicles & transport).

7.37. Our regressions estimate a cost function using historical expenditure and historical cost drivers for 2010-11 to 2012-13 as described in Chapter 3. We have grouped certain activities together based on a common cost driver. Table 7.2 sets out our cost grouping and the cost drivers for each of the disaggregated model.

7.38. For a number of the regressed activities DNOs have forecast a decrease in costs. Where DNOs' submitted forecast costs are lower than the results of our modelling (based on historical data) we adjust the model results using a scaling factor based on a ratio of normalised submitted costs to modelled costs.

7.39. For costs subject to econometric analysis, we forecast costs for RIIO-ED1 using the estimated cost relationship in conjunction with forecast values of the cost driver(s). This takes account of our view of efficient forecast workload (where applicable – see Table 7.2).

7.40. We have estimated efficient workloads in a number of ways depending on the activity area being assessed. For example, our workload assessment for Occurrences Not Incentivised (ONIs) uses industry median ONIs per customer. DNOs with a ratio of ONIs per customer higher than the industry median have their workload adjusted to reflect the industry median but where the ratio of ONIs per customer is below the industry median we have given the submitted workload. However, no separate volume adjustments are required for the network design, project management and system mapping regression and the EMCS[21], stores and network policy regression. As expenditure is assessed against MEAV, which is a scale variable rather than a volume of activity, the regressions take account of both unit cost and volume efficiencies.

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[21] Engineering management and clerical support.

Table 7.2 Cost activities and associated cost drivers used in the activity-level regressions

Cost activity		Cost driver	Workload adjustment applied	Scaling adjustment applied
Closely associated indirects	Network design, project management and system mapping	Weighted MEAV[22]	No	Yes
	Engineering Management & Clerical Support, Stores and Network Policy	Weighted MEAV	No	Yes
	Control Centre	Total faults including ONIs volumes and employees	Yes	Yes
	Call Centre	Total faults and total ONIs volumes	Yes	No
Tree cutting	Tree cutting	Spans cut	No	Yes
Trouble call	LV/HV overhead line faults	Fault volume LV/HV overhead Lines	Yes	Yes
	LV plant and equipment	Fault volume LV plant and equipment	Yes	Yes
	HV plant and equipment	Fault volume HV plant and equipment	Yes	Yes
ONIs	ONIs faults	ONIs fault volume	Yes	Yes

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[22] This cost driver is MEAV weighted by asset replacement and refurbishment expenditure over the first three years of DPCR5. The weighted MEAV is broken down by overhead, underground, plant and other types of assets.

Other activities assessed using ratio benchmarking or trend analysis

Overview of approach

7.41. For the remaining cost activities we are either using ratio or trend analysis.

Workload efficiency

7.42. We assessed efficient workload in a number of ways depending on the cost activity area. The detailed methodology matrix in Table 7.3 sets out our approach for each activity. For asset refurbishment, for example, we modelled an efficient view of refurbishment volumes by benchmarking the DNO submitted volumes against the industry median refurbishment volumes as a proportion of the DNOs' asset bases. The workload adjustment is expressed in monetary terms by multiplying the volume adjustment by the expert / efficient view of unit costs.

Unit cost efficiency

7.43. We have assessed unit cost efficiency using either an expert view of unit costs (based on consultancy input and historical and forecast cost information from the DNOs) or industry median unit costs. For example, for refurbishment we have reviewed information from the DNOs and our consultants and used this to form a view of appropriate unit costs for each asset category. This is then multiplied by our view of volumes to determine efficient modelled costs for each DNO.

Qualitative adjustments

7.44. We have applied qualitative adjustments to modelled volumes or costs based on our review of the business plan narrative, which suggested that our costs should be higher than a purely quantitative assessment would suggest. For example, where a DNO has provided appropriate evidence and a high quality CBA to support refurbishment work, despite our quantitative analysis suggesting volumes or unit costs were inefficient, we considered a qualitative adjustment to our analysis.

Matrix setting out approach for each activity

7.45. Table 7.3 below sets out the approach we have used to assess volume and unit cost efficiency for each of the relevant activities.

Table 7.3: Volume and unit cost assessment for remaining activities

Cost activity area	Disaggregated cost activity area	Volume assessment	Volume - lower of industry median view or company submission	Unit cost assessment
Connections	**Connections**	Applied individual DNO volumes. Analysis was carried out at a disaggregated voltage level, and since different DNOs have forecast different mixes of projects, our concern is that boundary issues would be created by modelling volumes at each voltage. This will be reviewed for the slow-track process	N/A	Industry median
Core Costs	**Diversions**	Breakdown of industry volumes not sufficiently comparable across DNOs. Applied individual DNO volumes	N/A	Industry median
	ESQCR	Volumes as agreed with HSE	No	Subject to qualitative adjustments
	Refurbishment	Industry median run-rate as proportion of asset base	Yes	Expert view
	Civil Works	Industry median run-rate as proportion of asset base	Yes	Industry median
	Operational IT & Telecoms	N/A	N/A	Applied lower of DNO average annual DR5 spend on IT&T (2010/11 to 2014/15) or forecast for RIIO-ED1
	Legal & Safety	N/A	N/A	Industry median
	Quality of Service	Ofgem view set to zero as QoS improvements are funded via an incentive mechanism		

Cost activity area	Disaggregated cost activity area	Volume assessment	Volume - lower of industry median view or company submission	Unit cost assessment
Non Core Costs	**BT 21st Century**	N/A	N/A	Industry median
	Losses and other environmental expenditure	Qualitative assessment based on business plans		
	High impact Low Probability (HILP)	Not applicable - no expenditure put forward by DNOs		
	Critical National Infrastructure	Not applicable - no expenditure put forward by DNOs for ex ante allowance. Managed through uncertainty mechanism		
	Black Start	Industry median run-rate as proportion of asset base	Yes	Industry median
	Rising Mains and Laterals	Industry average volumes over 13 years as per DPCR5 actuals and RIIO-ED1 forecasts	No	Industry median
Network Operating Costs	**Faults LV Underground**	Applied average model volumes (based on median run rates as percentage of asset base), DPCR5 actuals and RIIO-ED1 forecasts.	Yes	Assessed using MEAV
	Faults HV underground			
	LV/HV switching faults			Industry median
	Submarine Cable Faults			
	EHV and 132kV Faults			
	Severe Weather-Atypical	N/A	N/A	Minimum of RIIO-ED1 forecast and roll forward of DPCR5
	Inspections & Maintenance	Assessed using MEAV	No	Industry median
	NOC's other	N/A	N/A	Substation electricity - industry median unit cost Dismantlement and remote location generation - applied lower of industry median change in annual spend from DR5 to ED1 or company submitted

Cost activity area	Disaggregated cost activity area	Volume assessment	Volume - lower of industry median view or company submission	Unit cost assessment
Closely Associated Indirects	**Operational Training**	All DNOs used the EU Skills/NSA workforce renewal model for volume assessment. We have accepted the outputs from this model for fast track. For non workforce renewals, we used number of leavers as the costs driver. This was normalised (to the median ratio of number of non-retirement leavers to current workforce) to account for differences in assumptions on non-retirement leavers.	N/A	Operational Training Costs split between workforce renewal (WFR) and non workforce renewal (NWFR). Costs assessed using ratio benchmarking versus median for DNO group: -Total WFR costs to number of leavers -Total NWF costs to current employees
Non Operational Capex	**Small Tools and Equipment**	N/A	N/A	Benchmark against DNO MEAV; lower of industry median benchmark or DNO submitted forecast
	Property	Assessed using the business support assessment model.		
	Vehicles	N/A	N/A	Lower of DPCR5 annual average for total vehicles expenditure and annual RIIO-ED1 forecast
	IT & Telecoms	Assessed using the business support assessment model.		

Streetworks

7.46. Streetworks costs vary between networks so it is necessary to exclude these costs from our comparative benchmarking analysis.

7.47. Given the materiality of streetworks costs submitted for RIIO-ED1 (less than one per cent of total submitted RIIO-ED1 expenditure) we have taken a proportionate approach in our assessment of these costs. We calculated an efficient view of streetworks expenditure based on either the minimum of submitted streetworks expenditure or streetworks expenditure adjusted to reflect the level of efficiency assessed at each disaggregated activity level. For example, if we have scaled back connections expenditure for a particular DNO by five per cent, we have applied this scaling factor to submitted streetworks expenditure associated with connections activity. Our efficient view of streetworks is added back to our modelled baselines for each cost activity and our totex assessment.

Smart grids, innovation and smart meters

7.48. We undertook a qualitative assessment of smart grids and innovation in the DNOs' business plans. This included assessing the overall strategy for the deployment of smart grid solutions and how well integrated the strategy was in the business plan to deliver specific benefits to customers. We scrutinised the narratives to understand each DNO's strategy for using innovation and smart grid solutions to realise cost efficiencies. We also assessed the justification for the claimed benefits including where the benefits had been reflected in the business plan. The assessment included the use of the DNOs' Transform models as a reference point for an appropriate level of benefits from smart and innovative techniques. We compared this against the techniques and benefits included in the DNOs' business plan data tables.

7.49. Our analysis of smart meter roll-out costs includes on-site/physical and indirect / IT and data services costs. For the volume assessment, we followed our Strategy decision, and accept that two per cent of the call-out rates will be funded ex-ante. On unit costs, we compared and benchmarked the DNOs' submitted costs against the industry median. We also considered the DNOs' strategies for use of smart metering data to improve performance on outputs and cost efficiency. We assessed the benefits of the strategy compared with the potential costs of the systems required to collect and process the data estimated by the DNOs.

7.50. Our assessment of LCT-related reinforcement cost set out in paragraphs 7.15 to 7.17 has been designed specifically to avoid discrimination between the use of 'smart grid techniques' and conventional reinforcement.

8. Totex benchmarking

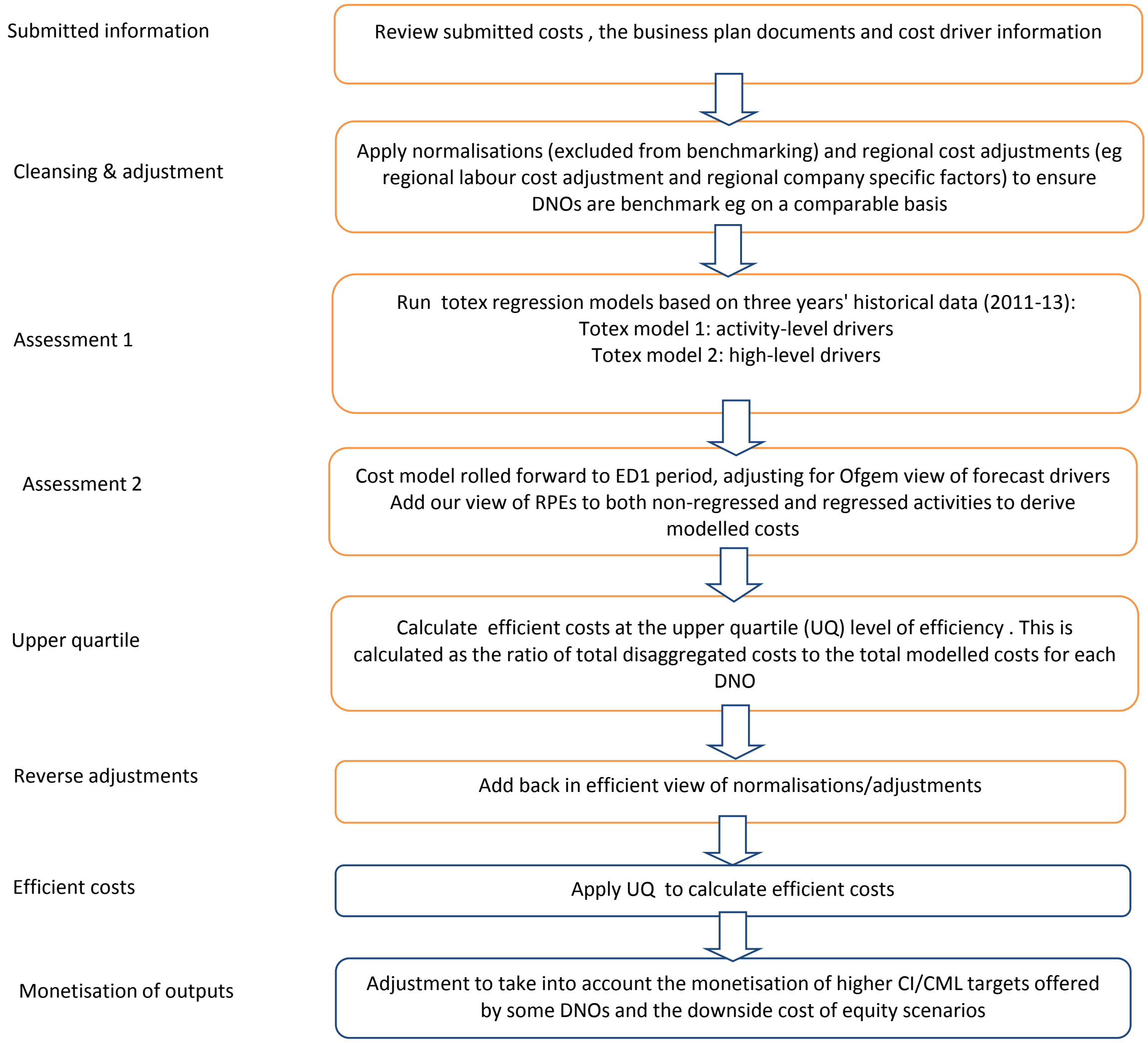
Chapter Summary

Our approach to the total expenditure (totex) regressions. This approach uses a single regression covering all areas of controllable expenditure.

Overview

8.1. As set out in our strategy decision, we use totex benchmarking as an important part of our overall toolkit approach for the fast-track cost assessment. Our totex methodology is summarised in Figure 8.1 below.

Figure 8.1: Summary of totex cost assessment methodology



8.2. This approach assesses totex as a whole using a single regression. We have adopted two alternative versions of this analysis. The first makes use of a high-level composite scale variable based on customer numbers, network length and units distributed. This is consistent with traditional economic literature. We have weighted each of the drivers equally.

8.3. The second approach uses a cost driver which is a weighted composite of the cost drivers used in our activity-level analysis. The weights for the composite scale variable (CSV) are based on industry spend proportions for the activity-level cost areas to which the drivers apply. Where no obvious activity-level driver exists we have used the scale variable MEAV as a proxy driver to assess the residual costs. We consider that this approach is both intuitive and takes into account the relative importance of each cost driver based on our knowledge of DNOs' costs.

8.4. DNOs have forecast a decrease in costs. Where DNOs' submitted forecast totex costs are lower than the results of our modelling (based on historical data) we adjust the model results using a scaling factor based on a ratio of normalised submitted costs to modelled cost. This approach is consistent with our assessment of activity-level regressed costs (see paragraph 7.38).

Totex assessment based on traditional economic approach

8.5. Traditional economic theory suggests that totex expenditure is a function of the outputs that a firm delivers, input prices and environmental variables. In this context outputs are taken to mean the high-level deliverables such as electricity distributed and peak demand served in each year.

8.6. Input prices describe the prices of inputs used by the DNOs, such as the price of direct and contractor labour and capital.

8.7. The environmental variables are factors that describe the operating environment of the firm. These variables are typically outside the firm's control (eg service area) but may affect its observed costs.

8.8. We have developed the first of our totex regressions based on this approach. We have made adjustments for differences in regional labour costs and company specific factors as described in Chapter 4. We have then run a regression of totex on a composite scale variable (CSV) based on an equal weighting of customer numbers, units distributed and network length. This is similar to the scale variable used in a number of previous electricity distribution price controls.

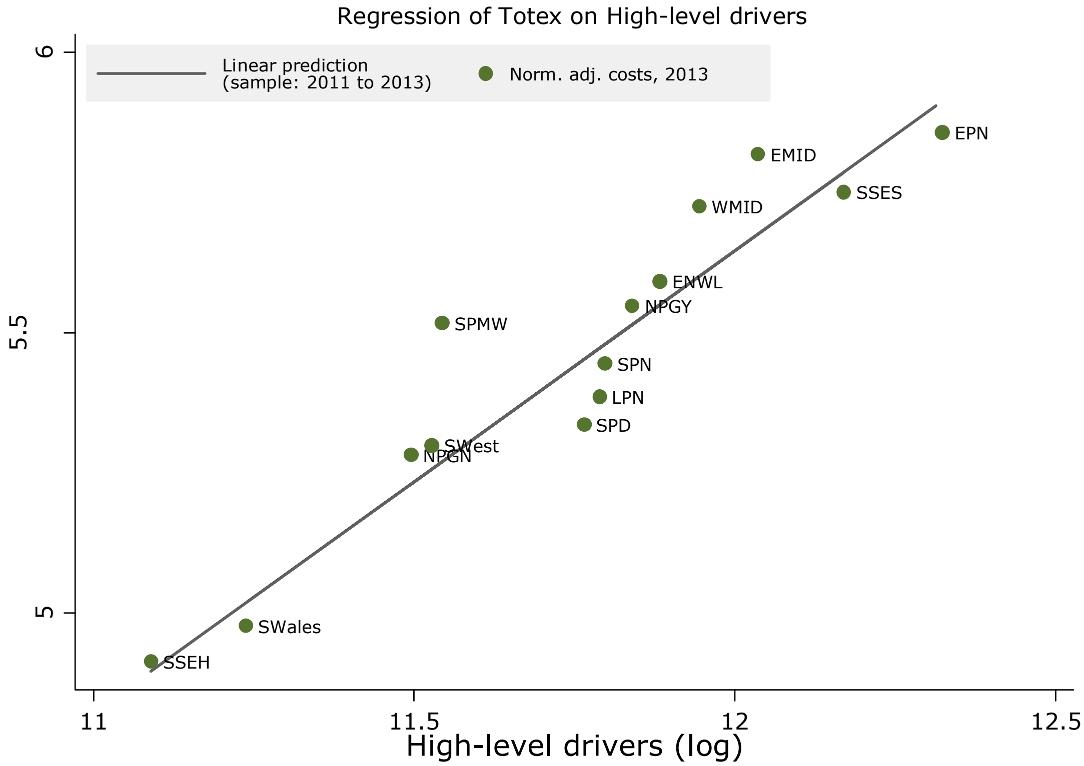
8.9. The advantage of using this composite cost driver is that it is largely outside the control of the DNOs, removing their ability to influence the efficiency results through changes in the cost drivers. It also captures both volume and unit cost efficiencies.

8.10. The disadvantage is that, as noted by Zachary and Gibbens[23] in their response to Frontier Economics, these variables may be weaker proxies for cost drivers than the variables we use in our activity-level analysis.

8.11. Our totex regression with high level cost drivers is shown in Figure 8.2 below. We have estimated the regression cost function using three years of historical data from 2010-11 to 2012-13.

8.12. The data points in the figure below are for 2012-13 and represent the historical efficiency for each DNO in that year. It is important to note that this does not show the appropriateness of the DNOs' forecasts for RIIO-ED1 as their forecasts also take into account their forecast movements in volumes and unit costs from 2012-13 onwards until the end of the RIIO-ED1 period.

Figure 8.2: Totex regression based on high-level cost drivers



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[23] Gibbens, RJ and Zachary, S, May 2013, *Commentary on the report by Frontier Economics to Ofgem on the feasibility of econometric benchmarking in DNO cost regulation*. Report prepared for Ofgem by Gibbens and Zachary on behalf of WPD.

8.13. We have tested the assumptions underlying the regression using our statistical tests discussed in Chapter 5 and Appendix 1. We forecast costs using the estimated cost relationship in conjunction with forecast values of the CSV cost driver. We apply our index for real input price growth to generate cost baselines including RPEs and finally to calculate the upper quartile efficiency scores.

8.14. We have adjusted the final upper quartile efficiency scores to take into account cases where companies have offered up tighter CI or CML targets than our benchmarking methodology process (see Chapter 2 for further discussion). These have been valued at the relevant incentive rates. As set out in our November document on the assessment of the RIIO-ED1 business plans we have also tested the DNOs' business plans against a range of realistic downside cost of equity scenarios.

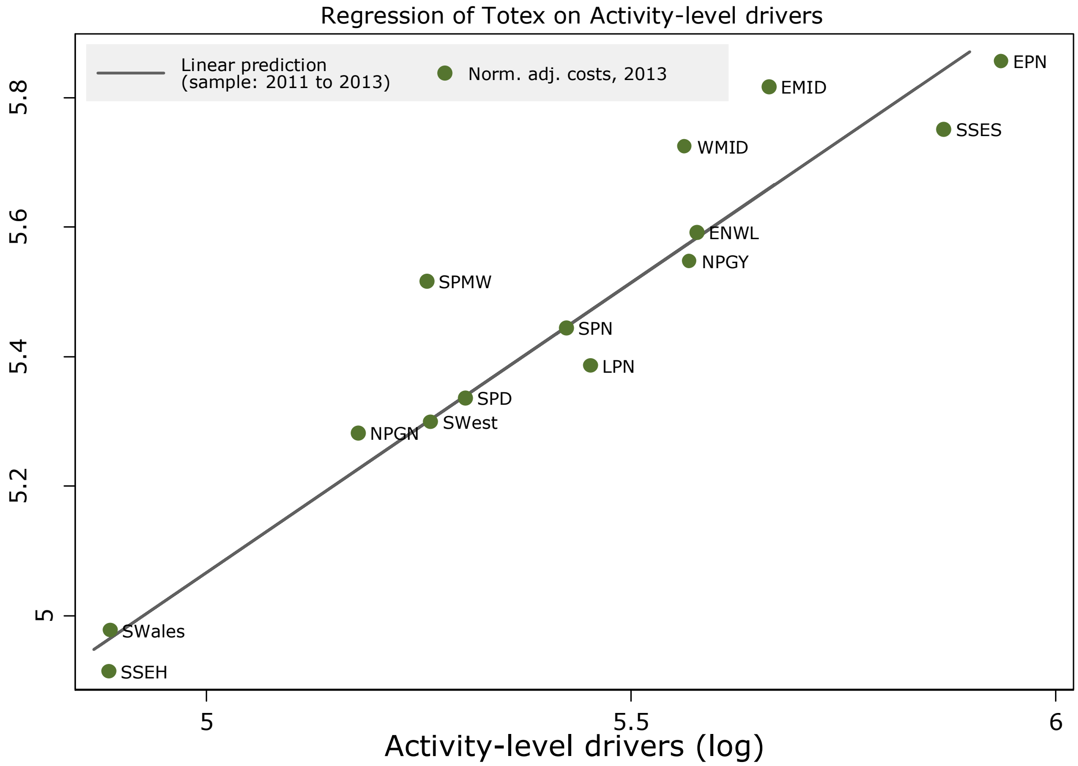
Totex assessment with cost drivers built up from disaggregated activity-level analysis

8.15. Given the limitations of the high-level composite scale variable we have also constructed an alternative. This combines the cost drivers used in the activity-level analysis into a single cost driver.

8.16. Our totex regression with cost drivers built up from disaggregated activity-level analysis is shown in Figure 8.3. As before the regression line is estimated using three years of historical data from 2010-11 to 2012-13, the data points are for 2012-13 and represent the historical efficiency for each DNO in that year.

8.17. As previously mentioned this does not show the appropriateness of the DNOs' forecasts for RIIO-ED1 as their forecasts also take into account their forecast movements in volumes and unit costs from 2012-13 onwards until the end of the RIIO-ED1 period.

Figure 8.3: Totex regression analysis based on activity-level drivers



8.18. We have tested the assumptions underlying the regression using our statistical tests discussed in Chapter 5 and Appendix 1. We forecast costs using the estimated cost relationship in conjunction with forecast values of the CSV cost driver.

9. Bringing our assessment together and sensitivities

Chapter Summary

Our approach to bringing our assessment together and carrying out sensitivity analysis.

Bringing our assessment together

9.1. Our overall approach is based on the thinking that we set out in the RIIO-ED1 Strategy decision and further development in light of the data submitted in the business plans.

9.2. We have applied a broad toolkit approach to our cost assessment for fast-tracking for RIIO-ED1. We have made use of quantitative and qualitative assessment, DNO narrative and supporting evidence, historical cost and performance data and company forecasts. We have carried out comparative analysis for both totex as a whole and on an activity-level basis. This ensures that no single approach is deterministic in reaching our view on the efficiency of expenditure in the DNOs' plans. We have taken qualitative evidence into account in our activity level analysis and where appropriate made adjustments to our quantitative benchmarking.

9.3. Our use of a variety of approaches acknowledges that there is no one definitive right answer for assessing comparative efficiency but a number of plausible ones, which we investigate through our assessment and sensitivity analysis. Our use of top-down totex benchmarking internalises trade-offs between different activities, whereas our activity-level analysis allows us to adopt a more tailored approach to different areas of costs.

9.4. We have decided that it is appropriate to place a greater weight on our activity-level analysis in reaching our conclusions for fast-tracking. This is because our activity-level analysis enables a richer model specification, ie we can take into account a greater number of potential factors that explain costs, including the efficiency of both volumes and unit costs. It also enables us to take into account the qualitative work carried out by our technical consultants, DNV KEMA, and economic consultants, CEPA, in reviewing the plans and the associated CBAs. This analysis gives greater clarity on where companies' forecasts are better or worse than our benchmarks. We have therefore also considered results applying a 75 per cent weighting to our activity-level assessment and 12.5 per cent to each of the totex approaches in our main analysis scenario with sensitivities around it.

9.5. We consider that our two versions of top-down totex analysis based on high-level drivers and drivers from the activity-level analysis respectively (further detail of both totex models can be found in Chapter 8) have provided significant value in helping us to challenge the results of our activity-level analysis and understand the key drivers of differences in performance. However, we consider it is important to recognise the limitations of the totex approach. We are concerned that some DNOs have submitted over optimistic forecasts of the cost drivers used in our totex analysis. This would favour them in the efficiency results. Given the limited number of data points it is only realistically possible to use a small number of cost drivers in the totex benchmarking and we consider that this approach may not sufficiently address differences in sparsity for SSEH and SWest, the uptake of distributed generation, or differences in the asset replacement cycle.

9.6. We have adjusted the final upper quartile efficiency scores to take into account cases where companies have offered up tighter CI or CML targets than our benchmarking methodology process. These have been valued at the relevant incentive rates. We have adjusted the efficiency level to ensure our testing is robust to downside cost of equity scenarios.

Sensitivity analysis

9.7. We have carried out a range of sensitivity analyses in our quantitative work to ensure the robustness of our assessment. These include:

- varying the regional labour- and company-specific factors
- using common allocation of indirects
- dropping SPEN's data from the benchmarking as SPEN is an outlier in our cost assessment, largely driven by the scale of expenditure requirements it has put forward for SPMW
- applying a fixed cost adjustment for each DNO based on the work that was carried out by KPMG on behalf of ENWL
- carrying out regressions using 13 years of data rather than just the historical years; and
- using Random Effects rather than our main pooled ordinary least squares (OLS) methodology.

9.8. These sensitivities give us confidence that the overall conclusions drawn from using our toolkit approach are robust.

9.9. We have circulated an early version of our models to the DNOs in order for them to check normalisations, linkages between workbooks and internal calculations. We appointed an academic advisor, and an external auditor, to minimise the risk of inaccuracies in our modelling. We have completed our cost assessment for fast-tracking and we do not intend to make any further corrections to this assessment for any points that may be subsequently identified by the DNOs. Our approach of applying the upper quartile, and using a broad toolkit including quantitative and qualitative analysis and a range of sensitivities, takes into account the possibility of inaccuracies in the modelling and we are therefore confident that our overall assessment is robust.

Appendices

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Appendix 1 – Statistical tests

1.1. We have developed a number of statistical tests in consultation with our academic advisor for the panel data models. These tests provide an indication of the robustness of the modelling results and also indicate where some of the parameter estimates from the regressions might be biased and require an adjustment to avoid misleading results.

1.2. We use results from statistical diagnostic tests to inform our judgement in identifying the best models. The tests are:

- Ramsey RESET test for model misspecification
- White test for heteroscedasticity
- Skewness and Kurtosis test for normality.

1.3. We investigated the outcome of the statistical tests and made appropriate adjustments. For example we re-specified models when the RESET test failed, we reviewed the functional form of the model and tested different drivers.

1.4. All the models that we have used in our regression have passed the diagnostic tests, with the exception of one of the closely associated indirect activities (call centre). However using our prior knowledge of this cost activity we feel that we selected the most appropriate drivers to assess this activity.

1.5. Some of these tests are more critical than others, particularly the Ramsey RESET test because it is directly relevant in assessing the validity of a given model specification. The tests of heteroscedasticity and normality are generally used to determine appropriate methods for assessing the accuracy of the estimates and hypothesis tests.

The Ramsey RESET test

1.6. The Ramsey Regression Specification Error Test (RESET) is a general test for model misspecification. For example, the test might identify incorrect functional form - some or all of the variables (i.e. the costs and the driver) may need to be transformed to logs, powers, reciprocals, or in some other way.

White test for heteroscedasticity

1.7. When an OLS regression is run it produces estimates of the standard errors for each of the coefficients in the model. These standard errors are a measure of the uncertainty surrounding the parameter estimates and can be used to perform hypothesis tests on the coefficients from the model.

1.8. Heteroscedasticity can cause the standard errors (and therefore any hypothesis testing) to be biased. It typically occurs when the variation in the residuals is very different over time. For example, if the residuals were very large in magnitude in some periods compared to others then this would be an indication of heteroscedasticity.

1.9. Heteroscedasticity may also be driven by the error variance differing as a result of the model not fully capturing scale differences for the cross-section of comparators. We test for heteroscedasticity since any violation might be an indicator of a more general model misspecification.

1.10. The White test examines whether the residual variance of the variable in the regression model is constant (homoscedasticity). If there is evidence of variation in the residual variance (heteroscedasticity) it implies that the standard errors of the coefficients (and therefore any hypothesis testing) may be biased. We address issues of heteroscedasticity through cluster robust standard errors discussed below.

Panel robust standard errors

1.11. We have estimated our models using clustered robust standard errors to allow for the fact that the set of observations in the panel are not independent but clustered by DNO. These standard errors are also robust to heteroscedasticity

Skewness and Kurtosis test for normality

1.12. The Skewness and Kurtosis test (SKtest) is used to test whether the residuals are normally distributed. Normality of residuals is not a necessity, but it is an indication of a well behaved model. The SKtest returns a combined test statistic for normality based on skewness and another based on kurtosis.

Appendix 2 - Totex by DNO

Table A2.1: Submitted net totex, including RPEs (£m, 2012-13 prices)

DNO	DPCR5					RIIO-ED1							
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
ENWL	229.4	250.7	247.9	274.5	254.0	238.4	230.3	230.5	232.7	236.4	238.7	247.5	245.5
NPGN	130.5	131.7	180.9	200.2	181.4	192.7	181.0	169.8	175.5	173.1	160.6	156.4	155.6
NPGY	180.4	188.9	237.0	253.9	251.1	252.1	241.9	239.6	242.5	232.1	224.2	209.5	217.5
WMID	243.6	250.1	284.2	316.8	297.7	259.6	260.0	252.5	256.1	264.6	264.9	263.0	265.7
EMID	226.2	226.6	313.5	295.6	264.7	281.8	275.3	244.8	249.0	248.4	258.3	271.5	263.9
SWALES	123.1	121.6	140.0	122.3	128.6	134.2	134.1	134.6	143.6	135.8	136.1	131.5	133.8
SWEST	174.1	175.7	185.6	190.9	199.4	211.2	211.3	209.1	213.0	209.3	211.7	211.3	219.2
LPN	203.6	182.2	208.4	257.0	261.3	260.2	260.6	254.6	244.4	245.8	239.3	234.5	228.4
SPN	245.8	222.0	219.1	229.1	235.4	232.7	251.2	246.5	237.0	230.8	234.2	237.3	227.4
EPN	364.4	323.0	320.0	369.4	353.6	357.4	364.2	360.0	358.4	359.3	351.9	359.4	350.4
SPD	180.1	199.1	188.4	220.4	224.9	219.8	221.6	226.0	220.7	218.9	210.2	210.4	212.4
SPMW	197.5	221.6	234.2	267.2	290.0	295.4	312.4	283.1	273.3	281.5	278.3	259.3	237.2
SSEH	106.1	129.5	130.7	133.9	135.9	152.5	151.6	153.4	155.8	157.0	156.7	160.1	156.6
SSES	230.5	260.6	293.7	318.4	338.6	318.1	330.0	321.3	323.0	292.5	297.1	305.9	301.8
Industry	**2,835.4**	**2,883.3**	**3,183.7**	**3,449.6**	**3,416.5**	**3,406.1**	**3,425.5**	**3,325.8**	**3,325.0**	**3,285.3**	**3,262.2**	**3,257.5**	**3,215.4**

[1] Table excludes costs associated with Network Rail's electrification programme submitted by WPD. See Chapter 4 for further detail on our assessment of rail electrification costs.

[2] Data sourced from disaggregated activity-level business plan data template tables (cost and volumes CV tables). Note totex presented above is different from totex published in our November document[24] which was sourced from high-level cost tables in the BPDTs (the C1, cost matrix and T1 total cost matrix tables). For some DNOs expenditure reported in the activity-level CV tables did not reconcile with expenditure reported in the high-level C1 BPDTs. These differences were small and account for the difference in reported totex.

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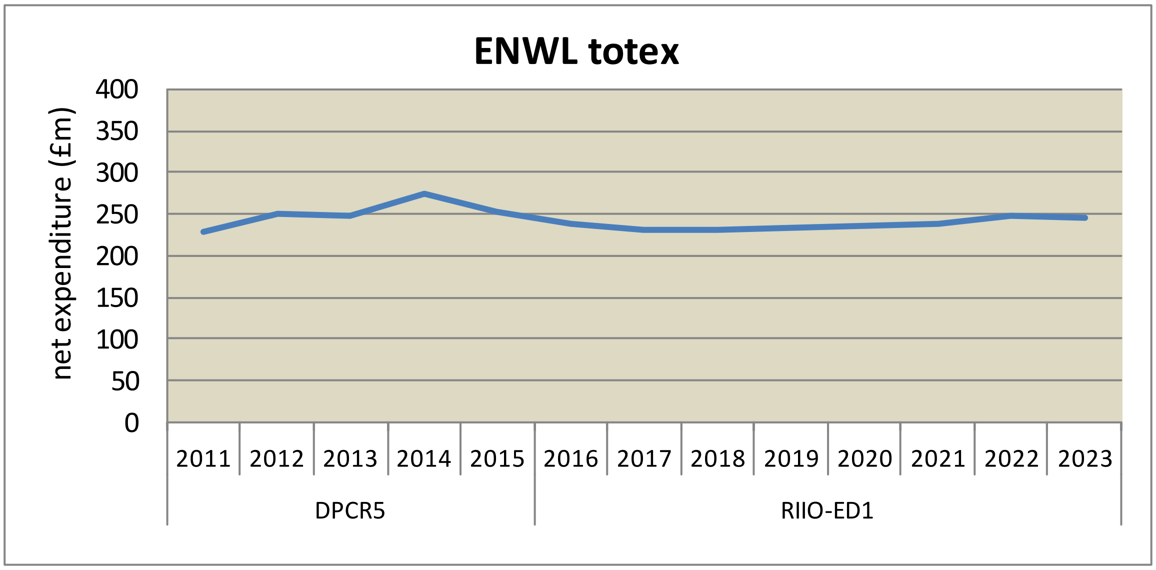
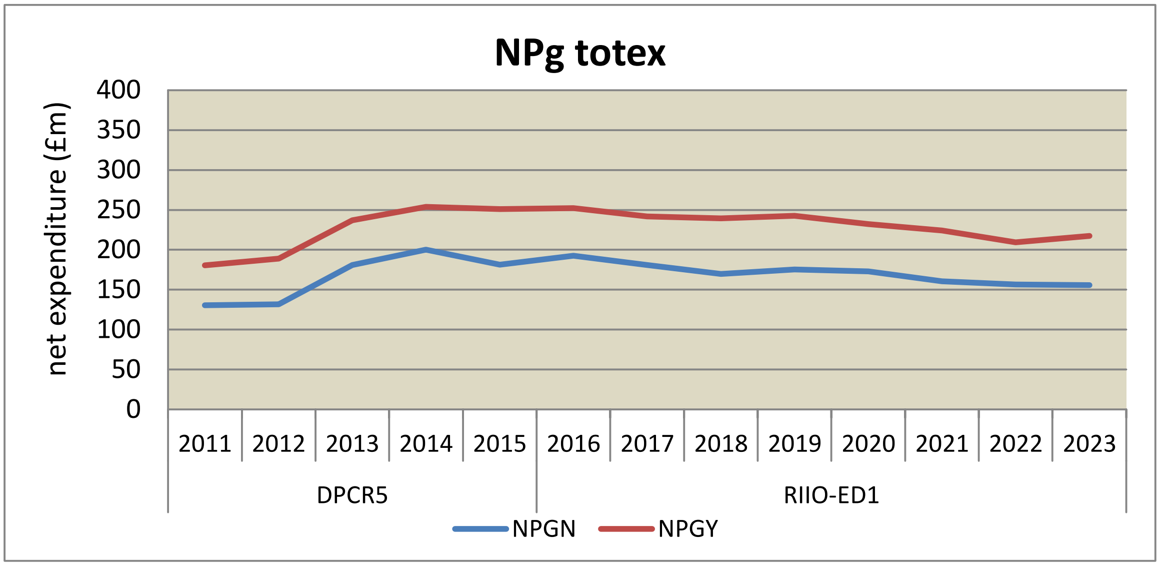
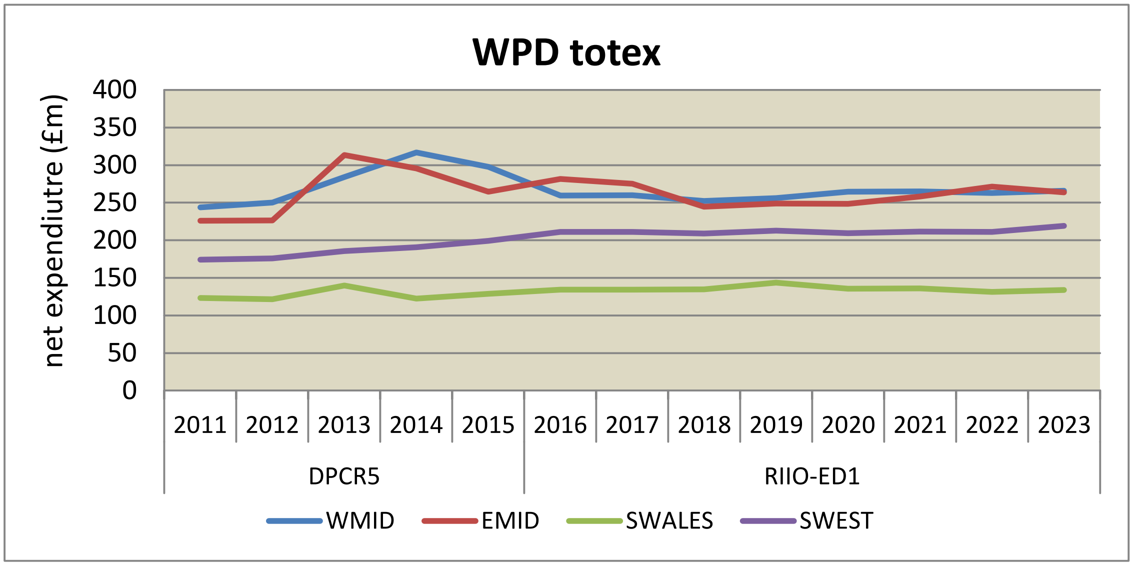
[24] https://www.ofgem.gov.uk/ofgem-publications/84606/assessmentoftheriio-ed1businessplans.pdf

Figure A2.1: Submitted net totex, including RPEs (2012-13 prices), by DNO group



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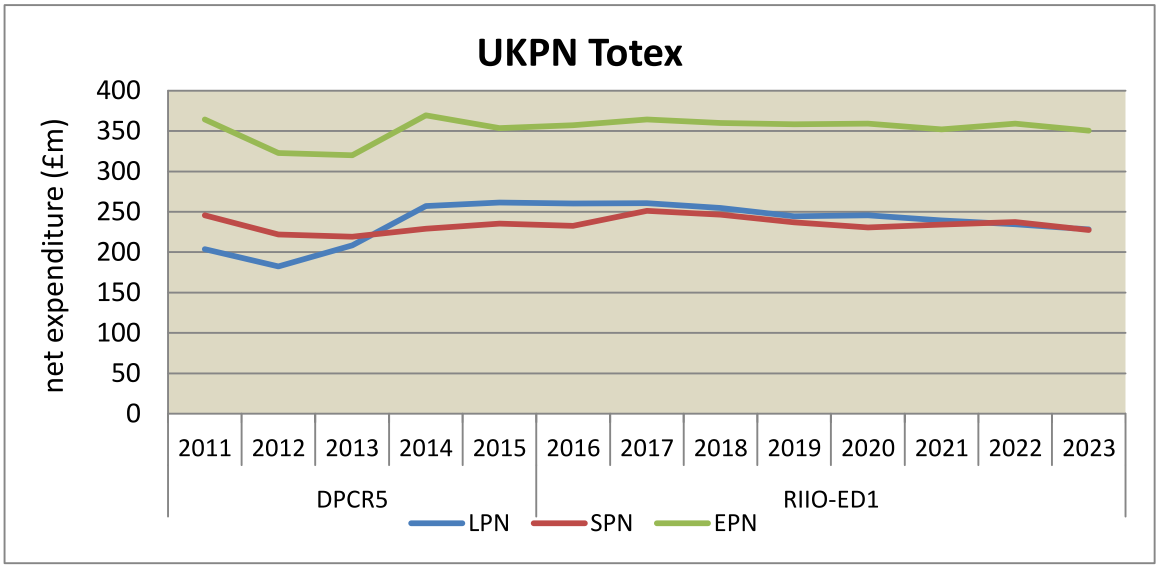
RIIO-ED1
WMID
EMID
SWALES
SWEST


UKPN Totex
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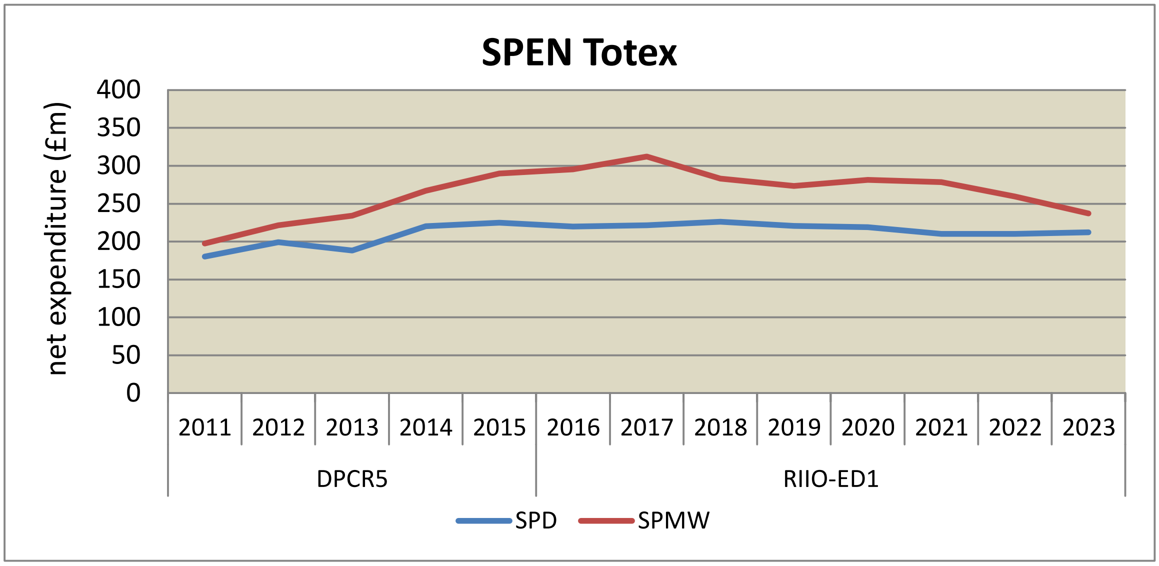
SPEN Totex
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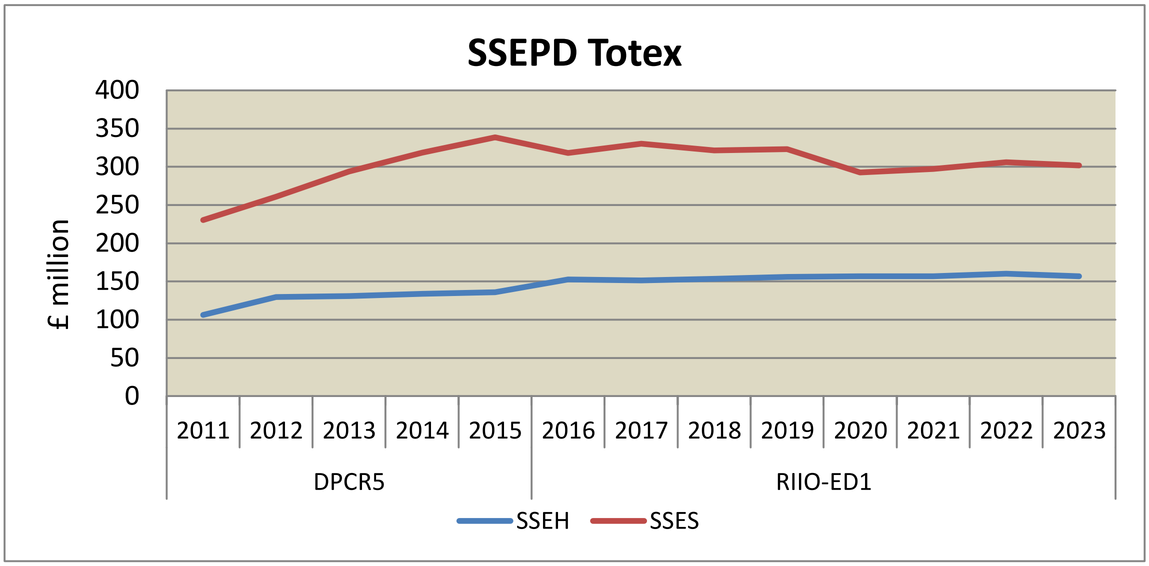
SSEPD Totex
£ million
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2023
DPCR5
RIIO-ED1
SSEH
SSES

Appendix 3 – Data Terms

Data term	Explanation of the term
ln_totex	The natural log of total expenditure
ln_BU_CSV	The natural log of the disaggregated activity-level analysis (units distributed, network length, customer numbers, MEAV, overhead line length, number of faults, number of ONIs, and spans cut)
ln_macro_csv	The natural log of the high level drivers (network length, customer numbers, and units distributed)
ln_tree_cutting	The natural log of tree cutting expenditure
ln_spans_cut	The natural log of the volume of spans cut
ln_tc_lv_hv_ohl	The natural log of low and high voltage overhead faults expenditure
ln_faults_lv_hv_ohl_ex_switching	The natural log of the volume of low and high voltage overhead faults
ln_tc_lv_pe	The natural log of low voltage plant and equipment faults expenditure
ln_faults_lv_pe	The natural log of the volume of low voltage overhead faults
ln_tc_hv_pe	The natural log of high voltage plant and equipment faults expenditure
ln_faults_hv_pe	The natural log of the volume of high voltage overhead faults
ln_onis	The natural log of Occurrences Not Incentivised expenditure
ln_onis_faults	The natural log of the volumes of Occurrences Not Incentivised
ln_cai_emcs_stores_np	The natural log of closely associated indirect expenditure for engineering management and clerical support, stores and network policy
ln_weighted_MEAV	The natural log of the Modern Equivalent Asset Value weighted by expenditure of asset replacement and refurbishment for overhead, underground, plant and other assets
ln_cai_control_centre	The natural log of closely associated indirect expenditure for control centre
ln_faults_total_onis	The natural log of the volume of troublecall faults, and occurrences not incentivised
ln_employees	The natural log of the number of employees
ln_cai_call_centre	The natural log of closely associated indirect expenditure for call centres
ln_cai_nd_pm_sm	The natural log of closely associated indirect expenditure for network design, project management and system mapping

Appendix 4 – Data Characteristics

4.1 Table A4.1 shows the characteristics of the panel data for both the natural log of totex and the natural log of the specified cost drivers (weighted Modern Equivalent Asset Value (MEAV), length, peak demand, units distributed and spans cut). A similar picture holds for the historical data and is set out in Tables A4.3 to A4.8.

Table A4.1: Data characteristics for the panel data

var	category	mean	sd	min	max	obs
ln_totex	overall	5.438499	.2785619	4.816185	6.060765	182
ln_totex	between	.	.2764566	4.887857	5.914762	14
ln_totex	within	.	.0789657	5.270484	5.653674	13
ln_totex	B/W Variation	.	3.500972	.	.	.
ln_weighted_MEAV	overall	7.864852	.4036821	7.154469	8.425431	182
ln_weighted_MEAV	between	.	.4172488	7.172565	8.392577	14
ln_weighted_MEAV	within	.	.0201248	7.814677	7.923702	13
ln_weighted_MEAV	B/W Variation	.	20.73311	.	.	.
ln_length_total	overall	10.92286	.2732796	10.46773	11.54033	182
ln_length_total	between	.	.2821155	10.49287	11.50417	14
ln_length_total	within	.	.0192156	10.88321	10.97295	13
ln_length_total	B/W Variation	.	14.68157	.	.	.
ln_units_dist	overall	9.884778	.4021844	8.939957	10.52245	182
ln_units_dist	between	.	.4154374	8.991955	10.48645	14
ln_units_dist	within	.	.0246233	9.820184	9.961873	13
ln_units_dist	B/W Variation	.	16.87169	.	.	.
ln_peak	overall	8.255632	.4120755	7.24604	8.854522	182
ln_peak	between	.	.4252118	7.301986	8.801179	14
ln_peak	within	.	.0314355	8.186172	8.4261	13
ln_peak	B/W Variation	.	13.52649	.	.	.
ln_spans_cut	overall	9.692952	1.538117	2.094946	10.95987	178
ln_spans_cut	between	.	1.837544	3.349156	10.88398	14
ln_spans_cut	within	.	.1769838	8.438742	10.05112	12.71429
ln_spans_cut	B/W Variation	.	10.38255	.	.	.

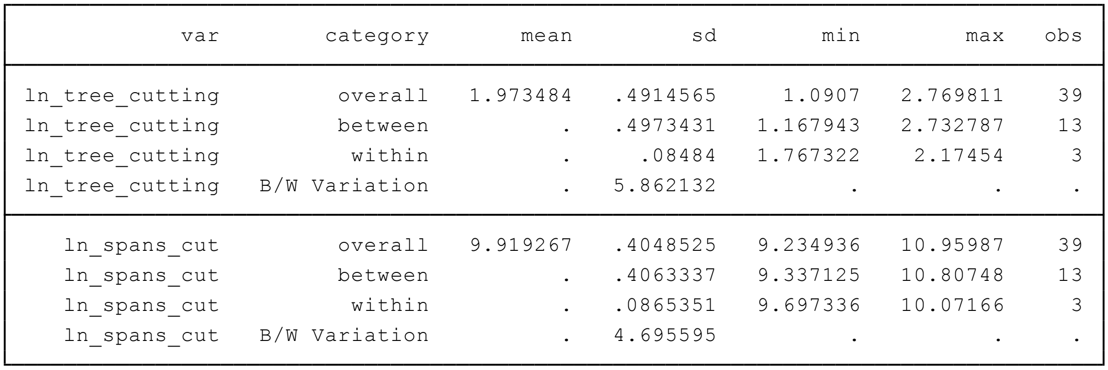
Table A4.2: Data characteristics for customers affected and HV overhead line faults

var	category	mean	sd	min	max	obs
ln_customers	overall	14.49576	.3955203	13.51582	15.12152	182
ln_customers	between	.	.4091265	13.54508	15.09874	14
ln_customers	within	.	.0122113	14.46617	14.52209	13
ln_customers	B/W Variation	.	33.50386	.	.	.
ln_faults_lv_hv_ohl	overall	8.702477	.3652849	7.881182	9.490242	182
ln_faults_lv_hv_ohl	between	.	.3749713	8.05354	9.390157	14
ln_faults_lv_hv_ohl	within	.	.0463823	8.53012	8.941409	13
ln_faults_lv_hv_ohl	B/W Variation	.	8.084355	.	.	.

Table A4.3: Submitted totex and totex drivers

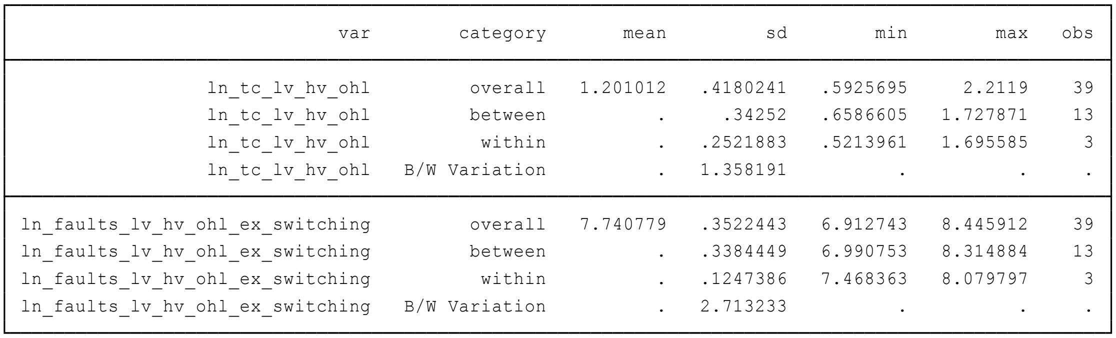
var	category	mean	sd	min	max	obs
ln_totex	overall	5.436956	.2952522	4.860765	6.060765	42
ln_totex	between	.	.2952013	4.92144	5.934829	14
ln_totex	within	.	.0654291	5.337208	5.602376	3
ln_totex	B/W Variation	.	4.511776	.	.	.
ln_BU_CSV	overall	5.413896	.3045175	4.866751	5.936171	42
ln_BU_CSV	between	.	.3116262	4.875614	5.919226	14
ln_BU_CSV	within	.	.018898	5.328228	5.459683	3
ln_BU_CSV	B/W Variation	.	16.48986	.	.	.
ln_macro_csv	overall	11.7465	.3322649	11.07776	12.32396	42
ln_macro_csv	between	.	.3406249	11.08575	12.31645	14
ln_macro_csv	within	.	.0058697	11.72313	11.76373	3
ln_macro_csv	B/W Variation	.	58.03114	.	.	.

Table A4.4: Submitted tree cutting expenditure and associated driver



var	category	mean	sd	min	max	obs
ln_tree_cutting	overall	1.973484	.4914565	1.0907	2.769811	39
ln_tree_cutting	between	.	.4973431	1.167943	2.732787	13
ln_tree_cutting	within	.	.08484	1.767322	2.17454	3
ln_tree_cutting	B/W Variation	.	5.862132	.	.	.
ln_spans_cut	overall	9.919267	.4048525	9.234936	10.95987	39
ln_spans_cut	between	.	.4063337	9.337125	10.80748	13
ln_spans_cut	within	.	.0865351	9.697336	10.07166	3
ln_spans_cut	B/W Variation	.	4.695595	.	.	.

Table A4.5: Submitted trouble call (LV/HV OHL) expenditure and associated drivers



var	category	mean	sd	min	max	obs
ln_tc_lv_hv_ohl	overall	1.201012	.4180241	.5925695	2.2119	39
ln_tc_lv_hv_ohl	between	.	.34252	.6586605	1.727871	13
ln_tc_lv_hv_ohl	within	.	.2521883	.5213961	1.695585	3
ln_tc_lv_hv_ohl	B/W Variation	.	1.358191	.	.	.
ln_faults_lv_hv_ohl_ex_switching	overall	7.740779	.3522443	6.912743	8.445912	39
ln_faults_lv_hv_ohl_ex_switching	between	.	.3384449	6.990753	8.314884	13
ln_faults_lv_hv_ohl_ex_switching	within	.	.1247386	7.468363	8.079797	3
ln_faults_lv_hv_ohl_ex_switching	B/W Variation	.	2.713233	.	.	.

Table A4.6: Submitted trouble call (LV and HV plant and equipment) expenditure and associated drivers

var	category	mean	sd	min	max	obs
ln_tc_lv_pe	overall	-1.037121	1.311257	-4.885495	1.237883	42
ln_tc_lv_pe	between	.	1.157349	-2.807706	1.017298	14
ln_tc_lv_pe	within	.	.6672908	-3.258687	.2722707	3
ln_tc_lv_pe	B/W Variation	.	1.7344	.	.	.
ln_faults_lv_pe	overall	5.783963	.5269406	4.49981	6.999423	42
ln_faults_lv_pe	between	.	.4661812	4.545573	6.596123	14
ln_faults_lv_pe	within	.	.2663507	5.014256	6.347708	3
ln_faults_lv_pe	B/W Variation	.	1.750253	.	.	.
ln_tc_hv_pe	overall	.0037349	.7199709	-1.978203	1.365713	42
ln_tc_hv_pe	between	.	.6312492	-.8765194	1.281522	14
ln_tc_hv_pe	within	.	.3732565	-1.494225	.8030742	3
ln_tc_hv_pe	B/W Variation	.	1.691194	.	.	.
ln_faults_hv_pe	overall	5.736764	.4827181	4.787492	7.180831	42
ln_faults_hv_pe	between	.	.4323125	5.058624	6.634494	14
ln_faults_hv_pe	within	.	.2350308	4.909965	6.283102	3
ln_faults_hv_pe	B/W Variation	.	1.839386	.	.	.

Table A4.7: Submitted ONIs expenditure and associated drivers

var	category	mean	sd	min	max	obs
ln_onis	overall	1.492337	.6541111	-.3714944	2.599024	42
ln_onis	between	.	.638579	.1710052	2.454989	14
ln_onis	within	.	.1999252	.9498369	1.943895	3
ln_onis	B/W Variation	.	3.19409	.	.	.
ln_onis_faults	overall	9.978111	.5100045	8.56484	10.86599	42
ln_onis_faults	between	.	.4985907	8.744917	10.6348	14
ln_onis_faults	within	.	.1537476	9.535543	10.23555	3
ln_onis_faults	B/W Variation	.	3.242917	.	.	.

Table A4.8: Submitted CAI expenditure and associated drivers

var	category	mean	sd	min	max	obs
ln_cai_emcs_stores_np	overall	2.925123	.4544351	2.104923	3.765882	42
ln_cai_emcs_stores_np	between	.	.435526	2.184969	3.49852	14
ln_cai_emcs_stores_np	within	.	.1614965	2.342969	3.299293	3
ln_cai_emcs_stores_np	B/W Variation	.	2.696814	.	.	.
ln_cai_nd_pm_sm	overall	2.596493	.3511986	1.570382	3.272691	42
ln_cai_nd_pm_sm	between	.	.3448738	1.7215	3.1192	14
ln_cai_nd_pm_sm	within	.	.1010169	2.350413	2.834522	3
ln_cai_nd_pm_sm	B/W Variation	.	3.414019	.	.	.
ln_weighted_MEAV	overall	7.842819	.3977514	7.154469	8.373723	42
ln_weighted_MEAV	between	.	.4075945	7.157844	8.360811	14
ln_weighted_MEAV	within	.	.0133016	7.78467	7.87235	3
ln_weighted_MEAV	B/W Variation	.	30.64241	.	.	.
ln_cai_control_centre	overall	1.356591	.3087358	.6995367	1.783529	42
ln_cai_control_centre	between	.	.3114104	.7078823	1.719519	14
ln_cai_control_centre	within	.	.0554252	1.197853	1.524382	3
ln_cai_control_centre	B/W Variation	.	5.61857	.	.	.
ln_faults_total_onis	overall	10.44029	.413993	9.408125	11.21093	42
ln_faults_total_onis	between	.	.4098322	9.515324	11.03657	14
ln_faults_total_onis	within	.	.1078008	10.11119	10.63943	3
ln_faults_total_onis	B/W Variation	.	3.801754	.	.	.
ln_employees	overall	7.11891	.2800403	6.457554	7.569561	42
ln_employees	between	.	.2785497	6.489795	7.553187	14
ln_employees	within	.	.0679521	6.932132	7.26246	3
ln_employees	B/W Variation	.	4.099208	.	.	.
ln_cai_call_centre	overall	.5402603	.3121544	-.1747377	1.166251	42
ln_cai_call_centre	between	.	.2970985	-.0896517	1.083629	14
ln_cai_call_centre	within	.	.1160972	.17804	.9394875	3
ln_cai_call_centre	B/W Variation	.	2.559049	.	.	.
ln_faults_total	overall	9.408818	.3374848	8.807622	9.984653	42
ln_faults_total	between	.	.3424032	8.825134	9.928409	14
ln_faults_total	within	.	.0487346	9.317631	9.497227	3
ln_faults_total	B/W Variation	.	7.025876	.	.	.
ln_onis_faults	overall	9.978111	.5100045	8.56484	10.86599	42
ln_onis_faults	between	.	.4985907	8.744917	10.6348	14
ln_onis_faults	within	.	.1537476	9.535543	10.23555	3
ln_onis_faults	B/W Variation	.	3.242917	.	.	.

Appendix 5 – Regression Results

Table A5.1: Summary of regressions used in our analysis

Cost area	Regression Number	Regression Equation
Totex	1	ln(Totex) = a + b1*ln(BU_CSV)
	2	ln(Totex) = a + b1*ln(macro_csv)
Tree Cutting	3	ln(Tree cutting) = a + b1*ln(Spans Cut)
Trouble call (Faults)	4	ln(Trouble call costs LV/HV OHL) = a + b1*ln(Fault vol LV/HV OHL)
	5	ln(Trouble call costs LV plant) = a + b1*ln(Fault vol LV plant)
	6	ln(Trouble call costs HV plant) = a + b1*ln(Fault vol HV plant)
ONIs	7	ln(ONIs) = a + b1 * ln(ONIs faults)
Closely Associated Indirects	8	ln(emcs+stores+network policy) = a + b1* ln(weighted MEAV)
	9	ln(Control centre) = a + b1*ln(total faults and onis) + b2*ln(employees)
	10	ln(Call centre) = a + b1*ln(Total faults) + b2*ln(total onis)
	11	ln(network design+project mgmt+sys mapping) = a + b1* ln(weighted MEAV)

Totex activity-level driver regression, number 1

```
Linear regression                                  Number of obs =      42
                                                   F(  1,    13) =  167.09
                                                   Prob > F      =  0.0000
                                                   R-squared     =  0.8513
                                                   Root MSE      =  .11525

                                (Std. Err. adjusted for 14 clusters in dno)
------------------------------------------------------------------------------
             |               Robust
    ln_totex |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   ln_BU_CSV |   .8946052   .0692072    12.93   0.000     .7450922    1.044118
       _cons |   .5936562   .3695559     1.61   0.132    -.2047207    1.392033
------------------------------------------------------------------------------
```

Statistical Test	**p-value**
Adjusted R-squared	0.85
RESET	0.43
White	0.31
Normality	0.65
Observations	42

Totex high-level driver regression, number 2

```
Linear regression                                      Number of obs =      42
                                                       F(  1,    13) =  173.57
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.8590
                                                       Root MSE      =  .11224

                                   (Std. Err. adjusted for 14 clusters in dno)
------------------------------------------------------------------------------
             |               Robust
    ln_totex |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ln_macro_csv |   .8235808   .0625127    13.17   0.000     .6885304    .9586313
       _cons |  -4.237239   .7435775    -5.70   0.000    -5.843641   -2.630837
------------------------------------------------------------------------------
```

Statistical Test	**p-value**
Adjusted R-squared	0.86
RESET	0.67
White	0.32
Normality	0.56
Observations	42

Tree Cutting regression, number 3

```
Linear regression                                      Number of obs =      39
                                                       F(  1,    12) =   23.99
                                                       Prob > F      =  0.0004
                                                       R-squared     =  0.3433
                                                       Root MSE      =   .4036

                                   (Std. Err. adjusted for 13 clusters in dno)
------------------------------------------------------------------------------
             |               Robust
ln_tree_cu~g |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ln_spans_cut |    .711292   .1452154     4.90   0.000     .3948948    1.027689
       _cons |   -5.08201   1.490919    -3.41   0.005    -8.330444   -1.833576
------------------------------------------------------------------------------
```

Statistical Test	**p-value**
Adjusted R-squared	0.33
RESET	0.46
White	0.05
Normality	0.52
Observations	39*

*LPN is excluded from this regression.

Troublecall LV and HV OH faults regression, number 4

```
Linear regression                                      Number of obs =      39
                                                       F(  1,    12) =   30.99
                                                       Prob > F      =  0.0001
                                                       R-squared     =  0.4652
                                                       Root MSE      =  .30981

                                    (Std. Err. adjusted for 13 clusters in dno)
------------------------------------------------------------------------------
                 |               Robust
 ln_tc_lv_hv_ohl |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
ln_faults_lv_hv_~g |   .8094032   .1453939     5.57   0.000     .4926171    1.126189
           _cons |  -5.064399   1.133085    -4.47   0.001    -7.533179    -2.59562
------------------------------------------------------------------------------
```

Statistical Test	**p-value**
Adjusted R-squared	0.45
RESET	0.74
White	0.85
Normality	0.05
Observations	39*

*LPN is excluded from this regression.

Troublecall LV Plant and Equipment, number 5

```
Linear regression                                      Number of obs =      42
                                                       F(  1,    13) =   17.17
                                                       Prob > F      =  0.0012
                                                       R-squared     =  0.2334
                                                       Root MSE      =  1.1624

                                      (Std. Err. adjusted for 14 clusters in dno)
------------------------------------------------------------------------------
                |               Robust
   ln_tc_lv_pe  |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
ln_faults_lv_pe |   1.202137   .2901068     4.14   0.001     .5753993    1.828875
          _cons |  -7.990237   1.617989    -4.94   0.000    -11.48569   -4.494784
------------------------------------------------------------------------------
```

Statistical Test	p-value
Adjusted R-squared	0.21
RESET	0.35
White	0.72
Normality	0.87
Observations	42

Troublecall HV Plant and Equipment, number 6

```
Linear regression                                      Number of obs =      42
                                                       F(  1,    13) =   18.22
                                                       Prob > F      =  0.0009
                                                       R-squared     =  0.2411
                                                       Root MSE      =  .63499

                                   (Std. Err. adjusted for 14 clusters in dno)
------------------------------------------------------------------------------
             |               Robust
  ln_tc_hv_pe |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ln_faults_hv~e |   .7323671   .1715557     4.27   0.001     .3617436    1.102991
       _cons |  -4.197683   .9616989    -4.36   0.001    -6.275307   -2.120059
------------------------------------------------------------------------------
```

Statistical Test	p-value
Adjusted R-squared	0.22
RESET	0.10
White	0.41
Normality	0.01
Observations	42

ONIs regression, number 7

```
Linear regression                                  Number of obs =      42
                                                   F(  1,    13) =   69.56
                                                   Prob > F      =  0.0000
                                                   R-squared     =  0.7162
                                                   Root MSE      =  .35282

                                  (Std. Err. adjusted for 14 clusters in dno)
------------------------------------------------------------------------------
             |               Robust
     ln_onis |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ln_onis_faults |   1.085376   .1301398     8.34   0.000     .8042263    1.366526
       _cons |  -9.337669   1.311384    -7.12   0.000    -12.17074   -6.504596
------------------------------------------------------------------------------
```

Statistical Test	p-value
Adjusted R-squared	0.71
RESET	0.57
White	0.54
Normality	0.55
Observations	42

CAI EMCS, Stores and Network Policy regression, number 8

```
Linear regression                                      Number of obs =      42
                                                       F(  1,    13) =    7.84
                                                       Prob > F      =  0.0150
                                                       R-squared     =  0.3646
                                                       Root MSE      =  .36674

                                       (Std. Err. adjusted for 14 clusters in dno)
---------------------------------------------------------------------------------
                 |               Robust
ln_cai_emcs_st~p |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+---------------------------------------------------------------
ln_weighted_MEAV |   .6898801   .2463286     2.80   0.015     .1577196    1.222041
           _cons |  -2.485482   1.968266    -1.26   0.229    -6.737662    1.766697
---------------------------------------------------------------------------------
```

Statistical Test	**p-value**
Adjusted R-squared	0.35
RESET	0.12
White	0.40
Normality	0.01
Observations	42

CAI Control Centre regression, number 9

```
Linear regression                                      Number of obs =      42
                                                       F(  2,    13) =   61.14
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6506
                                                       Root MSE      =  .18711

                                          (Std. Err. adjusted for 14 clusters in dno)
------------------------------------------------------------------------------
                  |               Robust
ln_cai_control_cen~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------------------------------------------------------------------
ln_faults_total_onis |   .1644787   .1732747     0.95   0.360    -.2098584    .5388159
       ln_employees |    .701863   .1932834     3.63   0.003     .2842996    1.119426
              _cons |  -5.357113   .7528819    -7.12   0.000    -6.983616   -3.730611
------------------------------------------------------------------------------
```

Statistical Test	**p-value**
Adjusted R-squared	0.63
RESET	0.64
White	0.07
Normality	0.84
Observations	42

CAI Call Centre regression, number 10

```
Linear regression                                      Number of obs =      42
                                                       F(  2,    13) =    4.84
                                                       Prob > F      =  0.0269
                                                       R-squared     =  0.4583
                                                       Root MSE      =  .23556

                                         (Std. Err. adjusted for 14 clusters in dno)
────────────────┬────────────────────────────────────────────────────────────────
                │               Robust
ln_cai_call_c~e │      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
────────────────┼────────────────────────────────────────────────────────────────
ln_faults_total │   .1937819    .224562     0.86   0.404    -.2913549    .6789187
 ln_onis_faults │   .3109158   .1541449     2.02   0.065    -.0220941    .6439257
          _cons │  -4.385351   1.820589    -2.41   0.032    -8.318495   -.4522069
────────────────┴────────────────────────────────────────────────────────────────
```

Statistical Test	**p-value**
Adjusted R-squared	0.43
RESET	0.01
White	0.28
Normality	0.72
Observations	42

CAI Network Design, System Mapping, and Project Management regression, number 11

```
Linear regression                                      Number of obs =      42
                                                       F(  1,    13) =    4.10
                                                       Prob > F      =  0.0640
                                                       R-squared     =  0.2623
                                                       Root MSE      =  .30539

                                   (Std. Err. adjusted for 14 clusters in dno)
------------------------------------------------------------------------------
             |               Robust
ln_cai_nd_pm_sm |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ln_weighted_MEAV |   .4522208   .2233779     2.02   0.064    -.0303579    .9347995
       _cons |  -.9501933   1.788238    -0.53   0.604    -4.813447     2.91306
------------------------------------------------------------------------------
```

Statistical Test	p-value
Adjusted R-squared	0.24
RESET	0.34
White	0.09
Normality	0.46
Observations	42