OFFICE OF RAIL REGULATION (ORR)

SCOPE FOR IMPROVEMENT IN THE EFFICIENCY OF NETWORK RAIL'S EXPENDITURE ON SUPPORT AND OPERATIONS: SUPPLEMENTARY ANALYSIS OF PRODUCTIVITY AND UNIT COST CHANGE

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FINAL REPORT

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CONTENTS

Important notice

EXECUTIVE SUMMARY

The Office for Rail Regulation (ORR) has started the process of determining Network Rail's revenue allowances over the five years of the fifth price control (CP5). The purpose of this study is to provide ORR with estimates of Network Rail's scope for achieving efficiency gains in operations and support costs over CP5. The estimates will assist ORR in setting appropriate performance targets over CP5.

This study draws on the historical performances of other UK network industries and different sectors' productivity performance in order to determine the possible scope for efficiency gains. Whilst it would be preferable to look at direct evidence of Network Rail's performance relative to a benchmark, as Network Rail is the only rail infrastructure operator of its type in the UK there are no direct comparators. Therefore, the top-down estimates produced are based on indirect measures of productivity performance (using comparators from other industries as benchmarks).

ORR has asked CEPA to estimate the following metrics to provide a range for the scope for efficiency gains:

- Real Unit Operating Expenditure (RUOE);
- Total Factor Productivity (TFP); and
- Labour, Energy, Materials and Services cost measure (LEMS);

It should be noted that, as is the case for all benchmarking exercises, there are limitations on the level of comparability that can be achieved with Network Rail and as such we would expect ORR to use this analysis as one of several inputs into the targets that it sets for Network Rail in CP5.

Real Unit Operating Expenditure (RUOE)

RUOE is a partial productivity measure, i.e. not taking into account all inputs, which is commonly used by regulators to assess efficiency changes. To obtain this measure, nominal operating expenditure is deflated to its real value and then divided by an appropriate measure of output. These outputs are sometimes referred to as 'cost drivers' since they represent activities through which the business provides its services and costs are typically incurred, such as laying track for railways or connecting customers to the network for telecommunications.

We use RUOE analysis to estimate the trend in unit cost reductions across regulated, network utilities in the UK and compare this to the same trend observed in Network Rail's results. RUOE unit cost trends include both frontier and catch-up efficiency.

The scope for efficiency gains by any regulated company is dependent on its starting point, i.e. where it is in relation to the frontier in the first year of the period being considered. The RUOE results have been provided in a number of ways that enable identification of Network Rail's scope for efficiency gains in operations and support expenditure during CP5. Where possible we estimate comparator industries' annual RUOE on the basis of operations and support costs (or that industry's equivalents). Table E1 below sets out the estimated ranges based on the different time periods based on the 'reset' hypothesis. The reset hypothesis assumes that the sharp increase in costs following the Hatfield derailment and the period of administration effectively reset Network Rail to an efficiency position pre-privatisation.

Table E1: RUOE results excluding England and Wales Sewerage, (average % change per annum)

	Range excluding England and Wales sewerage	Average excluding England and Wales sewerage
Reset Hypothesis		
By control period (third)	2.1 to 6.5	4.4
By years since privatisation (11-15)	2.1 to 6.7	5.1

We have excluded England and Wales sewerage from our reset hypothesis ranges, as we have identified it as an outlier during these periods.

Total Factor Productivity (TFP)

TFP takes into account all the factors of production (e.g. capital, and labour) used to produce goods and services. TFP growth therefore captures the component of the change in output that is not explained by changes in inputs. TFP indices provide a way of comparing the efficiency with which companies / industries deploy their inputs in a multi-input, multi-output environment. They can be used both to compare firms / industries at a specific point in time and over time.

In the economy as a whole, or where there is assumed to be a reasonable amount of competition, if the sample of firms is both (i) large and (ii) random, it seems reasonable to expect that the efficiency improvement should be largely driven by frontier shift. In these circumstances, an equal number of firms ought to be moving closer to the frontier as those that are moving away from it, on average. By contrast, if the sample contains a significant proportion of companies that are commonly recognised to be experiencing catch-up, through the effect of privatisation or comparative competition, then it is appropriate to make an adjustment to the TFP figure to recognise that not all of the efficiency improvement is likely to relate to frontier shift.

Given that there are no direct comparators for Network Rail we have created a weighted 'composite' TFP index to cover sectors that we consider comparable to parts of Network Rail's operations and support activities. As we are only investigating the scope for efficiency gains in operations and support expenditure, which is predominantly made up of labour costs, we have adjusted the TFP estimate for capital substitution (i.e. the replacement of labour with capital) which brings it in line with a labour productivity measure. It should be noted however, that Network Rail would need to have capital expenditure (likely to be on IT) to support this labour productivity growth, therefore caution would be needed in order to allow Network Rail to undertake an appropriate level of capital expenditure to achieve the labour productivity gains.

Productivity is a highly cyclical variable, which shows marked variation over the economic cycle as well as differences across economic cycles. It is standard practice to consider TFP growth over complete economic cycles. The most recent business cycle according to research done by H.M. Treasury was during the period 1997-2006 and we have used this for the purpose of our analysis. This cycle is beneficial to our analysis in that it is also the first full business cycle since privatisation in the electricity, gas and water supply sector, which are sectors used in the composite index.

Table E2 sets out our estimates, based on gross output TFP estimates, for Network Rail's scope for opex efficiency savings over CP5 from frontier shift only. Our estimates are based on the composite gross output TFP estimates over 1997-2006 (1.3% per annum) using a 0.50 (in the low case) adjustment for catch-up (0.75 in the high case). The 0.50 adjustment is based on the lower end of other industries regulators' decisions in relation to frontier shift, and the 0.75 assumption is taken from Oxera (2008).

Table E2: Initial estimates for ongoing (frontier shift), based on gross output TFP

Operation and support expenditure	CP5 average annual efficiency target – Frontier shift only	Total CP5 efficiency target - frontier shift only (CAGR)
Low case	0.7% (per annum)	3.8%
High case	1.0% (per annum)	5.6%

Note: TFP estimates are gross, i.e. ***not*** *net of economy TFP*

Labour, Energy, Materials and Services (LEMS) cost measure

There is an alternative methodology to the RUOE and TFP efficiency estimates, which is based on an analysis of labour (L), energy (E), materials (M) and services (S) – (LEMS). The LEMS cost measure is a unit cost measure which is comparable to the RUOE results, and covers both catch-up and frontier efficiency. It uses costs which are broadly consistent with operating and support costs, and combines them with output to derive a unit cost measure over time. The unit cost measure will therefore reflect productivity improvements and input price inflation (wages and intermediate input prices) in the sectors.

We construct, in the same way as our TFP estimate, a composite LEMS cost measure as a comparator for Network Rail.

As with the TFP measure we consider that the time period of 1997-2006 is the most appropriate for the comparison of Network Rail's possible scope for efficiency gains against the sectors in our composite benchmark. In addition we also consider that focusing on electricity, gas and water supply LEMS cost measure growth may be more appropriate to estimate Network Rail's scope for opex efficiency improvements over CP5. This is because it:

- is more comparable with the RUOE averages for these industries; and
- reflects the catch-up and frontier shift of other network industries subject to comparative benchmarking. Although there are companies within this sector that are not subject to price controls, it could be argued, based on the long-run estimates for these sectors and other sectors, that these companies experience lower LEMS cost measure growth.

Our estimates for Network Rail's scope for efficiency gains in relation to operations and support costs are shown in Table E3 below.

Table E3: Initial estimates for efficiency gains over CP5, based on LEMS cost measure

Operation and support expenditure	CP5 average annual efficiency target – catch-up and frontier shift	Total CP5 efficiency target - catch-up and frontier shift
Low case	1.8% (per annum)	9.3%
High case	5.1% (per annum)	28.2%

There is a substantial difference between the low case and the high case. We consider that this is mainly driven by the differences in catch-up efficiency. The low case includes industries which have been operating in a competitive market for a long time, while the high case contains a number of companies that were not operating in a competitive market and, since privatisation, are now subject to economic regulation.

Network Rail's possible scope for efficiency gains

We have been asked to provide an estimate for the overall scope for Network Rail's efficiency improvements over CP5 and have used a number of different approaches to develop the ranges included in this report. Potential overall efficiency gains (both catch-up and frontier shift) were assessed through the RUOE and LEMS cost measure, while the TFP measure provided an estimate of frontier shift alone

Table E4 below provides the average annual efficiency estimates for the three measures.

Table E4: Summary of estimates for efficiency gains over CP5, based on the different measures

Measure	CP5 average annual efficiency target range (per annum)
Frontier Shift and Catch-up	
RUOE (third price control)	2.1% - 6.5% (4.4% average)
RUOE (11-15 years since privatisation)	2.1% - 6.7% (5.1% average)
LEMS cost measure	1.8% - 5.1%
Frontier Shift only	
TFP	0.7% - 1.0%

The actual target that ORR might set for Network Rail over CP5 depends on its performance relative to best practice at the end of CP4. Actual performance is not yet known although we understand that Network Rail is somewhat behind target currently. We note however that a number of projects which deliver efficiency savings in operations and support are back end loaded e.g. the move of administrative functions from London to Milton Keynes.

If Network Rail is able to deliver against its targets then average annual growth based on that reported for RUOE, of 4.4% (for comparator industries in their third price control), and the LEMS cost measure for electricity, gas and water supply (11-15 years since privatisation), of 5.1%, respectively might represent an appropriate annual target for CP5. Savings of this order would be consistent with broader studies of Network Rail's relative efficiency e.g. the benchmarking work undertaken as part of the recent Rail Review, which suggests that Network Rail's costs are significantly higher in a range of activities than those of its international peers.

Adjustment would of course need to be made to these figures if Network Rail either under or outperforms its targets. The ranges provided in this report will help ORR to assess the appropriate annual percentages to apply in these circumstances.

1. INTRODUCTION

1.1. Aim of study

This report has been prepared by Cambridge Economic Policy Associates (CEPA) for ORR to provide estimates of productivity and unit cost change in relation to Network Rail's support and operations expenditure. These estimates are designed to help ORR set Network Rail's scope for efficiency improvement over Control Period 5 ('CP5', April 2014 – March 2019).

This study focuses on top-down estimates of productivity performance with the estimates produced being indirect measures of productivity performance (using comparators from other industries as benchmarks). Whilst it would be preferable to look at direct evidence of Network Rail's performance relative to a benchmark, as Network Rail is the only rail infrastructure operator of its type in the UK there are no direct comparators. The choice of productivity measures is based on studies that ORR previously commissioned namely: Oxera/ LEK (2005), Oxera (2008), and Reckon (2011).

As with other areas of expenditure, the scope for unit cost reductions in respect of expenditure on support and operations is made up of three elements: 'catch-up', 'frontier shift' and an 'input price inflation differential'. This report deals with the first two elements, namely catch-up and frontier shift. Catch-up is defined as efficiency improvements which are made by adopting *current* technology or working practices, thus it relates to the extent to which firms should be able to catch-up against current best practice. Frontier shift represents the movement over time that is achieved by the firms that are at the frontier of performance. For example, a frontier shift efficiency in UK Rail could be the development of a new form of train engine technology which was more efficient than the current technology, whereas catch-up efficiency would involve ensuring that all current trains had the most efficient engines based on currently available technology. It is a concept used by private companies, consultancy firms and regulators to help understand and compare businesses' performance.[1]

For CP4 (April 2009 – March 2014), ORR set Network Rail's annual catch-up efficiency for controllable operating expenditure (opex) at 4.9%. ORR identified in its draft determination that Network Rail's scope for efficiency improvement (the gap between its performance and that of a best performing company) in controllable opex to be 35 percent. ORR estimated that two-thirds of the gap could be closed by the end of CP4, with the remainder of the gap being closed by the end of CP5. ORR's estimates drew on a report commissioned by ORR from Oxera in 2008, and by an LECG report for Network Rail in 2008.

ORR determined that the frontier shift element of Network Rail's scope for efficiency improvement in controllable expenditure was 0.2 per cent per annum (net of economy wide total factor productivity growth).

1.2. Approach

This study is intended to review and update, where necessary, the assumptions and methodology used to calculate these three productivity measures.

[1] The differences between these different elements are discussed further in Annex A

In particular ORR has asked CEPA to estimate the following metrics:

- Real Unit Operating Expenditure (RUOE);
- Total Factor Productivity (TFP); and
- Labour, Energy, Materials and Services cost measure (LEMS);

with a view to providing an initial estimate for the scope for Network Rail's efficiency gains in relation to support and operations over the course of CP5.

The methodology used to calculate productivity changes under each of these measures is discussed in the following sections of this report. We note that these measures are likely to contain both frontier shift and catch-up. However, as our TFP measure contains companies which are in competitive markets, and therefore more likely to be efficient than those included in our RUOE measure, we have separated out catch-up from the TFP estimates (this is discussed in detail in Section 3.4).

This study makes some use of existing data and datasets developed by Oxera – shared with CEPA and ORR for the purposes of this study. While we received some data directly from Network Rail, they were not actively engaged throughout the project, but the results were presented to them for discussion prior to publication. We understand that this report is intended to complement other efficiency work and analysis that ORR is undertaking.

Given the technological differences, and scope for frontier shift, between the comparator industries there are likely to be wide ranges in the productivity estimates. We have produced the estimates as request by ORR, however we have not assessed, and cannot assess all the relevant differences between the industries. Therefore, the estimates provided should be used in conjunction with other studies produced for ORR and an actual efficiency target will depend on ORR's judgement.

1.3. Previous studies

The collective aim of previous relevant studies was to analyse the performance of industries comparable to Network Rail, and in doing so, produce indirect benchmarks (or targets) for Network Rail's future efficiency performance.

There are three studies of particular relevance to this project. All three were commissioned by ORR:

1. LEK/Oxera (2005): Assessing Network Rail's scope for efficiency gains over CP4 and beyond: a preliminary study;
2. Oxera (2008): Network Rail's scope for efficiency gains in CP4; and
3. Reckon (2011): Productivity and unit cost change in UK regulated network industries and other UK sectors: initial analysis for Network Rail's periodic review.

We have used each of these reports as an input into our thinking. We consider below both the analysis undertaken in them and how the methodology has evolved over time.

1.3.1. LEK/Oxera (2005)

This study sought to determine a range for the scope for efficiency improvements in Network Rail's controllable operating, maintenance and renewals (OM&R) expenditure.[2]

The analysis focused first on RUOE trends, which indicate how unit costs change over time with changes in output. LEK/Oxera undertook RUOE calculations for US Rail and several other UK network industries, and considered the comparability of these figures with Network Rail. In particular, they hypothesised that the high capex costs resulting from the Hatfield disaster (2000) would have effectively "reset" the industry, so that CP4 is most comparable with other industries' *second* price control period. LEK/Oxera also adjusted their RUOE results to net-off productivity gains due to economies of scale.

Secondly, LEK/Oxera considered productivity improvement estimates for similar regulated industries in the UK using TFP to provide an alternative benchmark for Network Rail's efficiency gains. This required two important assumptions: (i) an adjustment to TFP for capital substitution to reflect the labour productivity growth associated with opex costs (given that opex is largely labour); and (ii) the removal of any "catch-up" elements, so as to leave a purely "frontier shift" estimate. LEK/ Oxera provided two estimates for the proportion of the change in TFP that could be attributed to frontier shift only, 50% and 75%. As TFP was used as a benchmark for operations and support costs, Oxera made a positive adjustment for capital substitution of 0.5 per cent to better reflect the labour productivity improvements for these activities as they predominantly comprise labour costs.

Based on their analysis, they proposed that "a plausible range of potential efficiency gains in CP4 is between 2% and 8% p.a.".[3]

1.3.2. Oxera (2008)

The aim of this study was to "update the analysis presented in the LEK/Oxera (2005) report", taking account of more recent data, and again aiming to provide estimates for Network Rail OM&R efficiency in CP4.

As would be expected, Oxera (2008) followed a similar methodology to LEK/Oxera (2005). The RUOE analysis covered similar comparator industries, and was adjusted for economies of scale using the same values as the 2005 report. Based on a comparison with other industries *second* price control (i.e. taking into account the 'reset' hypothesis resulting from the Hatfield disaster), Oxera estimated an annual cost reduction range of 5-7% per annum, including both catch-up and frontier shift.

Oxera used the EU KLEMS database, 1970-2005,[4] to provide TFP estimates for sectors of the UK economy. They created a composite TFP benchmark for Network Rail by assigning relevant comparator industries to different activities within Network Rail, and then weighting these activities based on Network Rail's profile of expenditure. The intended effect was to create an estimate of what might be expected from a company carrying out similar activities to Network Rail, but in a competitive environment. Oxera estimated ongoing operating and support

[2] Although OM&R excludes capex, it is a broader measure than simply just 'operations and support costs'.
[3] LEK/Oxera (2005), p46.
[4] http://www.euklems.net/

expenditure productivity gains at 1%, but estimated that 75% of this could be attributed to frontier shift. Oxera's estimate included a 0.5 percent adjustment for capital substitution.

Based on their analysis, they proposed an efficiency target for Network Rail of up to 7%, and stated that the position within this range would depend on Network Rail's current level of efficiency. They concluded by suggesting that "there is still a significant gap to best practice", indicating that Network Rail's scope for improvement was likely to fall in the upper half of the range.

1.3.3. Reckon (2011)

Reckon was commissioned by ORR to carry out an update of the analysis that was used to inform its CP4 decision on the opex efficiency elements of frontier shift and catch-up.

Reckon's RUOE analysis was very similar to Oxera's (2008): It analysed similar industries (plus Network Rail, and minus BT); and used the same economies of scale assumptions in almost every case. Reckon presented their results as a weighted average between Oxera's (2008) results, and their estimates for more recent data, 2008 - 2010. However, they also produced RUOE results using alternative output measures and showed that the results are sensitive to the output measure chosen. Reckon were not asked, and did not provide, an estimate for Network Rail's scope for opex cost efficiency improvement.

Reckon's TFP analysis was again similar to Oxera's, both in terms of the comparator sectors and weightings used. Reckon used the more recent release of the EU KLEMS dataset which covers the period 1970-2007. Reckon queried the robustness of Oxera's 0.5 capital substitution figure, and the appropriateness of using a TFP measure at all if a capital substitution adjustment is required. Reckon posited that if a capital substitution adjustment was required then a labour productivity measure may have been a more appropriate measure for operations and support costs rather than TFP.

Reckon also indicated a preference for using a gross output based TFP measure rather than one based on value-added, as used by Oxera (2008).[5] Reckon updated the composite benchmark using value-added TFP for comparability with Oxera (2008), but provided sector estimates using gross output TFP.

In addition to the RUOE and TFP measures, Reckon used the EU KLEMS dataset to produce a cost measure and productivity measure which excludes capital. This was done by isolating the increase in productivity for labour and intermediate inputs (LEMS). Reckon considered that this measure is more comparable to the RUOE measure than TFP. Their analysis covers 30 sectors across the UK economy.

Reckon did not provide a final range for Network Rail's target efficiency for OM&R. However, they did make several qualifications to Oxera's results: (i) the large efficiencies calculated from Oxera's (2008) RUOE analysis was not repeated over the 2006/7 to 2010/11 years; and (ii) that this may be due to companies experiencing high productivity gains following privatisation, or

[5] Reckon (2011), page 93, state "We see no reason to use a measure of output that is based on the value-added concept."

because they substituted operating expenditure for capital expenditure (capital substitution) in response to price control incentives.

1.4. Structure of report

The paper is structured as follows:

- Section 2 provides CEPA's methodology for estimating RUOE, the results for comparator industries and our estimate for Network Rail.
- Section 3 provides CEPA's methodology for estimating TFP, the formation of the composite benchmark and our estimates including sensitivity analysis.
- Section 4 provides CEPA's methodology for estimating the LEMS cost measure, the formation of the composite benchmark and our estimates including sensitivity analysis.
- Section 5 sets out CEPA's conclusions and estimating for Network Rail's scope for operation and support expenditure efficiency improvements over CP5.

Appendix 1 provides TFP estimates for maintenance and renewal expenditure. Annex A provides a discussion on the differences between frontier shift and catch-up efficiency. Annex B sets out our RUOE measures for each of the comparator industries. Annex C provides the ranges for RUOE using controllable opex only. Annex D provides a discussion on some methodological issues and approaches taken in previous studies. Annex E describes the difference between gross output and value-added TFP measures. Annex F provides a table setting out our capital substitution adjustment estimates and Annex G provides the mathematical formulation of the LEMS cost measure.

2. Real Unit Operating Expenditure

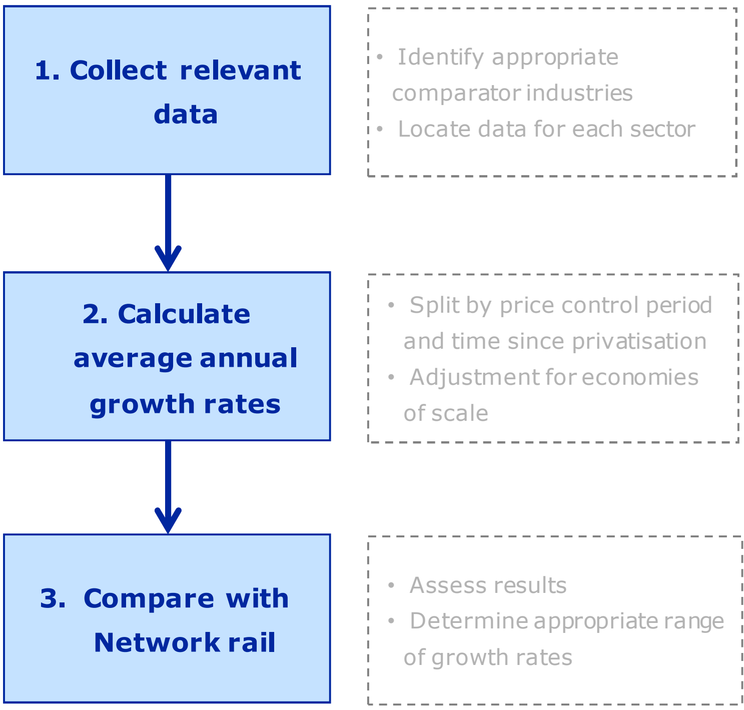
2.1. Introduction

RUOE is a partial productivity measure, i.e. not taking into account all inputs, which is commonly used by regulators to assess efficiency changes. To obtain this measure, nominal operating expenditure is deflated to its real value and then divided by an appropriate measure of output. These outputs are sometimes referred to as 'cost drivers' since they represent activities through which the business provides its services and costs are typically incurred, such as laying track for railways or connecting customers to the network for telecommunications. Examples of cost drivers that are typically used to analyse gas distribution include: network length, throughput, capacity and customer numbers. Because the operating expenditure is deflated to its real value (relative to RPI), the RUOE results reflect both productivity improvements and input price inflation (relative to RPI). We use RUOE analysis to estimate the trend in unit cost reductions across regulated, network utilities in the UK and compare this to the same trend observed in Network Rail's results. RUOE unit cost trends include both frontier and catch-up efficiency.

2.2. Methodology

Our methodology for estimating RUOE cost measures to assess Network Rail's scope for efficiency improvements on expenditure on operations and support activities during CP5 is summarised in Figure 2.1 below.

Figure 2.1: Summary of methodology for RUOE measures



2.2.1. Comparators

There are a number of regulated network industries in Great Britain for which trend growth in RUOE can be calculated. However, to use this measure effectively the industries, and the associated operators, chosen should:

- conduct similar operations and support activities to those in the industry to which they are being compared, in this case Network Rail; and
- be subjected to economic regulation, which imposes efficiency incentives.

The selected comparators are all UK based and as such subject to common tax and accounting rules and legal framework.

Oxera (2008) choose five industries to calculate RUOE growth estimates for:

- water and sewerage (in England & Wales and Scottish Water);
- electricity transmission;
- electricity distribution;
- telecommunications; and
- gas distribution.[6]

Oxera pointed out that they examined the airport industry but concluded that their results were not sufficiently robust due to uncertainty in relation to BAA's costs. Reckon (2011) updated Oxera's analysis for all the industries listed above with the exception of telecommunications. Reckon reached an agreement with ORR to exclude BT from the analysis on the basis that the output measures used – call minutes and exchange lines – were no longer appropriate given the range of services that BT now offers. Reckon appear to conclude that given the changes in BT's business over time and competition in different parts of the value chain, estimating RUOE for BT would be inappropriate.

We have agreed with ORR to analyse the same industries as Reckon (i.e. excluding telecommunications) but with the addition of gas transmission. This provides a sample of 46 companies in total. We have undertaken research into a suitable driver for BT, but given the changing nature of BT's business we have not identified a consistent and robust output measure. In addition, the scope for technical change appears to be substantially greater in this sector than in the other network industries, although this may be more limited in relation to operations and support. The industries used as comparators by Oxera (2008), Reckon (2011) and this study is provided in Table 2.1.

Table 2.1: RUOE comparators used in ORR studies

Industries	Number of companies in 2011	Oxera (2008)	Reckon (2011)	CEPA
Electricity distribution	14 operators	✓	✓	✓
Electricity Transmission	1 operator	✓	✓	✓

[6] Oxera (2008), p 40.

Industries	Number of companies in 2011	Oxera (2008)	Reckon (2011)	CEPA
(England and Wales)				
Gas distribution	8 operators	✓	✓	✓
Gas Transmission	1 operators	×	×	✓
Water and sewerage (England and Wales)	21 water operators. 10 sewerage operators	✓	✓	✓
Water and Sewerage (Scotland)	1 water and sewerage operator	✓	✓	✓
Telecommunications	1 operator	✓	×	×

While there are obvious differences in the physical characteristics of each of the industries, we consider that the comparators selected provide a reasonable indicator of the potential for Network Rail to make cost reductions.

2.2.2. Data

There is significant variance in the reporting requirements for operating expenditure across the industries, and in fact over time within the industries. This makes it difficult to source consistent data over a long-time period. Although we tried to estimate RUOE using similar expenditure categories to Network Rail's operations and support, we have only been able to gather data at this level of granularity for the water and sewerage industries. For all other industries we have used total controllable operating expenditure, which includes maintenance expenditure. The operating expenditure level we have been able to gather for each of the industries is set out in Table 2.2. We note that Oxera (2008) and Reckon (2011) used total controllable opex for all industries. There are also differences between some our controllable opex measures and those used by Oxera (2008), for example we have removed doubtful debts from the water and sewerage opex as we consider that this is in line with Reckon (2011). A discussion of our data sources for each of the industries, and where they differ to previous studies, is set out in Annex B.

We have only presented RUOE estimates using our preferred output measure for each industry; however, we note that for some industries multiple output measures were available. We consider that the output measures chosen are the most appropriate available cost drivers for operations and support costs for each of the industries. For most of the industries we have used the same output measures as Oxera (2008) for total controllable opex; however, for some industries we have preferred alternative measures, for example, customer numbers were used for electricity distribution[7] and we adopted the Reckon (2011) approach for England and Wales water and sewerage total controllable opex – weighting together the RUOE for 'indirect operating costs' and 'direct operating costs'.[8] Annex B provides our estimates for each industry where alternative output measures were available. Our preferred output measures are set out in Table 2.2 below.

[7] Farsi et al (2010) state that customer numbers "is an adequate measure of the main activities of the [electricity] distributor company, which in contrast with the delivered electricity", p 7.

[8] Reckon (2011), p 60.

Table 2.2: RUOE operating expenditure and output measure[9]

Industries	Operating expenditure	Output measure
Electricity distribution	Total controllable opex	Customer numbers
Electricity Transmission (England and Wales)	Total controllable opex	Electricity demand (MWh)
Gas distribution	Total controllable opex	Customer numbers
Gas Transmission	Total controllable opex	Annual demand (throughput)
Water (England and Wales)	General & support expenditure, and business activities.	Properties billed
	Total controllable opex	Water delivered / Properties billed
Sewerage (England and Wales)	General & support expenditure, and business activities.	Properties billed
	Total controllable opex	Population connected/ properties billed
Water (Scotland)	General & support expenditure, and business activities.	Properties billed
	Total controllable opex	Water delivered (MI/d)
Sewerage (Scotland)	General & support expenditure, and business activities.	Properties billed
	Total controllable opex	Population connected

2.2.3. Economies of scale adjustment

RUOE economies of scale calculation

A standard unit cost measure, shown in Equation 2.1 below, makes no adjustment for economies of scale.

$$\Delta RUOE_t = \left(\frac{ROE_t}{O_t} \div \frac{ROE_{t-1}}{O_{t-1}}\right) - 1 \quad (2.1)$$

Where ROE is real operating expenditure (i.e. expenditure adjusted for the impacts of RPI), O is the output measure.

However, our comparator industries contain natural monopolies which exhibit the characteristics of economies of scale. The existence of economies of scale in our output measure would mean that the calculation of unit costs would be affected by the extent to which the volume of output would change over time.[10] The greater the economies of scale experienced by a company/ industry the lower the marginal cost of producing the next unit of output, which means that average costs fall as output increases.

[9] Oxera (2008) output drivers, where they differ to those listed in Table 2.2: electricity distribution – total units distributed (electricity demand); gas distribution – annual demand forecast (throughput); England and Wales, and Scotland water – water delivered; England and Wales, and Scotland sewerage – population connected.

[10] Reckon (2011), p 57.

We have followed Oxera (2008) and have adjusted all our industry RUOE estimates for the impact of economies of scale. We adjust for the effects of economies of scale using Equation 2.2 set out below:

$$(2.2) \qquad Corrected\ RUOE_t = ROE_t \times \frac{(1 + \Delta O_{t,t+1} \times \varepsilon)}{O_{t+1}}$$

Where ε is the cost elasticity for the industry for which we are calculating the changes in RUOE. Combining Equations 1 and 2, we obtain the following equation which produces estimates of growth in RUOE taking account of economies of scale:

$$(2.3) \qquad \Delta RUOE_{t,t+1} = \left(\frac{ROE_{t+1}}{O_{t+1}} \div Corrected\ RUOE_t\right) - 1$$

Cost elasticity estimates

The cost elasticities used by Oxera (2008) are set out in Table 2.3 below. Oxera (2008) used the same elasticity estimates as LEK/ Oxera (2005). Reckon (2011) do not attempt to update the cost elasticity estimates and also use Oxera (2008) estimates.

Table 2.3 - Industry cost elasticities used in LEK/Oxera (2005), Oxera (2008) and Reckon (2011)

Sector	Cost elasticity	Original source
Electricity distribution	0.72	Burns and Weyman-Jones (1994)
Electricity transmission	0.72	As for distribution
Gas distribution	0.9	Oxera assumption: TFP elasticity figure
Water / Sewerage	0.96	Competition Commission (2000)

We have undertaken a review of the literature with a view of updating the LEK/ Oxera (2005) cost elasticities. The availability of academic papers and reports on economies of scale varies by industry type. Below we report on the most relevant papers we were able to source for each of the industries.

For electricity distribution, Olmez (2008) estimated that economies of scale existed if the 14 UK distribution network operator *licences* were modelled. However, the author finds that if the licences are grouped by ownership then the existence of constant returns to scale could not be rejected. Based on the scale estimates presented in the study we estimate the cost elasticity to be 0.66. Farsi et al (2010), estimated that medium to large French electricity distribution networks exhibited economies of scale, while their findings were less conclusive on smaller networks. Both Omlez and Farsi used a number of output variables to establish the scale economies, namely customer numbers, units distributed and network length. We estimate, based on the figures presented in their papers, a cost elasticity in the range of 0.78 to 0.88.

Given that the Burns and Weyman-Jones (1994) estimate used by Oxera (2008) is around the mid-point of our estimates based on the Olmez and Farsi et al papers, and as there is no strong evidence to choose one estimate over the other, we consider that it is appropriate to continue with the cost elasticity adjustment based on our calculations of 0.72 for electricity distribution. We were unable to find any additional reliable evidence for electricity transmission, therefore we also use the same value (0.72) for the economies of scale adjustment for electricity transmission.

In Annex B we provide sensitivities using both the 0.66 and 0.88 scale elasticities, these illustrate a small impact from varying this assumption.

LEK/Oxera (2005) and Oxera (2008) do not identify a specific cost elasticity adjustment for gas distribution, or document their adjustment for economies of scale. Reckon (2011) conclude that the adjustment used in Oxera (2008) was based on a cost elasticity of 0.9 and we assume this is based on the 0.9 adjustment used for an economy–wide adjustment for economies of scale in the TFP analysis. LEK/ Oxera (2005) noted the source for this is "based on a conservative assumption of economies of scale of 0.9 for all sectors used by other consultants and academics."[11] Further evidence for the existence of economies of scale in the gas distribution industry is given in Pollitt (2011), in which the author notes that Ofgem's proposal for the unbundling of National Grid Transco in 2004 was met with some criticism and a report provided by Oxera at the time cited concern that economies of scale would be lost through the demerger.[12] However, while these studies point to the existence of economies of scale in the gas distribution industry, no estimates are provided. As such we consider a conservative adjustment of 0.9 to be appropriate.

More evidence on economies of scale exists for the water and sewerage industries; however, it contains mixed results, with some studies indicating the potential for diseconomies of scale while other ones pointing to economies of scale. Saal et al (2011) focuses on water only companies and finds that the average sample firm is subject to diseconomies of scale. However, it concludes that vertically integrated firms gain significant benefits from economies of scope and scale. Saal and Parker (2005) estimate economies of scale for water and sewerage companies and water only companies during the years soon after privatisation; however, these economies of scale appear to reduce over time.[13] The LEK/ Oxera (2005) cost elasticity assumption for water and sewerage of 0.96 is taken from a Competition Commission (2000) model of the overall water service.[14] It should be noted though that the cost elasticity coefficient (0.96) is not significantly (statistically) different from unity, suggesting that we cannot reject the null hypothesis of constant returns to scale based on that study. While the evidence is mixed for economies of scale in the water industries we maintain Oxera's (2008) 0.96 adjustment and provide sensitivity analysis of varying this assumption in Annex B. The sensitivity analysis indicates that varying the cost elasticity assumption between 0.9 and one (constant returns to scale) has a minimal impact on the results.

It is worth noting that we are referring to economies of scale as increasing output and, at the same time, varying the size of the network. An alternative to this is economies of density, which considers adding more customers or KWh to an existing network (in the case of electricity). In the former case it might be considered that there are more limited returns (to scale). However, in the later case the economies (of density) will likely be greater.[15] There may be an argument to use economies of density adjustments, particularly given the output measures for each industry.

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[11] LEK/ Oxera (2005), 26.

[12] Pollitt (2011), p 19.

[13] Saal and Parker (2005), Table 4: Returns to Scale for the Average Firm by Year, p 33.

[14] Competition Commission (2000), *Mid Kent Water plc: A Report on the References under Section 12 and 14 of the Water Industry Act 1991*¸ P 267.

[15] Farsi (2010) estimate economies of density and found them to be much greater than their economies of scale estimates, for large networks the authors estimate economies of scale to be 1.21 (>1 indicating economies of scale) and economies of density at 1.41 (>1 indicating economies of density).

However, we are not sure on the basis of which some of the earlier cost elasticities were calculated (we have not been able to access Burns and Weyman-Jones, 1994, for example[16]). We consider that further work in this area would be valuable, but would require a considered review of the literature across a range of industries which is beyond the scope of this project.

Given the above discussion, it is further important to note that the elasticity of opex with respect to train-km is likely to be close to zero for Network Rail, so that its unit costs should fall as train-km rise even if the company makes no improvements in its efficiency performance. An elasticity of zero for operating costs is assumed within the variable usage charge calculation for Network Rail[17]. This suggests that its efficiency target should be set higher for Network Rail if elasticities for comparators are close to one. Even if economies of density are more prevalent in the comparator sectors, implying elasticities further away from unity, they are unlikely to be close to zero as for Network Rail operating costs.

The cost elasticities that we have used for each of our comparator industries are set out in Table 2.4. As discussed above, the cost elasticity estimates are based on economies of scale, rather than economies of density (although while we understand this to be the case for the electricity cost elasticity we have been unable to confirm this).

Table 2.4 - RUOE cost elasticities

Sector	Cost elasticity
Electricity distribution	0.72
Electricity transmission	0.72
Gas distribution	0.90
Gas transmission	0.90
Water / Sewerage	0.96

2.2.4. Time periods

In order to estimate the scope for Network Rail's efficiency improvements in operation and support expenditure over CP5 we need to determine appropriate time periods over which to calculate RUOE trends.

We consider, in line with Oxera (2008), that as our comparators are subject to economic regulation in the form of periodic price control, taking trends across the price controls for the different industries is an appropriate way of determining ranges for average annual changes in RUOE. The selection of an appropriate comparative time period is particularly important as the scope for efficiency gains are dependent on the initial level of efficiency of the companies within

[16] A later paper, Burns and Weyman-Jones (1996) estimated strong economies of scale, but does not appear to report a specific value. It does appear to be measure the cost elasticity, however, given the range of regressors included in the model. It is not totally clear whether the cost variable includes capital costs or not.

[17] Econometric work carried out by Emile Quinet using data for the French network, indicated a cost variability of approximately 10-15% of operating costs (or a proxy for costs) with respect to traffic; see Catrin Project Deliverable D8 – Rail Cost Allocation for Europe, Annex 1Diii – Analysis of operation costs in France. However, the author notes some issues, including the mis-specification of some of the variables, that mean that the results are indicative only..

an industry (i.e. the scope for catch-up). By using price control time periods we take into account the elapsed time since privatisation, albeit on a slightly inconsistent basis as price control length have varied over time and between industries, and the efficiency incentives applied by regulators in each price control. We have also provided RUOE estimates on the basis of years since privatisation

Once we have estimated the comparator industries' RUOE trends over each of their price controls we need to determine against which of these Network Rail's scope for efficiency gains in CP5 should be assessed. As noted in Oxera (2008), Network Rail experienced a sharp increase in its operating costs after the Hatfield derailment (2000) and during the period of administration (2002).[18] The Hatfield accident impacted on operating costs (which includes HR, safety and compliance, insurance and asset management), as well as the more obvious impact on maintenance and renewal costs. Oxera considered that the impact of these events effectively 'reset' Network Rail to the pre-privatisation level of efficiency. Oxera concluded for CP4 that information on RUOE trends 6-10 years after privatisation (the equivalent to Network Rail's being in its second price control period) may provide a more accurate indication of Network Rail's potential efficiency gains than the other time periods.[19]

We consider that Oxera's 'reset hypothesis' is an appropriate assumption to make and note that this proposition was accepted by ORR in setting efficiency targets in the last price control. Therefore, we consider that an RUOE trend estimate covering the period 11-15 years post-privatisation is appropriate for assessing Network Rail's scope for efficiency gains over CP5. Table 2.5 provides a summary of the years since privatisation, year of first price control and current price control.

Table 2.5: RUOE comparators

Industries	**Year of privatisation**	**Price control (as at March 2011)**
Electricity distribution	1990/91	Fifth
Electricity Transmission (England and Wales)	1990/91	Fifth
Gas distribution	2005/06 (since split of NGT)	First
Gas Transmission	1990/91	Fifth
Water and sewerage (England and Wales)	1990/91	Fifth
Water and Sewerage (Scotland)*	2002/03 (not privatised, year of first price control)	Second

2.3. Results

Table 2.6 below provides the results for each of the comparator industries across the full time period for which data is available for each of the industries. Unless otherwise stated all average growth rate are compound average annual growth rates. A positive number reflects a decrease in

[18] Oxera (2008), p 17.
[19] Ibid.

unit expenditure relative to RPI, while a negative number reflects an increase in unit expenditure relative to the RPI.

Table 2.6: RUOE results over entire period, (average % change per annum)

Comparator	**Period**	**General and support RUOE**	**Controllable opex**
Electricity distribution	1992/3-2009/10		3.0
Electricity Transmission (England and Wales)	1992/3-2010/11		5.6
Gas distribution	2006/07-2009/10		2.1
Gas Transmission	2002/03-2009/10		2.9
Water – England and Wales	1992/3-2009/11	2.2	1.1
Water – Scotland	2002/03-2009/11	3.6	2.1
Sewerage – England and Wales		1.0	0.3
Sewerage – Scotland	2002/03-2009/10	6.5	5.3
Range		1.0 to 6.5	0.3 to 5.6

Our estimates differ from Oxera (2008) for a number of reasons. We have set these out in detail in Annex B and provided a comparison with Reckon (2011) results, however key differences include:

- the exclusion of doubtful debts in the opex of the water and sewerage industries;
- the use of different output measures for a number of the industries;
- increased/ updated number of observations (i.e. annual movements), which impacts on all price control periods; and
- use of actual gas distribution outturn opex and demand.

For the rest of this section we only include the ranges calculated for the water and sewerage industries based on general and support expenditure. Annex C provides range estimates using controllable opex only.

As discussed in the preceding section, we have averaged annual changes in RUOE across price controls for each of the comparator industries. Table 2.7 below provides a summary of the range of RUOE across the industries by price control.

Table 2.7: RUOE by control period, (average % change per annum)[20]

Control period	**Range**	**Average**
First	-4.6 to 12.0	3.5
Second	-0.9 to 13.2	4.4

[20] Please note that we only have a limited number of annual data points available for the Fifth price control for a number of industries, namely electricity distribution, water and sewerage. This may distort the estimates for this time period, particularly as the regulators for these industries have required the companies to achieve all estimated catch-up efficiency over the price control.

Third	**-0.1 to 6.5**	**3.3**
Fourth	-0.7 to 4.2	2.2
Fifth	-1.1 to 4.7	2.7

Based on the reset hypothesis, we consider that the third price control period (in bold) may provide the most accurate indication of the scope for Network Rail's efficiency gains over CP5. We can see from the table that during the third price control comparator industries' RUOE changes have ranged from an annual average of -0.1% (an increase in unit costs) to an annual average of 6.5%. In other words, one industry experienced reductions in its unit costs of 6.5% on average for each year of its third price control.[21] The average annual change across all the industries during the third price control is 3.3%. England and Wales sewerage RUOE estimate over the third price control is -0.1%, this result appears to be an outlier and we note that the result is being driven by a small number of companies with increasing opex across one or two years of this period. If we exclude England and Wales sewerage from our estimates for the third price control the range for the third price control is 2.1% to 6.5% with an average of 4.4%.[22]

In addition to the bullet points above which summarised our key differences with Oxera (2008), the exclusion of BT from our analysis has also impacted on the third, fourth and fifth price control period ranges.[23] It has also led to the exclusion of a sixth price control period range. A further difference, is that only support and operations RUOE estimates for water and sewerage industries are included in the ranges. Oxera's estimates are provided in Table 2.8 below for comparative purposes.

Table 2.8: Oxera's RUOE estimates by control period, (average % change per annum)

Control period	Range	Average
First	-3.7 to 8.8	2.2
Second	4.5 to 12.8	6.8
Third	**-1.7 to 15.9**	**6.3**
Fourth	-4.9 to 14.7	3.4
Fifth	-6.6 to 11.6	2.6

In addition to calculating RUOE changes over price control periods we have also looked at annual averages based on the time elapsed since privatisation in each industry as the length of the price controls vary. Table 2.9 provides the estimates for RUOE by years since privatisation. The estimates for the 11-15 year period, -0.2% to 6.7% are very close to the annual average estimates for the third price control. This is not surprising given that a number of the comparator industries have five year price controls.

Table 2.9: RUOE by years since privatisation (average % change per annum)

Years since privatisation	Range	Average

[21] Not all comparator industries are considered to have experienced three price controls.

[22] The industries include in this time period are: electricity distribution, England and Wales water, and electricity transmission.

[23] Both estimates for 'BT, using call minutes' and 'BT, using exchange lines' were included. We understand that both these estimates for the third, fourth and fifth price control are at the upper end of Oxera's ranges.

1-5	-4.6 to 14.7	3.8
6-10	-0.4 to 6.7	2.9
11-15	**-0.2 to 6.7**	**3.7**
15+	-2.3 to 3.4	0.4

If we exclude England and Wales sewerage from our estimates for 11-15 years since privatisation the RUOE range is 2.1 to 6.7% with an average of 5.1%.[24] Oxera's estimates are provided in Table 2.10 below for comparative purposes.

Table 2.10: Oxera's RUOE estimates by years since privatisation, (average % change per annum)

Years since privatisation	Range	Average
1-5	0.6 to 8.6	4.3
6-10	4.5 to 6.3	5.2
11-15	**-1.7 to 14.7**	**5.2**
15+	-6.6 to 3.7	-1.5

2.3.1. Distribution of RUOE estimates

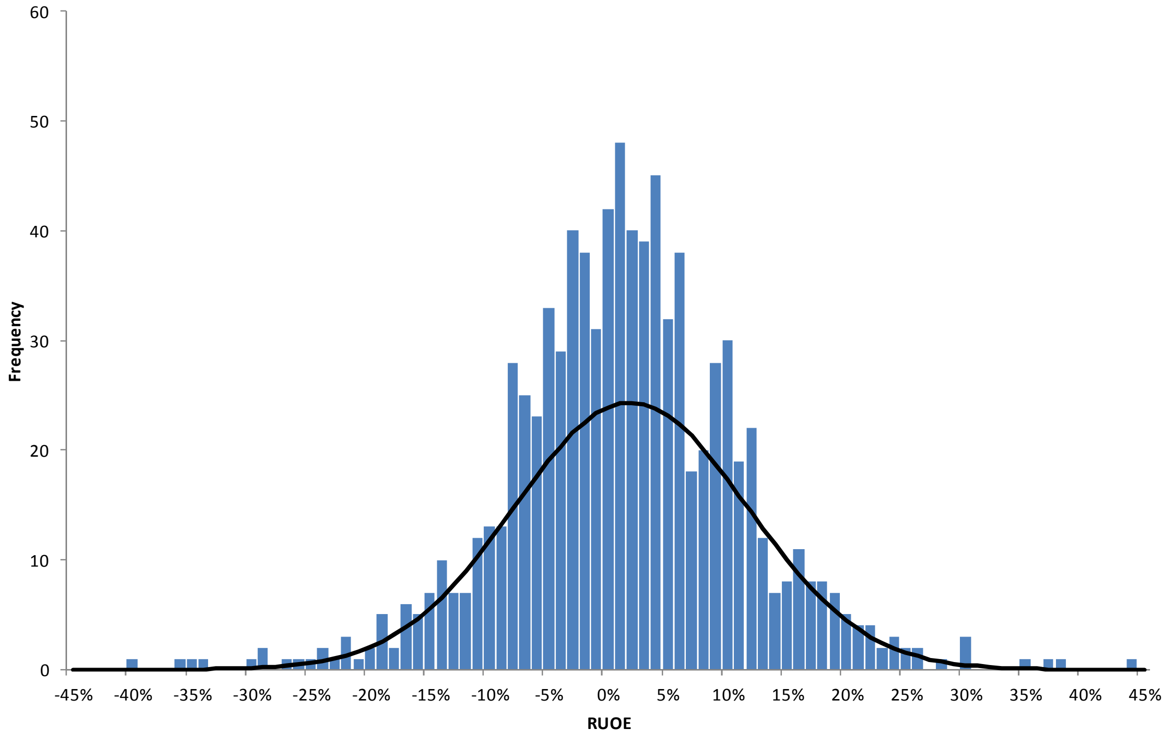
In keeping with the Oxera (2008) report we also produced distribution analysis for RUOE at the company and industry level. This distribution analysis provides a further way of analysing the RUOE results and illustrates the variance in annual RUOE change estimate.

Company level

Figure 2.2 below shows the company level distribution of year-on-year RUOE changes. The total number of observations included is 833. We have excluded some outliers, namely the 1999/2000 electricity distribution year (discussed in Annex B). Besides this there were a few other outliers that were removed.

24 The industries include in this time period are: electricity distribution, England and Wales water, and electricity transmission.

Figure 2.2: Company level distribution of annual RUOE *% changes*



The dashed line shows the median, other relevant statistics are set out in Table 2.11 below.

Table 2.11: Distribution of RUOE *results at the company level (% per annum) for the period 1992/3-2010/11*[25]

Mean	Median	25th percentile	75th percentile
1.8	1.9	-3.9	7.7

The median and mean are very similar indicating a relatively even spread of annual RUOE estimates. The inter-quartile range indicates that 50% of the observations fall within a range of -3.9% and 7.7% RUOE change per annum.

Industry level

The distribution of annual RUOE growth rates is shown in Figure 2.3 below. We can see that the spread of annual changes is reduced while there is still a relatively even distribution around the median.

[25] The distribution of RUOE results in table 2.11 is based on all sectors. For some sectors, data was available for the whole period (1992/3 - 2010/11), although for other sectors data was only available for a subset of these years. See table 2.6 above to see the years of data which were available for each industry.

Figure 2.3: Industry level distribution of annual RUOE *% changes*

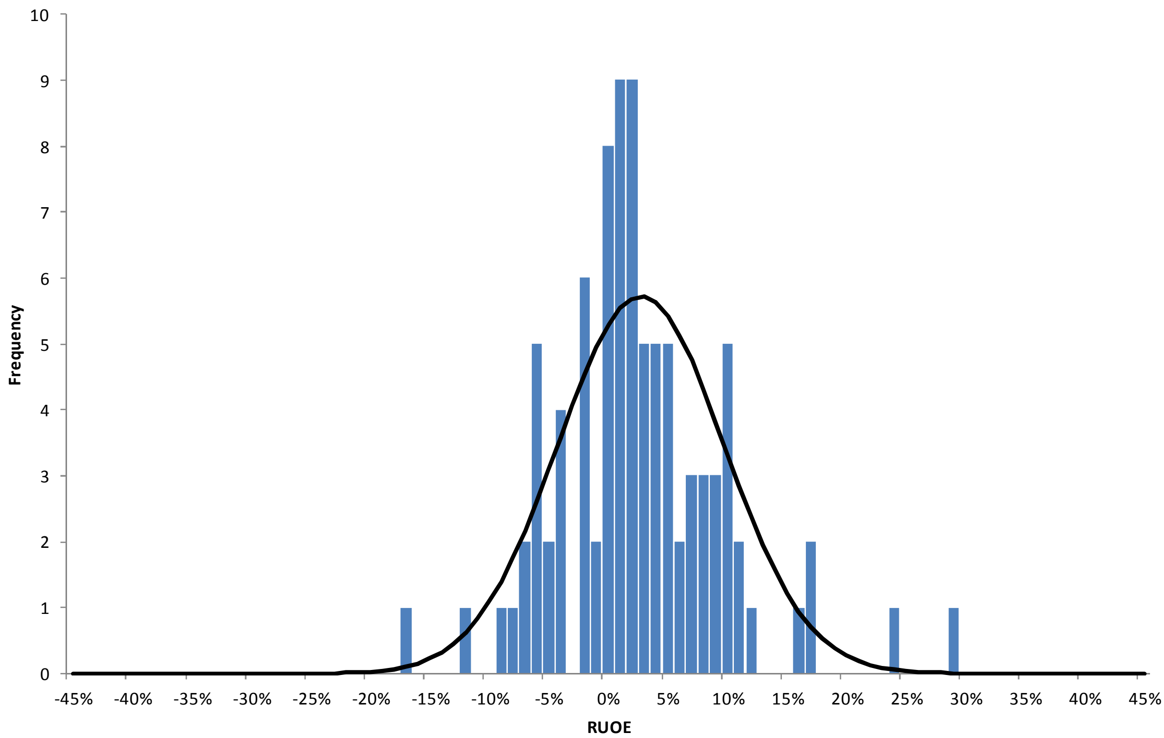


Table 2.12 indicates that the mean and median are again similar. The inter-quartile range, 0.7 to 6.2, is also significantly tighter than that observed at the company level.

Table 2.12: Distribution of RUOE *results at the industry level (% per annum)*

Mean	Median	25th percentile	75th percentile
2.6	3.1	-0.7	6.2

2.3.2. Economies of Scale

As stated earlier, we have made an economies of scale adjustment for each of the output measures used in our RUOE analysis by applying a cost elasticity figure to the RUOE calculation. We also undertook a sensitivity analysis by adjusting the cost elasticity, which enabled us to see the impact of the cost elasticity, and the robustness of the results. In Annex B we provide the results of this sensitivity analysis for each sector, and we find that the RUOE results for each industry are not overly sensitive to variations in the cost elasticity. There are some small changes produced in the results, but these variations are marginal.

One factor that this study does not address, and which would be interesting to investigate further, is the potential impact of economies of density. Economies of density exists when marginal costs fall as a result of using the existing scale of the network more intensely (or with a greater density). Whether these economies of density would have an impact on the RUOE results depends on whether changes in RUOE are mainly driven by changes in expenditure or outputs.

2.4. Conclusion

The scope for efficiency gains by any regulated company is dependent on its starting point, i.e. where it is in relation to the frontier in the first year of the period being considered. The RUOE results have been provided in a number of ways that enable identification of Network Rail's scope for efficiency gains in operations and support expenditure during CP5. Where possible we estimate comparator industries' annual RUOE on the basis of operations and support costs (or that industry's equivalents); however, the results provided in this section contain estimates based on total controllable operating expenditure as well. Table 2.13 below sets out the ranges we estimated based on the different time periods and the distribution analysis.

Table 2.13: RUOE results, (average % change per annum)[26]

	Range
Industry average (both total opex, and operations and support)	0.3 to 6.5
Reset Hypothesis	
By control period (third)	-0.1 to 6.5
By years since privatisation (11-15)	-0.2 to 6.7
Distribution	
At company level	-4.0 to 7.7
At industry level	-0.8 to 6.1

Table 2.13 shows that, excluding the company level distribution, our estimates range from -0.8 to 6.7%. This range will reflect the differing levels of technology growth across the difference industries (i.e. frontier shift) as well as the differencing levels of catch-up required by the individual companies within each industry. The ranges will also reflect any differences in efficiency changes between the industries where only controllable opex was available and those where operations and support opex was available, i.e. there may be differing scope for improvement across these cost areas. If England and Wales sewerage is excluded from our reset hypothesis ranges, then the banding is much smaller, 2.1% to 6.5% and 2.1% to 6.7% for the third price control period and 11-15 years since privatisation respectively. [27] The averages over these time periods are 4.4% and 5.1% respectively.[28] These are provided in Table 2.14 below.

Table 2.14: RUOE results excluding England and Wales Sewerage, (average % change per annum)[29]

	Range excluding England and Wales sewerage	Average excluding England and Wales sewerage
Reset Hypothesis		

[26] Please note that the estimates set out in this section include both catch-up and frontier shift. These estimates are comparable to the LEMS cost measure that we discussed in Section 4, however they are not comparable to our estimates for TFP in the following section.

[27] The range is based on results for Electricity Distribution, Electricity Transmission and England and Wales water.

[28] The averages are mean averages of the three sectors included, and therefore is not necessarily equal to the mid-point of the range.

[29] Please note that the estimates set out in this section include both catch-up and frontier shift. These estimates are comparable to the LEMS cost measure that we discussed in Section 4, however they are not comparable to our estimates for TFP in the following section.

By control period (third)	2.1 to 6.5	4.4
By years since privatisation (11-15)	2.1 to 6.7	5.1

Given that Network Rail were only required to achieve two-thirds of ORR's estimated catch-up efficiency for controllable opex (total controllable opex not just operations and support expenditure) it is likely that Network Rail's scope for efficiency gains in operations and support expenditure in CP5 would be towards the upper end of the estimates presented in Table 2.13.

Table 2.15 sets out our estimates, based on the RUOE estimates, for Network Rail's scope for opex efficiency savings over CP5. Our estimates are based on the range of RUOE measures for the comparators third price control, and 11-15 period since privatisation, excluding England and Wales sewerage.

Table 2.15: Initial estimates for potential efficiency gains, based on RUOE

Operation and support expenditure	CP5 average annual efficiency target	Total CP5 efficiency target (CAGR)
Low case	2.1% (per annum)	11.0%
High case	6.7% (per annum)	38.3%

Source: CEPA

3. TOTAL FACTOR PRODUCTIVITY

3.1. Introduction

TFP takes into account all the factors of production (e.g. capital, and labour) used to produce goods and services. TFP growth therefore captures the component of the change in output that is not explained by changes in inputs. TFP indices provide a way of comparing the efficiency with which companies / industries deploy their inputs in a multi-input, multi-output environment. They can be used both to compare firms / industries at a specific point in time and over time.

The approach quantifies 'efficiency' based on the residual or 'unexplained' component of output growth once the growth in inputs has been accounted for. This residual does not identify whether the improvement in efficiency is due to the firm(s) catching up to the frontier or the frontier moving itself. Instead, it is necessary to attribute the efficiency improvement to either catch-up or frontier shift based on an a priori knowledge of the sample from which the data are drawn.

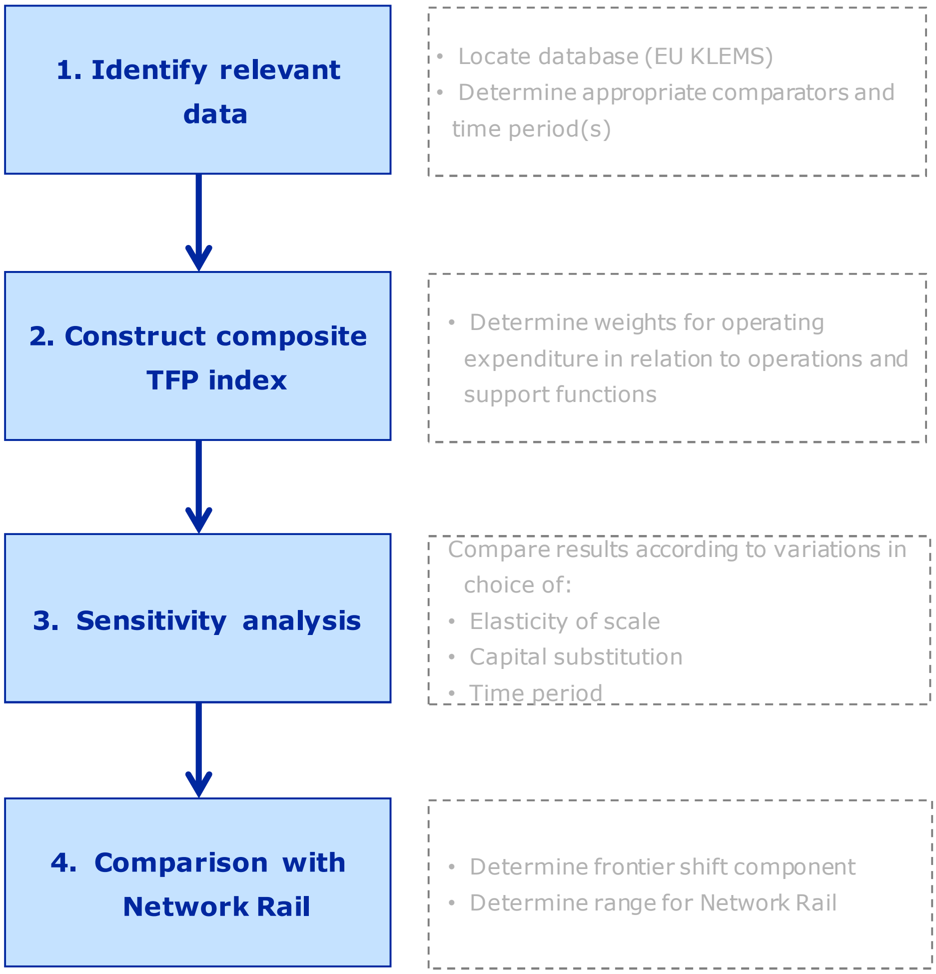
In the economy as a whole, or where there is assumed to be a reasonable amount of competition, if the sample of firms is both (i) large and (ii) random, it seems reasonable to expect that the efficiency improvement should be largely driven by frontier shift. In these circumstances, an equal amount of firms ought to be moving closer to the frontier as those that are moving away from it, on average. By contrast, if the sample contains a significant proportion of companies that are commonly recognised to be experiencing catch-up, through the effect of privatisation or comparative competition, then it is appropriate to make an adjustment to the TFP figure to recognise that not all of the efficiency improvement is likely to relate to frontier shift. A more detailed discussion on this issue and possible adjustments are provided in Section 3.4 below.

As part of our remit is to estimate the scope for Network Rail to achieve cost reductions indirectly we need to establish a benchmark TFP growth rate. Our approach is discussed in the following sections.

3.2. Methodology

Our methodology for estimating a composite TFP index for Network Rail is summarised in Figure 3.1 below.

Figure 3.1: Summary of methodology for composite TFP index



3.2.1. Dataset – EU KLEMS

We have used the EU KLEMS database, since this is the only source of historic TFP growth by industry over a long time period. The EU KLEMS dataset provides TFP productivity estimates based on gross output and value-added measures of productivity. The data are available on an annual basis from 1970 until 2007. They are available at the first level of the ONS Standard Industry Classification, which is a relatively high level of aggregation for the industry. For example, it provides TFP data that can be split between the manufacturing and service sectors.

3.2.2. Time period

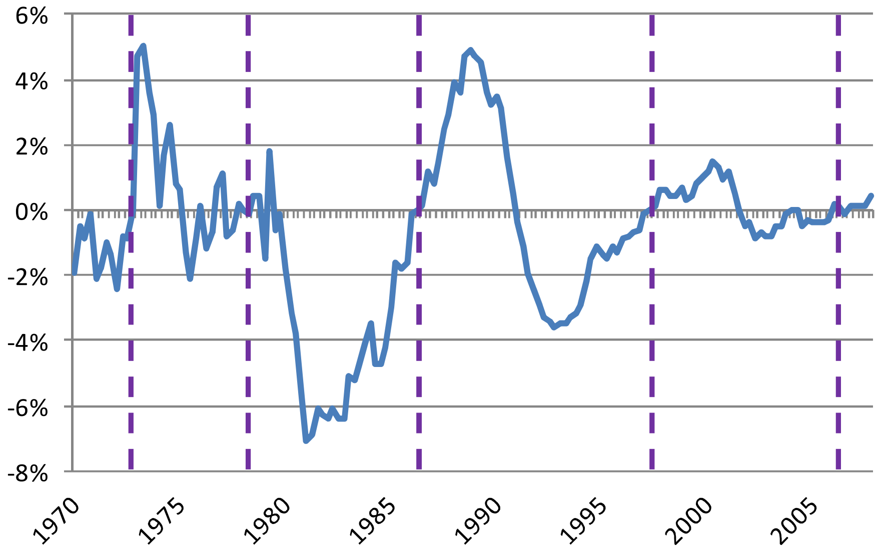
In order to estimate the scope for Network Rail's efficiency improvements we need to determine an appropriate time period with which to estimate our benchmark TFP growth. In this section we seek to identify the business cycles covered by the EU KLEMS database, and then use these to determine the most appropriate economic cycles over which to analyse the TFP performance of the selected comparator industries.

Productivity is a highly cyclical variable, which will show marked variation over the economic cycle as well as differences across economic cycles. It is standard practice to consider TFP growth over complete economic cycles.[30]

There is however a debate over the definition of economic cycles: Oxera define an economic cycle as the time period over which the TFP growth rate has moved from trough to trough;[31] HM Treasury provides a comprehensive analysis of evidence on the economic cycle, and define an economic cycle as a period of time over which the economy is on trend (i.e. there is a zero output gap).[32] Based on the HM Treasury analysis, the EU KLEMS database holds information about TFP growth for the following full economic cycles[33], which are shown below in Figure 3.2:

- 1972 – 1978
- 1978 – 1986
- 1986 – 1997
- 1997 – 2006

Figure 3.2 – UK Output Gap (%) and identification of complete business cycles



Source: Data from the Office for Budget Responsibility

In our TFP analysis we are attempting to identify the trend in productivity growth rate. Therefore, in choosing the economic cycles to be analysed, it is important to consider the trade-off between (i) maximising the duration of data, and (ii) maximising proximity to the period of analysis:

- If the analysis includes a greater number of business cycles, it is more robust to the possibility that an industry has observed atypical TFP growth over a single business cycle

[30] OECD (2003), p 119.

[31] See for instance: Oxera (2008), *What is Network Rail's likely scope for frontier shift in enhancement expenditure over CP4?*.

[32] HM Treasury (2008), *Evidence on the Economic Cycle.*

[33] The first three of these economic cycles are sourced from HM Treasury (2005), *Evidence on the UK economic cycle*, p19. The latest cycle (1997-2006) is sourced from HM Treasury (2008), *Evidence on the economic cycle*, p23.

due to industry specific reasons. An example of an industry specific shock in the case of UK rail would be the Hatfield disaster.

- However, a longer time period is arguably less robust to the possibility that there has been a permanent structural break in the TFP performance of an industry over time, which would mean that productivity performance in business cycles further back in the past is less relevant to current productivity performance. Such a structural break might be a technological innovation in the industry or a secular decline in the industry's level of international competitiveness.

In choosing our base case we have taken this trade-off into account and we also considered the fact that the most recent business cycle (1997-2006) is the first full business cycle since privatisation in the electricity, water and gas sector (one of our comparators). We consider that for indirect comparative purposes our base case will cover the time period:

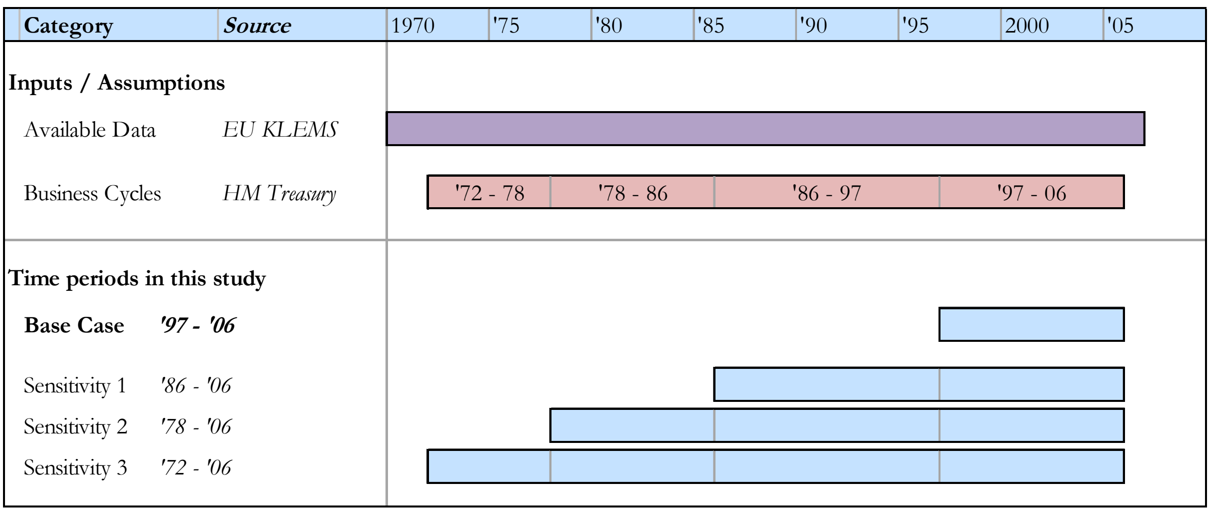
- 1997-2006.

However, in view of the other side of the trade off (maximising the duration of data), we conduct sensitivity analysis for periods of longer duration. This approach is supported by previous studies (Oxera 2008 and Reckon 2011), which show that the TFP results can be sensitive to the time period chosen. For our sensitivities, we have chosen to consider time periods that still contain a whole number of business cycles:

- 1986 - 2006 (two cycles);
- 1978 - 2006 (three cycles); and
- 1972 - 2006 (four cycles).

Figure 3.3 illustrates our choice of time periods for this study, and how they relate to available data and business cycle estimates from HM Treasury.

Figure 3.3 – Analysis of Time Periods chosen in this study



While the EU KLEMS data is available until 2007, we consider that it is inappropriate to include only the first year of a business cycle. Data from 2007 is therefore excluded from out analysis.

3.2.3. Gross output versus value-added

There are two different types of TFP statistics: Growth output TFP and Value-added TFP. In this section we explain these two measures, the difference between them, and our choice of TFP measure.

Value-added measures of productivity are generally calculated on the following basis:

$$(3.1) \qquad TFP_{VA} = {(Y-M)}\big/{(L^{s_L} \times K^{s_K})}$$

Where TFP_{VA} is gross value-added productivity, intermediate inputs is denoted M, output is denoted Y, labour is denoted L, capital is denoted K, and s_L and s_K are labour and capital share of value respectively. All the measures are relative to RPI (i.e. in real terms). Value-added (Y-M) is the difference between the value of output produced in a sector and the expenditure on intermediate inputs in their production.

Output measures of productivity are calculated on the following basis:

$$(3.2) \qquad TFP_{GO} = {Y}\big/{(L^{s_L} \times K^{s_K} \times M^{s_M})}$$

where TFP_{GO} is gross output productivity ands_M is materials share of value. Under output measures of productivity, intermediate inputs are assumed to contribute to productivity growth. This outcome seems more plausible where the definition of output is broad enough to allow for reduced intermediate input use arising from technological innovation. The OECD (2003) manual on productivity measures notes "*Conceptually the [value-added TFP measure] is not an accurate measure of technical change [at industry or firm level]. It is however an indicator of an industry's capacity to contribute to economy wide growth of income per unit of primary input*".[34] Gross output measures of TFP growth are the preferred concept for industry specific studies because "*the role of intermediates in production is fully acknowledged*".[35]

Unlike Oxera (2008) we have chosen to use gross output TFP as the basis for the composite benchmark. We agree with Reckon's (2011) view that the concept of valued added is not well suited to business accounting or business concepts such as operating expenditure.[36]

We consider that gross output TFP is more appropriate than value-added TFP for comparisons to a specific company's productivity improvements as it better reflects how a company is managed and records its inputs and outputs.

We note that the rate of change in value-added TFP will be greater than the rate of change in gross output TFP given the mathematical relationship between the two – a further explanation of the difference is set out in Annex E. Figure 3.4 below illustrates the difference in the two TFP measures. It is worthwhile noting the differences in the two measures by comparing the gross output TFP estimates presented in this study with the figures ORR used for CP4.

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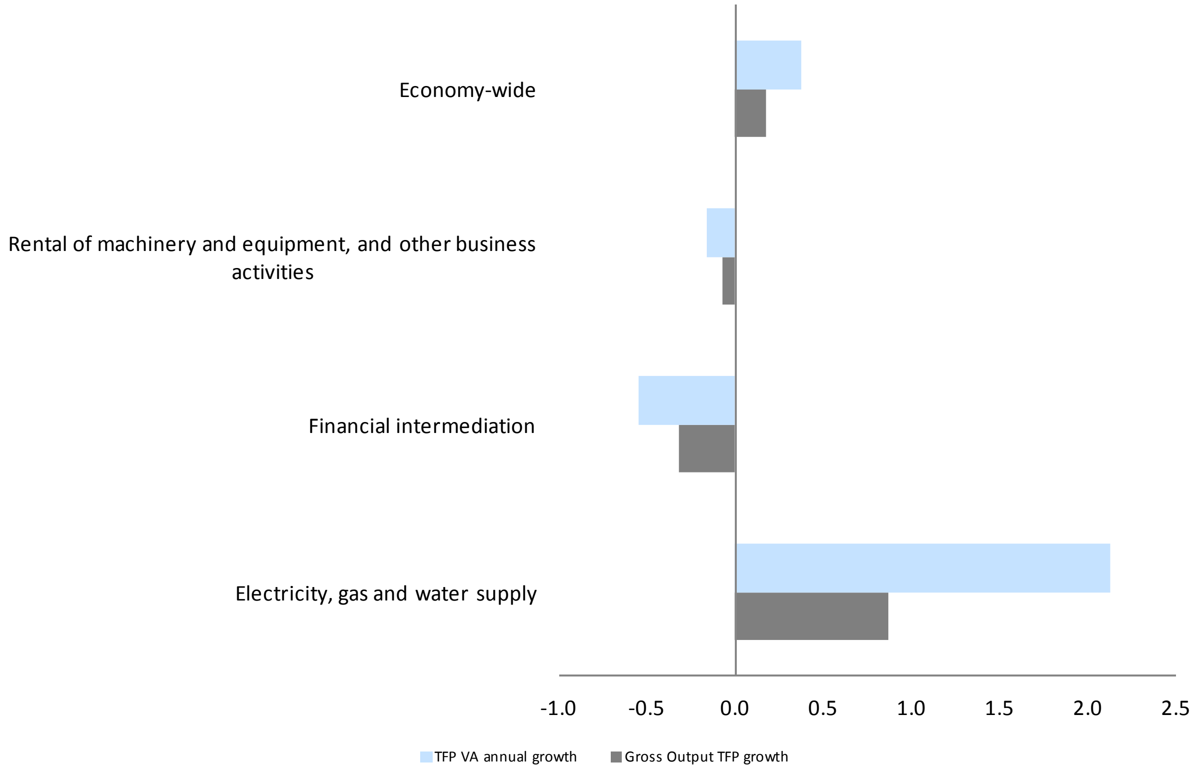
[34] OECD (2003), p 19.

[35] Ibid, p 18.

[36] Reckon (2011), p 93.

Figure 3.4: Comparison of average annual valued added and gross output TFP growth in selected sectors, 1970-2007



We discuss the regulatory implications of differences between value-added and gross output TFP growth in section 3.3.1 below.

ORR specifically requested that we reproduce Reckon's (2011) TFP estimates for maintenance, renewals and enhancements using gross output TFP. These results are presented in Appendix 1.

3.2.4. Selection of comparators

TFP growth estimates are not available at a detailed level of disaggregation, thus establishing a close match to sectoral growth in rail is not possible. Even if this level of disaggregation was available the results would be influenced by Network Rail's own performance. Therefore, we intend to create a benchmark performance with which to compare Network Rail against. We have taken the approach, in line with Oxera (2008) of creating a 'composite' benchmark TFP performance.

TFP gross output measures are available for a wide range of sectors, some of which undertake similar activities to those of Network Rail. The TFP measures for these sectors can be weighted on the basis of their applicability to Network Rail's operations and support activities to produce a single figure (composite) benchmark estimate for Network Rail's TFP. Therefore, the comparator industries need to be selected. For the purposes of developing the composite benchmark we have split the operation and support costs in to four categories: operations and customers services; other functions, corporate services and group activities.[37]

[37] This is the same breakdown as set out in Oxera (2008), p 28.

Network Rail's operations, customer support and corporate services functions are likely to be similar to those undertaken by other large network operators providing these functions. There is likely to be elements of professional services in these activities which has led to the inclusion of the rental of machinery and equipment and other business activities sector. Group activities relate to insurance and financing support functions, similar in scope to the financial intermediation sector.

We analysed the EU KLEMS database with a view to identifying appropriate comparators for Network Rail's operations and support activities. For some sectors in the dataset, variables are available to calculate both labour productivity and total factor productivity (i.e. growth accounting), whereas for some sectors there are only enough variables to calculate labour productivity.[38]

From a review of potentially relevant sectors, there were several containing "other business activities", which existed in the EU KLEMS database, but insufficient information was available to produce TFP estimates.

In light of this, and having reviewed the sectors chosen by Oxera (2008), we do not see any strong reasons to change the selected comparators, and so propose to use the same comparators for our TFP analysis. There is an additional benefit, which is that this enables a like-for-like comparison between our results and the previous studies. These comparators are shown in the Table 3.2.

Table 3.2 - Selected comparators for Network Rail's operations and support activities

Operations & support activities	Selected comparators
Operations & customer services	Electricity, gas and water supply Rental of machinery and equipment, and other business activities
Other functions	Electricity, gas and water supply Rental of machinery and equipment, and other business activities
Corporate services	Rental of machinery and equipment, and other business activities
Group activities	Financial intermediation

These comparator sectors involve:

- **Electricity, gas and water supply.** Includes activities related to the production and distribution of electricity and gas, and the collection and treatment of water and sewerage.
- **Rental of machinery and equipment, and other business activities.** Includes activities related to: Renting of transport equipment; Renting of other machinery and equipment; Renting of personal and household goods not elsewhere classified; Hardware consultancy; Software consultancy and supply; Data processing; Data base activities; Maintenance and repair of office, accounting and computing machinery; Other computer related activities; Research and experimental development on natural sciences and

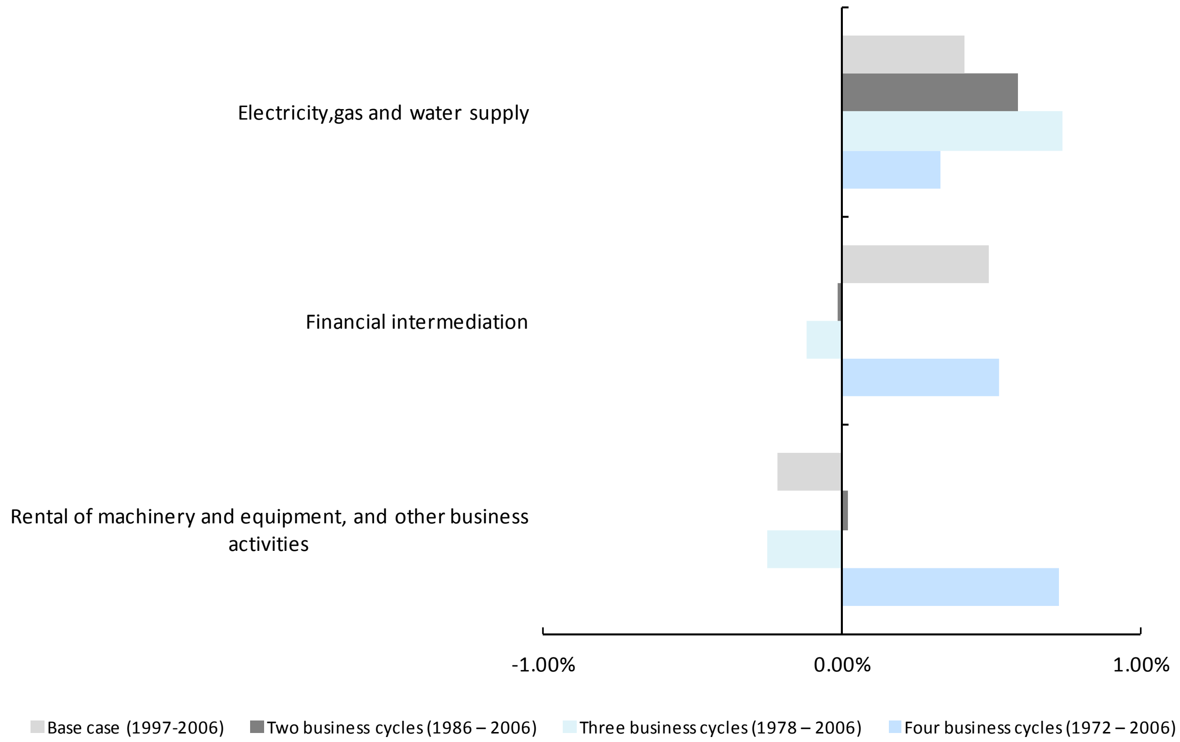
[38] See 'EU KLEMS Growth and Productivity Accounts, Version 1.0, Part I Methodology', March 2007, p10. The industries with TFP variables are then listed within the 'GA' column in table 2.3, on pages 11 and 12.

engineering; Research and experimental development on social sciences and humanities; Legal, accounting, book-keeping and auditing activities; tax consultancy; market research and public opinion polling; business and management consultancy; Architectural, engineering and other technical activities; Advertising; and business activities not elsewhere classified.

- **Financial intermediation.** Includes activities related to: monetary intermediation (banks, building societies and other institutions); insurance and pension funding, except compulsory social security; activities auxiliary to insurance and pension funding; and activities auxiliary to financial intermediation.

Figure 3.5 below shows gross output TFP figures for the three relevant comparators selected for our study. The figures are shown as averages over four different time periods: 1997-2006, 1986-2006, 1978-2006, and 1972-2006.

Figure 3.5 – Average annual gross output TFP growth in selected sectors



3.2.5. Operating expenditure weights

Having selected the comparator sectors for Network Rail's different operating and support activities, the second part of developing a composite TFP index is to assign weightings to the these different activities.

Following from Oxera (2008) and Reckon (2011), we have calculated weightings based on Network Rail's total CP4 costs. Our weightings are based on the latest available figures for *actual* CP4 operations and support expenditure, and so are an update to the weightings used by Oxera (2008) and Reckon (2011) which used forecast costs. Table 3.2 below sets out our proposed weights based on Network Rail's average expenditure for the activities from 2009/10 to 2010/11.

Table 3.2 – CEPA weightings for operations and support activities

Operations & support activities	CEPA weighting	Comparators
Total Operations and Customer Services	47%	Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total Other Functions	20%	Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total Corporate Services	20%	Rental of machinery and equipment and other business activities
Total Group Activities	12%	Financial intermediation

Source: CEPA, ORR, Network Rail Regulatory Accounts.

3.2.6. Capital substitution adjustment

Total Factor Productivity (TFP) as its name suggests, includes the productivity of all (i.e. the "total") factors of production - namely labour and capital.[39] Activities which have a relatively balanced mix between capital inputs and labour inputs are therefore better suited to indirect comparisons with industry wide TFP. However, operating and support activities' costs predominantly comprise labour costs. In order to maintain consistency with previous ORR reports we are using TFP as the benchmark for Network Rail's operating and support costs, although we consider that labour productivity is a more appropriate measure. As such, an adjustment to the TFP estimates is required to adjust for capital substitution, which, when calculated on a similar basis to the composite measure, results in a labour productivity estimate. In other words, the TFP estimate with a capital substitution adjustment is equal to labour productivity measure.

Capital substitution describes the shift from labour inputs towards capital inputs, which generally accompanies economic progress.[40] An example is the purchase of a new capital asset (e.g. automated assembly line) that reduces labour requirements. In other words, capital substitution occurs when the growth in capital inputs exceeds the growth in labour inputs. Gross output based labour productivity can be decomposed into TFP growth, the growth in the capital-labour ratio, and growth in the material-labour ratio (i.e. the change in use of intermediate inputs relative to the change in labour). This is illustrated in the following equation:

$$gLP = gTFP + S_k(g(K) - g(L)) + S_M(g(M) - g(L)) \quad (3.3)$$

Where gLP refers to growth in labour productivity, $gTFP$ refers to growth in TFP, S_k is the capital share of value, $g(K) - g(L)$ is the growth in the capital-labour ratio, S_M is the materials share of value, and $g(M) - g(L)$ is the growth in the material-labour ratio. The capital

[39] Intermediate inputs are also considered as inputs under the gross output measure, but not under the value-added measure.

[40] Ofwat, PR04, Scope for Efficiency Improvement (2003), prepared by Europe Economics.

substitution adjustment is equal to $S_k(g(K) - g(L))$. The derivation of this formula is set out in Annex F. The capital adjustment can be more simply considered as the change in capital (relative to labour) over time. By making an adjustment for capital substitution to the TFP measure the changes in gross output that result from changes in capital are attributed to (labour) productivity growth. This does mean however, that in order to achieve this level of productivity growth, some capital expenditure, for example, on IT would likely need to occur (or have occurred).[41]

Oxera (2008) estimated a capital substitution adjustment of 0.5. Oxera state that this is based on the same principles as the Oxera/ LEK (2005) report and an assumption that the capital share of value is the same as the UK economy (0.35). It is not clear how Oxera (2008) arrived at the 0.5 estimate; however, we accept Reckon's (2011) assessment that this was calculated based on Europe Economics' (2001) report. The increase in the volume of capital employed per unit of labour is equal to the growth in capital inputs minus the growth labour inputs. Europe Economics (2003)[42] assumed volume growth to be 1.7%, with the adjustment factor being calculated as 1.7%*0.3=0.5. Our formula is different to that used by Oxera (2008) as we are using gross output rather than value-added.

Reckon (2011) use the EU KLEMS database to calculate the share of value-added which is due to capital (over the period 1981-2004), and find this to be approximately 0.3.

Rather than estimate an economy-wide capital substitution based on 1980-1990 data, we estimate capital substitution adjustments for each of the sectors included in our composite measure on the same period as our base case (1997-2006) and weighted these together on the same basis. Our estimate for the capital substitution adjustment for the base case is 0.8%. Annex F sets out our estimates for each of the sectors in the composite benchmark, including an economy-wide estimate, and across the other time periods considered in our sensitivity analysis.

3.2.7. Measurement issues

In order to properly interpret these results, compare them to the RUOE estimates and to correctly apply them to Network Rail it is important to consider any limitations in the data. Any potential measurement errors with the data, would provide a caveat to any final conclusions.

EU KLEMS Database

In Section 3.2.1 we note that the EU KLEMS dataset provides the best available data for undertaking an analysis of both TFP and LEMS measures (and has been used in both Oxera (2008) and Reckon (2011)). However, it does have limitations.

As with any dataset the EU KLEMS database may be susceptible to measurement error. Reckon (2011) observe that there are a number of sectors which have negative productivity growth data, even over long time series (e.g. rental of machinery and equipment, and other business activities 1972-2006), which may not reflect the true performance of suppliers in those industries.[43]

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[41] Note the share of capital relative to labour can decrease, which may lead to labour productivity being lower than TFP.

[42] Europe Economics (2003), pp 26-27.

[43] Reckon (2011), p 19.

However, it is also plausible that some sectors would experience negative productivity growth over time, for reasons such as increased costs from health and safety, etc.

Given the possibility of measurement error in the database it would stand to reason that as the number of variables included in a measure increase the risk of measurement error would also increase. Therefore, as the TFP measure includes more variables than the LEMS cost measure (the calculation of which only includes the gross output price index, quantity of capital services and gross output, as set out in Annex G) the risk of measurement error in the estimates is higher. Reckon (2011) also noted this issue.[44]

Composite benchmark

The TFP composite benchmark relies on the assumption that Network Rail's functions can be separated out and compared to different sectors of the economy. It is then assumed that Network Rail will be able to achieve the same productivity growth for each of its functions as one or two selected sectors. While this allows us to produce a single benchmark estimate for Network Rail's operation and support costs, there is a risk that the productivity gains are incorrectly estimated. For example, it is probable that there will be differences in the activities of operations and customer services, and the economic activities in electricity, gas and water sector as a whole.

3.3. Results

3.3.1. Base case

The gross output TFP benchmarks are provided in Table 3.3 below. We have included an estimate for economy wide TFP growth as well as the composite benchmark with the adjustment for capital substitution. Our estimate for the growth in the composite benchmark; that is, performance that might be expected from a company carrying out similar operation and support activities as Network Rail, is 1.3% per annum (including both frontier shift and catch-up).

Table 3.3: Gross output TFP growth, 1997-2006 (% per annum)

	Support and operations
Economy wide TFP	0.1
Estimated TFP benchmark	
(a) Composite benchmark	0.6
(b) Capital substitution	0.8
Estimated TFP benchmark (a) + (b)	1.3*

Source: CEPA

** Estimated TFP benchmark is **not** net of economy TFP. Figures (a) and (b) may not add due to rounding.*

Table 3.4 below provides a comparison to the composite benchmark if it were based on value-added TFP, rather than gross output, and also provides an illustration of the differences when economy-wide TFP is netted out (as is standard practice in incorporating TFP growth

44 Ibid, p 96.

benchmarks into the RPI-X formula). As can be seen the implications are less serious when the economy-wide TFP growth is netted off.

Table 3.4: Net TFP growth, average % per annual

	Composite benchmark TFP (a)	**Economy-wide TFP (b)**	**Net TFP (a) – (b)**
1997-2006			
Gross output	0.6	0.1	0.4
Value-added	1.2	0.3	0.8
1970-2007			
Gross output	0.2	0.2	0.0
Value-added	0.5	0.4	0.1

** Excluding the capital substitution adjustment.*

3.3.2. Sensitivities

We have made a number of assumptions in formulating the composite benchmark. These assumptions impact on the composite TFP estimate, particularly the capital substitution adjustment and the time period covered. Another area, where we have not made an adjustment, but which may be considered pertinent is an adjustment for economies of scale.

Economies of scale

Network industries are commonly considered to enjoy economies of scale — as they grow in size, their costs fall in proportionate terms. If this effect is ignored, and a company has grown over the period, the estimate of TFP might be too large. We have not adjusted our base case estimates for economies of scale for the following reasons:

- we do not have robust evidence on the scale economies for all the sectors in the composite benchmark; and
- the high level of aggregation makes applying any adjustments difficult.

We note that we are consistent with Oxera (2008) where authors did not make adjustments for economies of scale in its base case.

However we also consider that it is important to conduct sensitivities in regards to economies of scale and have adjusted our estimates for volume using the following formula:

Volume-adjusted TFP = Unadjusted TFP - $(1 - \varepsilon) \times$(change in outputs over the period)

The cost elasticity is denoted by ε and we have drawn on the elasticity assumption used by Oxera/LEK (2005) and Oxera (2008) in their sensitivity analysis of 0.9 for our composite TFP benchmark. Oxera/LEK noted that this is drawn from a conservative estimate of elasticities used by other consultants and academics. We note that this estimate is broadly an average of the industry elasticities presented in the Section 2.2.3. While there is not a lot of empirical evidence to support this as an economy wide figure, we consider that for the purposes of this study it is an appropriate value to use given that it is in line with an average for the sectors included in the composite benchmark and it maintains consistency with previous studies. However, for further information on the effect of the cost elasticity adjustment we have also included a sensitivity using an elasticity of 0.8.

As discussed in Section 2.2.3, the elasticity of opex with respect to train-km is likely to be close to zero for Network Rail, so that its unit costs should fall as train-km rise even if it does nothing. This suggests that its efficiency target should be set higher if elasticities for comparators are more like 0.7 or 0.9.

Results

We have undertaken a number of sensitivities around our base case relating to assumptions for:

- economies of scale;
- the time period;
- comparators (electricity, gas and water supply sector only, 1997-2006);
- the composite benchmark weights (we have used the Oxera (2008) weights); and
- a capital substitution adjustment (we have used the Oxera (2008) estimate).

The estimates for these sensitivities are presented in Table 3.5 below.

Table 3.5: Gross output TFP growth sensitivity analysis (% per annum)

	Support and operations
Base case	**1.3**
Assuming 0.9 cost elasticity	1.2
Assuming 0.8 cost elasticity	1.0
Two business cycles (1986 – 2006)	1.1
Three business cycles (1978 – 2006)	1.0
Four business cycles (1972 – 2006)	1.0
Electricity, gas and water supply (1997-2006)	1.0[a]
Oxera (2008) weights	1.3
Oxera (2008) capital substitution adjustment (0.5)	1.1

Notes: [a] We estimate an electricity, gas and water supply capital substitution adjustment of 0.7, 0.3 higher than our adjustment for the composite benchmark.
Source: CEPA

The difference between the base case and the cost elasticity sensitivities is small, 0.1 percentage points for 0.9 elasticity and 0.2 percentage points for an elasticity of 0.8. This indicates that varying our assumption on the elasticities of scale at the margin would not have a significant impact. However if the capital substitution adjustment is removed then the percentage difference between these two measures is much greater.

The sensitivity analysis shows that the TFP composite benchmark estimates are relatively stable over the different time periods i.e. as the duration is extended. The TFP growth in the electricity, gas and water sector is slightly lower than the composite benchmark over this time frame.

Using the Oxera (2008) weights for the composite benchmark has a very small impact on the estimate (less than 0.1 percentage points per annum). If the Oxera (2008) capital substitution adjustment is used the benchmark estimate decreases by 0.4 percentage points per annum to 1.1% per annum.

3.4. Frontier Shift versus Catch-up

Total Factor Productivity (TFP) offers a method of measuring firm performance. It is an index based approach that quantifies 'efficiency' based on the residual or 'unexplained' component of output growth once the growth in inputs has been accounted for.

This residual does not identify whether the improvement in efficiency is due to the firm(s) catching up to the frontier or the frontier moving itself. (Annex A provides an explanation of the difference between frontier shift and catch-up.) Instead, it is necessary to attribute the efficiency improvement to either catch-up or frontier shift based on an *a priori* knowledge of the sample from which the data is drawn.

In the economy as a whole, or where there is assumed to be a reasonable amount of competition, if the sample of firms is both (i) large and (ii) random, it seems reasonable to expect that the efficiency improvement should be largely driven by frontier shift. In these circumstances, an equal number of firms ought to be moving closer to the frontier as those that are moving away from it, on average. This view is supported by NERA's advice to the OPPPA, which stated that since 'TFP studies cover many different sectors of the economy, including sectors that are thought to be broadly competitive' the results are 'often used to provide an indication of "frontier shift" rather than "catch-up"'[45]. In contrast, if the sample contains a significant proportion of companies that are commonly recognised to be experiencing catch-up, through the effect of privatisation or comparative competition, then it is appropriate to make an adjustment to the TFP figure to recognise that not all of the efficiency improvement is likely to relate to frontier shift.

The TFP composite benchmark contains industries which include companies subject to comparative competition and that may still be experiencing some of the effects of privatisation, namely the electricity, gas and water sector. Therefore, we consider that an adjustment for catch-up is appropriate.

3.4.1. Previous studies for ORR

Oxera (2008) determined that the TFP growth estimates it produced could be equated to frontier-shift improvements only under the hypothesis of no technical inefficiency or no change in technical or allocative inefficiency over time. Oxera noted that these assumptions are not supported by empirical evidence, but consider the long timeframe and competitive nature of the

[45] NERA 2006, High Level Efficiency Estimates for the Second Review Period, Report for the Office of the PPP Arbiter, p. 15.

industries in the composite benchmark to be sufficient to limit the contribution of improvements in technical efficiency to productivity.

Nonetheless Oxera concluded that an adjustment for catch-up should be made to the composite TFP benchmark. Oxera based the adjustment on an academic study which estimated that 75% of economy-wide TFP growth is due to frontier shift.[46] Oxera considered this to be a lower bound as the academic study included 'non market' sectors.

Reckon (2011) question the use of this approach and consider the concept of catch-up in productivity between countries and that of catch-up to a particular company are different concepts.[47] They also noted that the 'notion of catch-up of the average level of productivity of one country compared to another does not seem the same as the notion of catch-up that is relevant to the estimates from the EU KLEMS data.'[48] Reckon (2011) did not estimate an adjustment for catch-up and state that 'it seems ambitious to try and find a single number that can be used to decompose productivity estimates from any sector of the economy into frontier-shift and catch-up elements.'[49]

3.4.2. Evidence from other regulators

An area where we consider further evidence on the potential split between catch-up and efficiency is other UK regulators' price control decisions. Table 3.6 shows the regulators' decisions on catch-up and efficiency for recent price controls.

Table 3.6: Regulators' efficiency estimates[50]

Type of expenditure	Years	Catch-up	Gross Frontier Shift[51]	Proportion of X-factor attributable to Frontier Shift
OPPPA				
Opex	2008-2013	0.50%	0.90%	64%
Postcomm				
Opex	2006-07	3.00%	0.00%	0%
Opex	2007-10	3.00%	0.00%	0%
Ofcom				
Opex	2005-09	3.00%	1.50%	33%
Opex	2009-14	2.00%	2.00%	50%

[46] Fäire et al (1994). This paper provided analysis of economy-wide level productivity for 17 OECD countries over the period 1978-1998.

[47] Reckon (2011), p 46.

[48] Ibid.

[49] Ibid.

[50] Regulators have not necessarily published their decisions in a way that allows easy identification/ decomposition of catch-up and frontier shift. The number is this table reflect CEPA's estimates based on the Regulators' Final Decision documents and, where applicable, associated consultant reports.

[51] 'Gross' refers to no adjustment being made for economy wide productivity i.e. the differences between the sector and the wider economy are dealt with through a differential inflation adjustment.

Type of expenditure	Years	Catch-up	Gross Frontier Shift[51]	Proportion of X-factor attributable to Frontier Shift
Ofgem				
Opex	2008-13	1.10%	1.40%	56%
Opex	2010-15	0.80%	1.0%	56%
CAA				
Opex (base)	2008-13	1.00%	1.20%	55%
Ofwat				
Opex (water)	2005-10	1.10%	1.00%	48%
Opex (sewerage)	2005-10	0.80%	1.20%	60%
Opex (water)	2010-15	2.90%	0.25 (net)	*
Opex (sewerage)	2010-15	2.20%	0.25 (net)	*

Source: CEPA

If we consider the electricity, gas and water supply sector decisions – i.e. Ofgem and Ofwat – this would indicate that around 50% - 60% of the scope for efficiency gains to be associated with frontier shift. For this sector the gross frontier shift has been determined to be between 1% and 2%. It should also be noted that the electricity, gas and water supply sector – on which the composite index is based – contains companies that are not subject to price controls (e.g. electricity generation).

The Ofgem and Ofwat price control decisions reported related to the fourth or fifth price control for their sectors and as such we would expect the scope for catch-up efficiency to have reduced since the early price controls. These regulators have recently started applying the full catch-up adjustment at the start of the price control period when determining price controls.

3.5. Conclusion

As noted earlier, 1997-2006 is the first full business cycle since privatisation in the electricity, gas and water supply sector. In addition to being one of the comparators in our composite benchmark there is the added benefit that this business cycle roughly covers the second and third price controls for these sectors. Therefore, as discussed in Section 3.2.2 we consider that the 1997-2006 time period to be the most relevant period over which to consider Network Rail's potential for CP5 opex efficiencies.

In Table 3.7 we set out our estimates, based on the gross output TFP estimates, for Network Rail's scope for opex efficiency savings over CP5 from frontier shift only. Our estimates are based on the composite gross output TFP estimates over 1997-2006 (1.3% per annum) using a 0.50 (in the low case) adjustment for catch-up (0.75 in the high case). The 0.50 adjustment is based on the lower end of other industries regulators' decisions in relation to frontier shift, and the 0.75 assumption is taken from Oxera (2008).

Table 3.7: Initial estimates for ongoing (frontier shift), based on gross output TFP

Operation and support expenditure	CP5 average annual efficiency target – Frontier shift only	Total CP5 efficiency target - frontier shift only (CAGR)
Low case	0.7% (per annum)	3.8%
High case	1.0% (per aannum)	5.6%

Source: CEPA

Note: Estimated TFP estimates are gross, i.e. ***not*** *net of economy TFP*

The estimates above are based on a gross output TFP basis, and as we are comparing this only to operations and support costs a capital substitution adjustment needs to be made (as the composite benchmark includes capital deepening). This brings our TFP measure more in line with a labour productivity measure, which leads us to consider whether a labour productivity or similar measure may be more appropriate. In regards to the latter, we discuss an alternative measure in the next section.

4. LABOUR, ENERGY, MATERIALS AND SERVICES (LEMS) COST MEASURE

4.1. Introduction

This section considers an alternative methodology to the RUOE and TFP efficiency estimates, which is based on an analysis of labour (L), energy (E), materials (M) and services (S) – (LEMS). It is useful to note that there are several inputs and assumptions which overlap with the TFP analysis and so this chapter frequently refers to the TFP chapter.

4.2. Methodology

The LEMS cost measure analysis is based on the methodology set out in Reckon (2011).[52] The measure is a unit cost measure which can be compared with the RUOE results (see Section 2.4). It uses costs which are broadly consistent with operating and support costs (i.e. expenditure on labour and intermediate inputs, but excluding expenditure on capital), and combines them with output to derive a unit cost measure over time. The unit cost measure will therefore reflect productivity improvements and input price inflation (wages and intermediate input prices) in the sectors. The data for this cost measure is taken from the EU KLEMS dataset.

We construct, in the same way as our TFP estimate, a composite LEMS cost measure as a comparator for Network Rail. Annex G contains the mathematical formulation of this measure.

4.2.1. Time period

As for TFP, it is preferable to develop LEMS results over whole business cycles as this reduces the likelihood that results are skewed by fluctuations in demand. Our analysis therefore utilises same time periods as selected for the TFP analysis, and a detailed discussion of our selection is contained within the TFP section of this report (see Section 3.2.2).

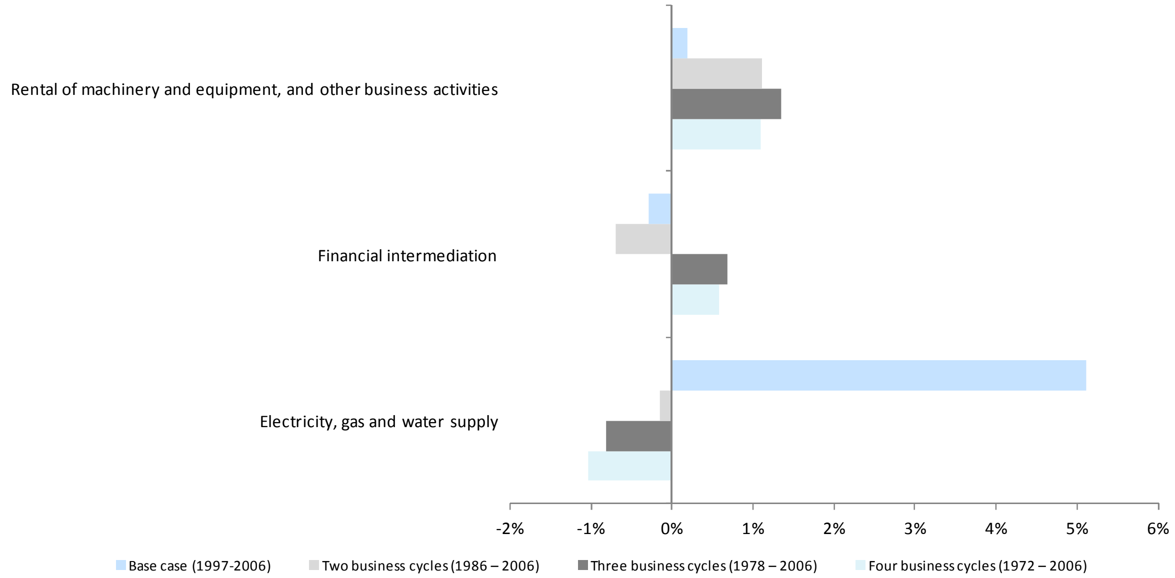
4.2.2. Selection of comparators

We use the same industries for comparison – electricity, gas and water; rental of machinery and equipment, and other business activities; and financial intermediation – as used in TFP composite estimate, for the reasons discussed in Section 3.2.4.

Figure 4.1 below shows the LEMS cost measure for the three relevant comparators selected for our study. The figures are shown as averages over four different time periods: 1997-2006, 1986-2006, 1978-2006 and 1972-2006. It is worth noting that Electricity, gas and water supply exhibit strong average annual growth (5.1% per annum) over the 1997-2006 business cycle this being the first full cycle since privatisation in 1990.

[52] Reckon (2011), p 89.

Figure 4.1 – Average annual LEMS cost measure growth in selected sectors



4.2.3. Operating expenditure weights

We see no reason to deviate from the weightings used in our TFP analysis (which are based on Network Rail's actual CP4 expenditure for 2009-11), and therefore have used the same weights to create a composite LEMS benchmark. A detailed discussion of the weightings used in this analysis is contained within the TFP section of this report (see Section 3.2.5).

We note that Reckon (2011) compare all 30 industries individually, and do not bring these industry figures together to form a composite benchmark. However, we consider that doing so provides a useful additional benchmark and enables comparability with the capital substitution adjusted TFP results.

4.3. Results

4.3.1. Base case

The LEMS cost measure benchmarks are provided in Table 4.1 below. We have included an estimate for economy wide LEMS growth as well as the composite benchmark.

Table 4.1: Growth in LEMS cost measure, 1997-2006 (% per annum)

	Support and operations (per annum)
Economy wide LEMS cost measure	0.2%
LEMS cost measure composite benchmark	1.8%

Source: CEPA

Sensitivities

We have undertaken a number of sensitivities, in line with those undertaken for the TFP measure, around our base case relating to assumptions for:

- economies of scale;
- the time period;
- comparators (electricity, gas and water supply sector only, 1997-2006); and
- using composite benchmark weights (Oxera (2008) weights are used).

Table 4.2 provides the results for these sensitivities.

Table 4.2: LEMS growth sensitivity analysis (% per annum)

	Support and operations (% per annum)
Base case (1997-2006)	1.8%
Assuming 0.9 cost elasticity	1.6%
Two business cycles (1986 – 2006)	0.5%
Three business cycles (1978 – 2006)	0.5%
Four business cycles (1972 – 2006)	0.3%
Electricity, gas and water supply (1997 – 2006)	5.1%
Oxera (2008) weights	1.6%

Source: CEPA

With the exception of the most recent time period, the sensitivity analysis shows that the LEMS composite benchmark estimates are relatively stable over the different time periods.

Interestingly the LEMS growth in the electricity, gas and water sector is much higher than the composite benchmark over the most recent business cycle. We saw in Figure 3.1 (presented earlier) the electricity, gas and water supply sector's TFP growth is much lower if the time period is extended to earlier business cycles, 0% to -1% per annum.

Using Oxera (2008) weights for the composite benchmark has a relatively small impact (0.2) on the benchmark estimate.

4.4. Conclusion

The LEMS cost measure is more of an equivalent to the RUOE measure than the TFP composite benchmark. We are interested in the LEMS cost measure as a comparator to the RUOE measure and as such we make no adjustment for catch-up.

As with the TFP measure we consider that the time period of 1997-2006 is the most appropriate with which to compare Network Rail's possible scope for efficiency gains against the sectors in our composite benchmark. In addition we also consider that focusing on electricity, gas and water supply LEMS cost measure growth may be more appropriate to estimate Network Rail's scope for opex efficiency improvements over CP5. This is because it:

- is more comparable with the RUOE averages for these industries; and
- reflects the catch-up and frontier shift of other network industries subject to comparative benchmarking. Although there are companies within this sector that are not subject to price controls, it could be argued, based on the long-run estimates for these sectors and other sectors, that these companies experience lower LEMS cost measure growth.

Our estimates for Network Rail's scope for efficiency gains in relation to operations and support costs are shown in Table 4.3 below.

Table 4.3: Initial estimates for efficiency gains over CP5, based on LEMS cost measure

Operation and support expenditure	CP5 average annual efficiency target – catch-up and frontier shift	Total CP5 efficiency target - catch-up and frontier shift
Low case	1.8% (per annum)	9.3%
High case	5.1% (per annum)	28.2%

There is a substantial difference between the low case and the high case. We consider that this is mainly driven by the differences in catch-up efficiency. The low case includes industries which have been operating in a competitive market for a long time, while the high case contains a number of companies that were not operating in a competitive market and, since privatisation, are now subject to economic regulation.

5. CONCLUSION

We have examined a range of measures in order to develop a view on Network Rail's scope for efficiency improvement over CP5 in relation to operations and support expenditure. Potential overall efficiency gains (both catch-up and frontier shift) were assessed through the RUOE and LEMS cost measure, while the TFP measure provided an estimate of frontier shift alone. We have been asked to provide an estimate for the overall scope for Network Rail's efficiency improvements over CP5 and have used a number of different approaches to develop the ranges included in this report. In should be noted that, as is the case for all benchmarking exercises, there are limitations on the level of comparability that can be achieved with Network Rail and as such we would expect ORR to use this analysis as one of several inputs into the targets that it sets for Network Rail in CP5.

The RUOE industry level analysis suggests a range of 0.2% to 6.5% average efficiency improvements per annum, which is clearly a wide range. If we exclude England and Wales Sewerage which appears to be an outlier with average annual growth of 0.2% then the industry range is 1.0% to 6.5%. Following Oxera's (2008) approach, we have used the reset hypothesis which assumes that the sharp rise in costs following the Hatfield derailment and Network Rail's administration effectively reset Network Rail's operating expenditure to pre-privatisation efficiency levels. Based on the timing of these events and CP5, we concluded that RUOE trends in the third price control for the other regulated industries, or 11-15 years since privatisation, would provide the most accurate estimates against which to consider Network Rail's scope for efficiency improvements. Taking the reset hypothesis into account, and excluding England and Wales sewerage, the range of average annual cost reduction is 2.1% to 6.5%, for the comparator's third price control and 2.1% to 6.7% for the period 11-15 since privatisation. The average across the comparators for these two periods is 4.4% and 5.1% (per annum) respectively.

In addition to the RUOE measure, we also estimate a LEMS cost measure. The scope of the LEMS cost measure is consistent with the RUOE measure, capturing both catch-up and frontier shift. We estimate the LEMS cost measure composite benchmark – based on industries undertaking similar activities – as 1.8% per annum. To provide further comparability with the RUOE measure we estimate the LEMS cost measure for the electricity, gas and water sector, to be 5.1% per annum. The 5.1% per annum estimate for electricity, gas and water supply is in line with our estimates for RUOE for electricity and water over their third price control period, and 11-15 years since privatisation (approximately the period covering 2000/01 to 2005/06).[53] We prefer the high case LEMS estimate to the low case as the latter includes industries which have been operating in a competitive market for a long time, while the electricity, gas and water supply contains a number of regulated companies which are not in a competitive market.

We have calculated a composite TFP measure on the same basis as the LEMS measure. As we are only assessing the scope for productivity gains in operations and support costs the TFP estimate was adjusted to make it equivalent to a labour productivity measure (i.e. via a capital substitution adjustment). As our TFP estimates include firms operating in competitive markets over a long period of time their performance should represent that of an efficient firm.

[53] Note, the electricity, gas and water supply sector includes non-regulated business as well as the network monopolies.

However, it is likely that some inefficiencies will be included in this measure. As such we further adjusted the TFP measure for catch-up efficiency, using the Oxera (2008) estimate of 0.75 and a 0.5 estimate based on regulators' decisions within the industries included in the composite benchmark. The estimates for TFP growth are 0.7% to 1.0% and, as noted above, these only relate to frontier shift and are not analogous to the RUOE or LEMS cost measures.

We consider that the LEMS cost measure covering electricity, gas and water and the RUOE measures are the most appropriate measures as they contain both catch-up and frontier shift, and cover similar network industries. We do not place as much weight on the TFP estimates as they do not contain catch-up efficiency (as such they only provides a lower bound).

Table 5.1 below provides the average annual efficiency estimates for the three measures.

Table 5.1: Summary of estimates for efficiency gains over CP5, based on the different measures

Measure	CP5 average annual efficiency target range (per annum)
Frontier Shift and Catch-up	
RUOE (third price control)	2.1% - 6.5% (4.4% average)
RUOE (11-15 years since privatisation)	2.1% - 6.7% (5.1% average)
LEMS cost measure	1.8% - 5.1%
Frontier Shift only	
TFP	0.7% - 1.0%

The actual target that ORR might set for Network Rail over CP5 depends on its performance relative to best practice at the end of CP4. Actual performance is not yet known although we understand that Network Rail is somewhat behind target currently. We note however that a number of projects which deliver efficiency savings in operations and support are back end loaded e.g. the move of administrative functions from London to Milton Keynes.

If Network Rail is able to deliver against its targets then average annual grow reported for the RUOE, of 4.4% (for comparator industries in their third price control), and the LEMS cost measure for electricity, gas and water supply and RUOE (11-15 years since privatisation), of 5.1%, respectively might represent an appropriate annual target for CP5. Savings of this order would be consistent with broader studies of Network Rail's relative efficiency e.g. the benchmarking work undertaken as part of the recent Rail Review, which suggests that Network Rail's costs are significantly higher in a range of activities than those of its international peers.

Adjustment would of course need to be made to these figures if Network Rail either under or outperforms its targets. The ranges provided in this report will help ORR to assess the appropriate annual percentages to apply in these circumstances.

Appendix 1 – TFP estimates for maintenance and renewals

App.1.1 **Introduction**

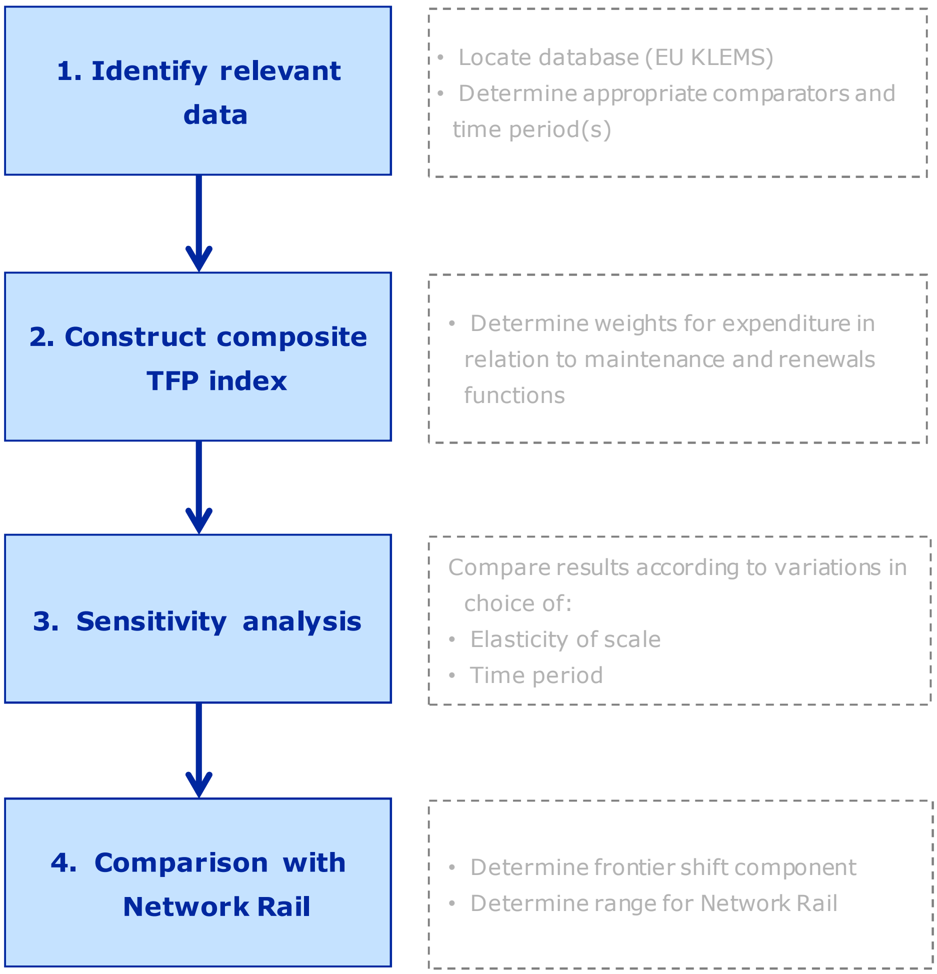
In addition to providing estimates of Network Rail's scope for efficiency improvement in operations and support expenditure, ORR has asked CEPA to estimate TFP growth benchmarks for maintenance and renewal expenditure.

As set out in the Section 3.1, TFP takes into account all the factors of production (e.g. capital, and labour) used to produce goods and services. TFP growth therefore captures the component of the change in output that is not explained by changes in inputs. TFP indices provide a way of comparing the efficiency with which companies / industries deploy their inputs in a multi-input, multi-output environment. They can be used both to compare firms / industries at a specific point in time and over time.

App.1.2 **Methodology**

Our methodology for estimating a composite TFP index for Network Rail's maintenance and renewals functions follows that set out in chapter 3 but for ease is summarised in Figure A1.1 below.

Figure A1.1: Summary of methodology for composite TFP index



The main difference between the methodology for calculating a TFP benchmark for maintenance and renewals expenditure, and operations and support is that a capital substitution adjustment is not required. This is discussed further in section App. 1.2.3 (see further below in this appendix).

App.1.2.1 **Data, time period and output measure**

We have used the EU KLEMS database as the source of data to create the composite benchmarks and have taken the approach of assessing TFP growth over full (economy wide) business cycles. Based on the HM Treasury analysis, the following full economic cycles[54] are covered by the EU KLEMS dataset:

- 1972 – 1978
- 1978 – 1986
- 1986 – 1997
- 1997 – 2006

Our base case time period is 1997 to 2006. This is the most recent full economic business cycle and is the only business cycle that includes data since privatisation in the electricity, water and gas sector (our key comparators). We have undertaken sensitivity analysis covering the following whole business cycles:

- 1986 - 2006 (two cycles);
- 1978 - 2006 (three cycles); and
- 1972 - 2006 (four cycles).

We consider that gross output TFP is the most appropriate to measure to use, rather than value-added TFP for the reasons set out in Section 3.2.3, but we also provide estimates for the composite benchmark using value-added TFP for comparative purposes in the results section below (Section A1.3).

App.1.2.2 **Selection of comparators and weights**

TFP growth estimates are not available at a detailed level of disaggregation, thus establishing a close match to sectoral growth in rail is not possible. Even if this level of disaggregation was available the results would be influenced by Network Rail's own performance. Therefore, we have taken the approach, in line with Oxera (2008) of creating a 'composite' benchmark of TFP performance.

TFP gross output measures are available for a wide range of sectors, some of which include similar activities to those undertaken by Network Rail. The TFP measures for these sectors can be weighted on the basis of their applicability to Network Rail's maintenance and renewal activities to produce a single figure (composite) benchmark estimate for Network Rail's TFP. This requires the selection of comparator industries. For the purposes of developing the composite benchmark maintenance expenditure is split into eight categories: track; signals; E&P; telecoms; maintenance – other; overheads; NDS; and other.[55] Renewal expenditure is split into

[54] The first three of these economic cycles are sourced from HM Treasury (2005), *Evidence on the UK economic cycle*, p19. The latest cycle (1997-2006) is sourced from HM Treasury (2008), *Evidence on the economic cycle*, p23.

[55] This differs from Oxera (2008), p 28, in that we do not have sufficient data to separate out engineering costs.

eight categories: track; signalling; civils; operational property; telecoms; electrification; plant and machinery; and, IT and other.[56]

Network Rail's maintenance functions are likely to be similar to work undertaken by other large network operators. However some elements specific to Network Rail's maintenance, e.g. track, will likely be included in the transport and storage sector. Engineering works, while undertaken by other network operators, can be covered under 'other business activities' which includes engineering professional services. Renewals will have similar costs structures to maintenance, however specific construction related activities, i.e. civils and operational properties, can be compared to the construction industry.

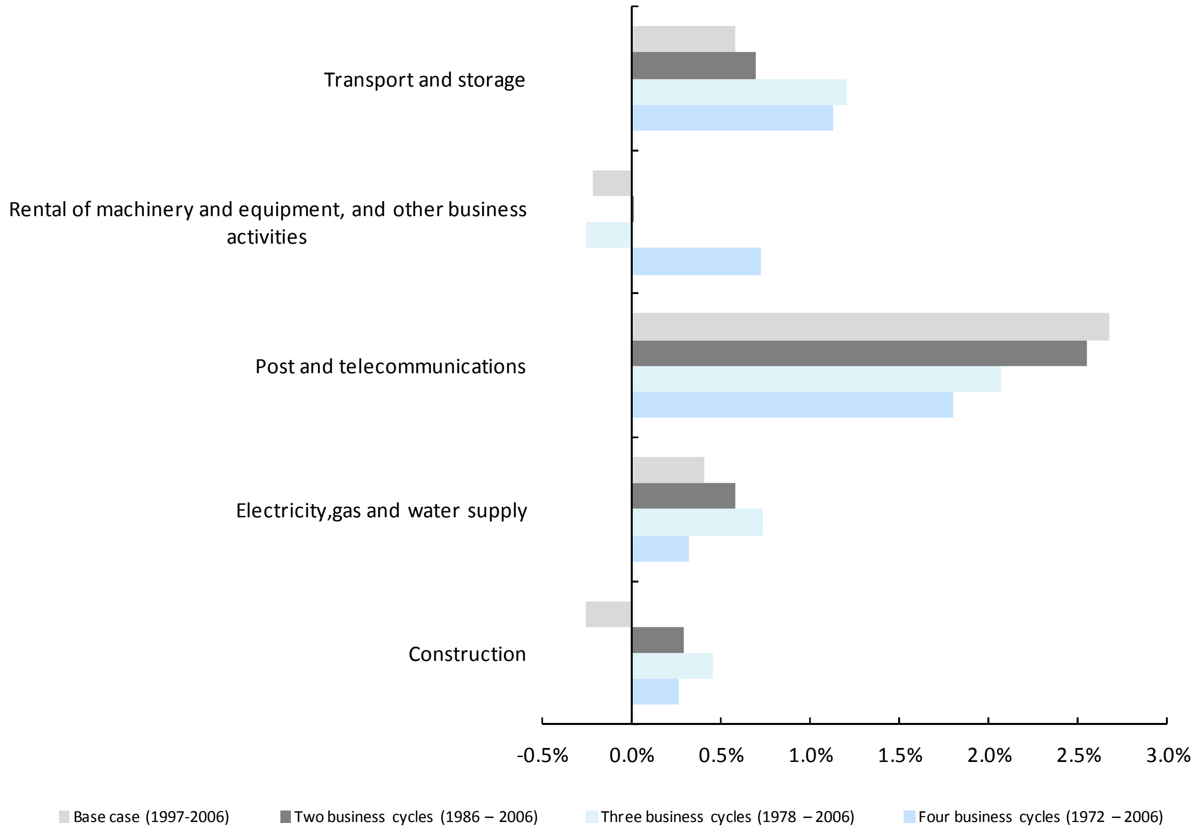
We have reviewed the KLEMS database to assess whether we could improve on the selection of comparators used in Oxera (2008), but although there are items that appear to be more comparable initially there is insufficient data on which to develop the TFP analysis. On this basis we concluded that the comparators used previously are the most appropriate for the study. There is an additional benefit, which is that this allows for easier like-for-like comparison between our results and the previous studies. These comparators include:

- **Electricity, gas and water supply.** Includes activities related to the production and distribution of electricity and gas, and the collection and treatment of water and sewerage.
- **Construction.** Includes activities related to: site preparation; building of complete constructions or parts thereof; civil engineering; building installation; building completion; and renting of construction or demolition equipment with operator.
- **Post and communications.** Includes activities related to: post and courier; and telecommunications.
- **Rental of machinery and equipment, and other business activities.** Includes activities related to: renting of transport equipment; renting of other machinery and equipment; renting of personal and household goods not elsewhere classified; hardware consultancy; software consultancy and supply; data processing; data base activities; maintenance and repair of office, accounting and computing machinery; other computer related activities; research and experimental development on natural sciences and engineering; research and experimental development on social sciences and humanities; legal, accounting, book-keeping and auditing activities; tax consultancy; market research and public opinion polling; business and management consultancy; architectural, engineering and other technical activities; advertising; and business activities not elsewhere classified.
- **Transport and storage.** Includes activities related to: transport via railways; other land transport; transport via pipelines; water transport; air transport; and, supporting and auxiliary transport activities; activities of travel agencies.

[56] This is the same breakdown as set out in Oxera (2008), p 28.

Figure A1.2 below shows gross output TFP figures for the three relevant comparators selected for our study. The figures are shown as averages over four different time periods: 1997-2006, 1986-2006, 1978-2006, and 1972-2006.

Figure A1.2 – Average annual gross output TFP growth in selected sectors



Source: CEPA, EU KLEMS

We now need to assign weights for to the comparator industries. Following from Oxera (2008) and Reckon (2011), we have calculated weightings based on Network Rail's total CP4 costs. Our weightings are based on the latest available figures for *actual* CP4 maintenance and renewals expenditure, and so are an update to the weightings used by Oxera (2008) and Reckon (2011) which used forecast costs. CP5 forecasts were not available for determining the weights. Our proposed weights are based on Network Rail's average expenditure for the relevant activities from 2009/10 to 2010/11.

The use of comparators by maintenance and renewal activities, and the associated weights are shown in Tables A1.1 and A1.2 respectively. We have provided the weights used in previous studies for reference. Note, Oxera (2008) had a separate category for engineering with a weight of 6% and matched to 'Rental of machinery and equipment, and other business activities'. We have been unable to separate this out and consider this to be spread relatively evenly over the other categories. We have included 'Rental of machinery and equipment, and other business activities' as a comparator for 'overheads' in order to capture the adjustment for indirect engineering elements.

Table A1.1 - Selected comparators for Network Rail's maintenance activities

Maintenance activities	Oxera weights (%)	CEPA weights (%)	Selected comparators
Track	36	42	Transport and storage Electricity, gas and water supply
Signals	11	16	Transport and storage Electricity, gas and water supply
E&P	5	6	Transport and storage Electricity, gas and water supply
Telecoms	6	6	Post and communications
Maintenance – other	5	3	Transport and storage Electricity, gas and water supply
Overheads*	23 (+ 6% for engineering)	23	Transport and storage Electricity, gas and water supply Rental of machinery and equipment, and other business activities
NDS	5	1	Transport and storage
Other	4	3	Transport and storage Electricity, gas and water supply Rental of machinery and equipment, and other business activities

Source: CEPA, Oxera (2008)

For maintenance functions Reckon (2011) used the same weights as Oxera (2008), however they updated the weights for renewal expenditure. Their weights are shown in Table A1.2 below.

Table A1.2 - Selected comparators for Network Rail's renewal activities

Maintenance activities	Oxera weights (%)	Reckon weights (%)	CEPA weights (%)	Selected comparators
Track	30%	29%	29%	Transport and storage Electricity, gas and water supply
Signalling	21%	17%	18%	Transport and storage Electricity, gas and water supply
Civils	17%	14%	16%	Construction
Operational property	13%	10%	11%	Construction
Telecoms	7%	9%	11%	Post and telecommunications
Electrification	4%	5%	4%	Transport and storage Electricity, gas and water supply
Plant and machinery	3%	3%	4%	Electricity, gas and water supply
IT and other	5%	11%	7%	Rental of machinery and equipment, and

				other business activities

Source: CEPA, Oxera (2008), Reckon (2011)

While there is some difference between the weights used between this and previous studies as the comparators used across a number of different categories of expenditure there little impact on the results from the weightings. To show this, we have undertaken sensitivity analysis using Oxera (2008) and Reckon (2011) weights, which is shown further below in Table A1.5.

App.1.2.3 **Capital substitution**

For the operations and support functions composite TFP benchmark an adjustment was made for capital substitution. This reflected the fact that operations and support costs predominately consist of labour costs, and capital costs (e.g. IT) would be recorded elsewhere. As we used a precise adjustment for the composite index the TFP measure reflected labour productivity (this meant that a separate allowance for capital substitution would need to be made elsewhere in Network Rail's costs to allow for this productivity to be achieved). However, as maintenance and renewals expenditure includes capital expenditure we assume that the effects of factor substitution in the comparator industries is similar. Therefore, making a further adjustment for capital substitution would be excessive.

App.1.3 **Results for Base case**

The gross output TFP benchmarks are provided in Table A1.3 below. We have included an estimate for economy wide TFP growth as well as the composite benchmarks. Our estimate for the growth in the composite benchmark; that is, performance that might be expected from a company carrying out similar maintenance and renewal activities as Network Rail, is 0.6% and 0.5% per annum respectively (including both frontier shift and catch-up).

Table A1.3: Gross output TFP growth, 1997-2006 (% per annum)

	Maintenance	**Renewals**
Economy wide TFP	0.1	0.1
Estimated TFP benchmark	0.6	0.5

Source: CEPA

Table A1.4 below provides a comparison to the composite benchmark if it were based on value-added TFP, rather than gross output, and also provides an illustration of the differences when economy-wide TFP is netted out (as is standard practice in incorporating TFP growth benchmarks into the RPI-X formula). As can be seen the implications are less serious when the economy-wide TFP growth is netted off. We have included the operations and support TFP measure, pre-capital substitution adjustment, for comparison.

Table A1.4: Net TFP growth, average % per annual

		Composite benchmark TFP (a)	**Economy-wide TFP (b)**	**Net TFP (a) – (b)**
Maintenance	**1997-2006**			
	Gross output	0.6	0.1	0.5
	Value-added	1.3	0.3	1.0

	1970-2007			
	Gross output	0.9	0.2	0.7
	Value-added	1.8	0.4	1.4
Renewals	**1997-2006**			
	Gross output	0.5	0.1	0.4
	Value-added	1.0	0.3	0.7
	1970-2007			
	Gross output	0.8	0.2	0.6
	Value-added	1.5	0.4	1.1
Operations and support*	**1997-2006**			
	Gross output	0.6	0.1	0.4
	Value-added	1.2	0.3	0.8
	1970-2007			
	Gross output	0.2	0.2	0.0
	Value-added	0.5	0.4	0.1

** Excluding capital substitution adjustment (to provide like-for-like comparison)*

Source: CEPA

We can see that for the 1997-2006 period the gross output estimates across the three different expenditure types is very similar, 0.6, 0.5 and 0.6 respectively for maintenance, renewals, and operations and support. Of course, as we convert the operations and support measure into a labour productivity measure through the capital substitution adjustment the TFP benchmark for operations and support is 1.3%.

App.1.4 **Sensitivities**

We have made a number of assumptions in formulating the composite benchmark. These assumptions impact on the composite TFP estimate. Another area, where we have not made an adjustment, but which may be considered pertinent is an adjustment for economies of scale.

Economies of scale

Network industries are commonly considered to enjoy economies of scale — as they grow in size, their costs fall in proportionate terms. If this effect is ignored, and a company has grown over the period, the estimate of TFP might be too large. We have not adjusted our base case estimates for economies of scale for the following reasons:

- we do not have robust evidence on the scale economies for all the sectors in the composite benchmark; and
- the high level of aggregation makes applying any adjustments difficult.

We note that we are consistent with Oxera (2008) which did not make adjustments for economies of scale in its base case.

We have used a cost elasticity of 0.9 in our sensitivity analysis. This is based on Oxera/LEK (2005) and Oxera (2008). Oxera/LEK noted that this is drawn from a conservative estimate of elasticities used by other consultants and academics. While there is not a lot of empirical evidence to support this as an economy wide figure, we consider that for the purposes of this study it is an appropriate value to use given that it is in line with an average for the sectors included in the composite benchmark and it maintains consistency with previous studies. For further information on the effect of the cost elasticity adjustment we have also included a sensitivity using an elasticity of 0.8.

Results

We have undertaken a number of sensitivities around our base case relating to assumptions for:

- economies of scale;
- the time period;
- comparators (electricity, gas and water supply sector only, 1997-2006);[57]
- the composite benchmark weights – using Oxera (2008) weights; and
- the composite benchmark weights – using Reckon (2011) weights;

The estimates for these sensitivities are presented in Table A1.5 below.

Table A1.5: Gross output TFP growth sensitivity analysis (% per annum)

	Maintenance	**Renewals**
Base case	**0.6**	**0.5**
Assuming 0.9 cost elasticity	0.6	0.5
Assuming 0.8 cost elasticity	0.5	0.4
Two business cycles (1986 – 2006)	0.6	0.6
Three business cycles (1978 – 2006)	0.9	0.8
Four business cycles (1972 – 2006)	0.9	0.8
Electricity, gas and water supply (1997-2006)	1.0	1.0
Oxera (2008) weights	0.6	0.4
Reckon (2011) weights	n/a	0.5

Source: CEPA

The difference between the base case and the cost elasticity sensitivities is small and for both expenditure types there is no change to the base case when a 0.9 cost elasticity is used and 0.1 percentage point change when a cost elasticity of 0.8 is used. This indicates that varying our assumption on the elasticities of scale at the margin would not have a significant impact.

[57] We note the Oxera (2008) undertook two sensitivities with different comparators: (i) replacing transport and storage with construction; and (ii) using only construction and business activities. We do not consider that Network Rail's inclusion in the transport and storage sector would unduly influence the estimates, and consider that the additional information from this industry outweighs the potential bias.

The sensitivity analysis shows that the TFP composite benchmark estimates increase when three or more business cycles are included. This indicates that TFP growth over two most recent business cycles has been slower than was experienced previously. The TFP growth in the electricity, gas and water sector is slightly higher than the composite benchmark over the most recent business cycle which is supported by the earlier Figure A1.2 which shows negative TFP growth in construction, and rental and business activities.

Using the Oxera (2008) weights for the composite benchmark has a very small impact on renewals, reducing the estimate by 0.1 percentage points from the base case. Whilst using Reckon (2011) weights for renewals does not have a noticeable impact to one decimal place.

App.1.5 **Frontier Shift versus Catch-up**

As we have discussed in Section 3.4 Total Factor Productivity (TFP) offers a method of measuring performance. It is an index based approach that quantifies 'efficiency' based on the residual or 'unexplained' component of output growth once the growth in inputs has been accounted for. This residual does not identify whether the improvement in efficiency is due to firm(s) catching up to the frontier or the frontier moving itself.

In the economy as a whole, or where there is assumed to be a reasonable amount of competition, if the sample of firms is both (i) large and (ii) random, it seems reasonable to expect that the efficiency improvement should be largely driven by frontier shift. In these circumstances, an equal number of firms ought to be moving closer to the frontier as those that are moving away from it, on average. In contrast, if the sample contains a significant proportion of companies that are commonly recognised to be experiencing catch-up, through the effect of privatisation or comparative competition, then it is appropriate to make an adjustment to the TFP figure to recognise that not all of the efficiency improvement is likely to relate to frontier shift.

The TFP composite benchmark contains industries which include companies subject to comparative competition and that may still be experiencing some of the effects of privatisation, namely the electricity, gas and water sector. Therefore, we consider that an adjustment for catch-up is appropriate.

We do not see any reason why the adjustment for catch-up efficiency should differ from that made for the operations and support composite benchmark. We have adopted the range used in this work, namely:

- 0.75 – based on Oxera (2008), which was in turn based on an academic paper (Fäire et al (1994)); and
- 0.5 – based on evidence from other regulators decisions on the mix of catch-up and frontier efficiency.

App.1.6 **Conclusion**

We consider the 1997-2006 time period to be the most relevant period over which to consider Network Rail's potential for CP5 opex efficiencies. As noted earlier, 1997-2006 is the first full business cycle since privatisation in the electricity, gas and water supply sector. In addition to being one of the comparators in our composite benchmark there is the added benefit that this business cycle broadly covers the second and third price controls for these sectors.

In Table A1.6 we set out our estimates, based on the gross output TFP estimates, for Network Rail's scope for maintenance and renewals efficiency savings over CP5 from frontier shift only. Our estimates are based on the base case composite gross output TFP estimates over 1997-2006 (0.6% and 0.5% per annum) using a 0.50 (in the low case) adjustment for catch-up (0.75 in the high case). The 0.50 adjustment is based on the lower end of other industries regulators' decisions in relation to frontier shift, and the 0.75 assumption is taken from Oxera (2008).

Table A1.7: Initial estimates for ongoing (frontier shift), based on gross output TFP

Expenditure	Range	CP5 average annual efficiency target – Frontier shift only	Total CP5 efficiency target - frontier shift only (CAGR)
Maintenance	Low case	0.3% (per annum)	1.6%
	High case	0.5% (per annum)	2.8%
Renewals	Low case	0.3% (per annum)	1.6%
	High case	0.4% (per annum)	2.2%

Source: CEPA

Note: Estimated TFP estimates are gross, i.e. ***not*** *net of economy TFP*

As we have discussed in the main report, we consider that the TFP estimate is at the lower end of the scope for improvements over CP5 as it only covers frontier shift. We note that the majority of scope for efficiency improvement outlined in the McNulty report relates to catch-up efficiency rather than frontier shift.

ANNEX A – FRONTIER SHIFT VS. CATCH-UP

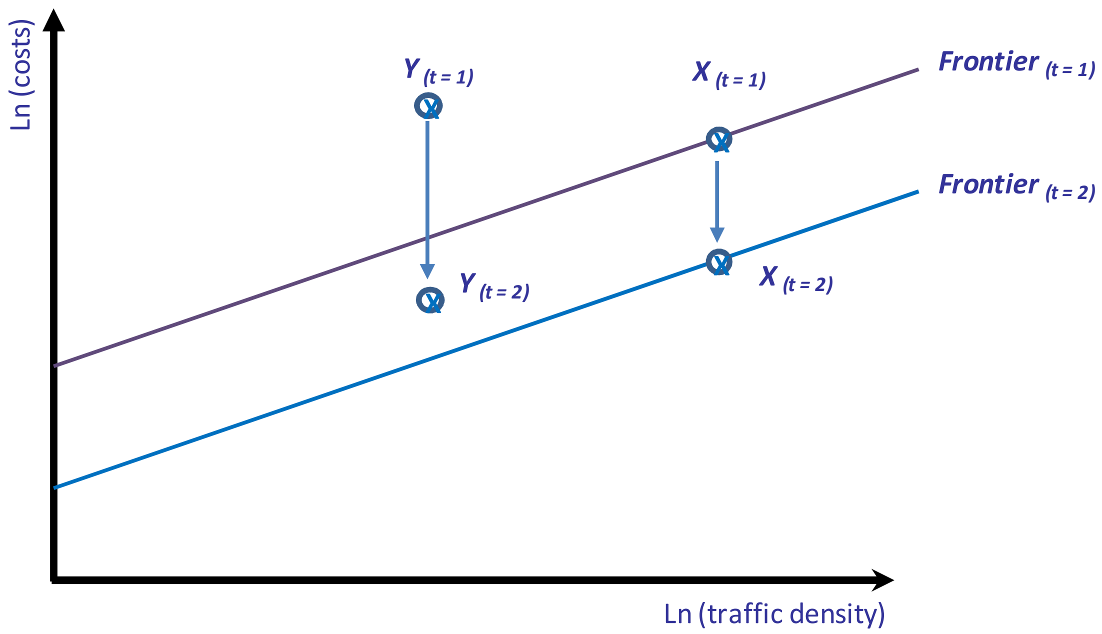
This section describes two different types of efficiency: (1) Frontier shift, and (2) Catch-up. Catch-up efficiency is perhaps more intuitive: It is defined as efficiency improvements which are made by adopting *current* technology or working practices, thus it relates to the extent to which firms should be able to catch-up to current best practice.

An organisation which is considered to be inefficient in the present is deemed to fall short of the level of efficiency that is feasible (or achievable) with current technology and working practices (also known as the frontier of performance). In order to become more efficient based on current technology, the organisation would need to update its systems / working practices in order to *catch-up* to this frontier of performance.

Frontier shift represents the movement over time that is achieved by the firms that are at the frontier of performance. For example, a frontier shift efficiency in UK Rail could be the development of a new form of train engine technology which was more efficient than the current technology, whereas catch-up efficiency would involve ensuring that all current trains had the most efficient engines based on currently available technology. It is a concept used by private companies, consultancy firms and regulators to help understand and compare businesses' performance.

Figure 6.1illustrates the situation by comparing data over two years for a number of companies. Two frontiers are therefore drawn on the diagram representing the two time periods (t=1 and t=2). In this example it will be seen that the frontier shifts downwards, indicating technological progress that reduces costs between the two periods. The frontier company, X, moves its performance in line with the frontier. The inefficient firm also improves its performance, but this time by more than the shift in the frontier, thus allowing it to move closer to the frontier. Company Y is therefore playing catch-up, and sees an improvement in its efficiency score; although it still does not quite reach the frontier.

Figure 6.1: Cost frontier shift for given output



ANNEX B – COMPARATOR INDUSTRIES RUOE

B1. Introduction

This annex contains details of our RUOE analysis for each of the specific comparator industries. Below we have included a section for each comparator, which:

- Provides a background to the sector;
- Describes the data inputs used in our analysis, including any assumptions made, and;
- Presents our results, with a comparison to Reckon (2011) where applicable.

B2. GB electricity distribution

Electricity distribution networks carry electricity from the transmission systems (and some generators) to industrial, commercial and domestic users of electricity.

There are 14 licensed distribution network operators (DNOs) in Great Britain (GB), which are owned by six different groups.[58] Each DNO is responsible for providing electricity distribution services to a particular area and are natural monopolies within each area.

In order to encourage DNO efficiency and protect consumers' interests, Ofgem administers a price control regime, which generally covers a five year period. The current price control is (Distribution Price Control Review 5, or DPCR5) the 5th control period since privatisation in December 1990. It runs from 1 April 2010 to 31 March 2015.[59]

B2.1 Data Inputs

We have sourced inputs to develop a RUOE metric for GB DNOs for the period 1992/93 - 2009/10. This section defines the data inputs, and provides details of their source. Data has been sourced from Ofgem and Oxera, who provided CEPA with access to the database used for the analysis in Oxera (2008).

Given that several sources of data were available for each type of input, it was necessary to compare them and make assumptions regarding which output measure we should use.

- **Controllable Opex.** Data sourced from Ofgem provided consistent data for five recent years (2005/06 - 2009/10), whilst the data from Oxera covered the years 1990/91 - 2006/07. The Oxera figures were considerably higher than the Ofgem figures, which is because they include "operating costs" whereas Ofgem's recent data is based on a narrower definition of controllable opex. We note that a report by Offer and Ofgas in 1999 provided a higher figure for controllable opex, which suggests that Ofgem's definition of controllable opex has narrowed over time.

  In order to create a time series for controllable opex across the entire modelling period, we took the Oxera data as our starting point. Given that the Oxera and Ofgem data

[58] There are also four independent network operators who own and run smaller networks embedded in the DNO networks, although these are excluded from this analysis.
[59] This information is sourced from Ofgem's website

sources overlapped in two years (2005/06 and 2006/07) we pro-rated the Ofgem data up to meet the Oxera data.[60]

Output measures. For electricity distributed, Ofgem distribution factsheet data[61] and the data provided by Oxera were perfectly overlapping, as such no manipulation was required to create a long time series. We sourced data from Ofgem for number of customers.

- **Economies of scale.** In line with Reckon (2011) and Oxera (2008), we have used an elasticity figure of 0.721 to allow for economies of scale in the Great Britain electricity distribution sector. This was used in a previous study for ORR by LEK/Oxera (2005), which originally sourced this 0.721 figure from a study by Burns and Weyman-Jones (1994), entitled 'The Performance of the Electricity Distribution Business: England and Wales 1971-1993'.

Finally, it is useful to provide a sense check between these inputs and those used in Reckon (2011). For opex, our figures are approximately 50% higher than Reckon's (2011) for the period 2006/07 - 2009/10, which is a significant difference. However, as discussed above, our figures for these later years are based on pro-rating Ofgem's data upwards to continue the trend in Oxera's data from previous years. Our higher figures likely reflect the broader definition of operating costs used by Oxera.

For the output measures, we note that the figures we use are the same as those published in the Reckon report for 2006/07 - 2009/10.[62]

We have excluded the year 1999/00-2000/01 from the analysis as there appears to be an abnormally large reduction in this year. This is in line with Oxera (2008), which cites the following possible reasons for this abnormal result:

- "during the third price control a significant proportion of costs were transferred from the electricity distribution business to electricity supply; and
- during the same period, the accounting standard changed from current cost accounting to historical cost accounting."[63]

[60] As we are only concerned with movements in RUOE the level of expenditure is not a concern, only its movement over time.
[61] See the Ofgem website
[62] See Reckon (2011), p68.
[63] Oxera (2008), p43.

B2.2 Results

Table B1 below shows our controllable opex RUOE results for electricity distribution network operators in Great Britain, and compares the figures with Reckon's (2011) results.

Table B1 - RUOE results for electricity distribution network operators in Great Britain (controllable opex)

Report	Period	Average annual change in RUOE (%)	Output measure used
Reckon (2011)	90/91 - 09/10 [64]	2.7	Electricity distributed (GWh)
This report	92/93 - 09/10	4.6	Number of customers
	92/93 - 09/10	4.6	Electricity distributed (GWh)

We note that in the main section of this report we have chosen to use "number of customers" as our output measure for electricity distribution, as opposed to Oxera (2008) and Reckon (2011) where electricity distributed was used. The disadvantage of using electricity distributed measure is that it has decreased in recent years due to greater energy efficiency efforts and rising prices. However, operating costs, particularly overheads, are likely to be dependent on the number of customers and length of the network.

B2.3 Sensitivity analysis

In Table B2 below we show the results of sensitivity analysis around the cost elasticity used to adjust for economies of scale.

Table B2 - RUOE results under sensitivity analysis

Output measure used and period	Scenario	Cost Elasticity	Average change in RUOE (%)
Number of customers 92/93 - 09/10	Base Case	0.72	4.6
	Sensitivity 1	0.66	4.6
	Sensitivity 2	0.88	4.8

Overall, this suggests that the results are fairly unresponsive to the cost elasticity.

[64] Reckon (2011) provide an "update" figure for 06/07 - 09/10, and then combine this with Oxera's (2008) figure for 90/91 - 06/07 to get a weighted average figure for the period 90/91 - 09/10.

B3. GB gas distribution

The gas distribution networks transport gas from the high pressure transmission system to energy users (industrial complexes, offices and homes) via a network of low pressure pipes.

There are eight gas distribution networks (GDNs) in GB, which are owned by four different groups.[65] Each GDNs covers a separate geographical region of GB.

The GDNs are regulated by Ofgem via a price control regime. Although there was a price control that applied during 2002-2007, there was a major change in the industry in 2005, whereby National Grid Gas plc were required to sell four of the eight GDNs to different ownership groups. As a result, regulation of the industry has been "reset", which means that the current price control period (GDPCR 2007-13) can be deemed to be the first.

B3.1 Data Inputs

We have sourced inputs to develop a RUOE metric for Great Britain GDNs for the period 2006/07 - 2009/10. This section defines the data inputs and provides details of their source.

- **Controllable Opex.** Controllable opex is sourced from the GDPCR financial model for 2005/06 - 2007/08, which is based on 'controllable opex' minus pensions and shrinkages costs. For 2008/09 - 2009/10, opex is taken from *Consultation on strategy for the next gas distribution price control - RIIO-GD1 Tools for cost assessment (December 2011).*

- **Outputs measures.** Annual gas demand is collected from the gas distribution companies ten-year statements (2007 and 2009) and long-term development plans (2011). For a small number of years where actual demand data was not available we have used the companies' forecasts. Ideally we would use weather adjusted demand estimates, however we were unable to collect this on a consistent basis across the GDNs.

- **Economies of scale.** In line with Reckon (2011) and Oxera (2008), we have used an elasticity figure of 0.9 to allow for economies of scale in the GB gas distribution sector. This was used in a previous study for ORR by LEK/Oxera (2005), where it was applied to total factor productivity growth in general (rather than specifically for gas distribution), and Oxera (2008) then applied this figure to the GDNs. The 0.9 figure is based on "a conservative assumption of economies of scale of 0.9 for all sectors, used by other consultants and academics" (LEK/Oxera, 2005).

We note that our opex figures are lower than Reckon (2011) estimates which we believe are sourced from company accounts rather than Ofgem; the different reporting requirements are likely to explain the differences. Our output measures are much more closely in line with Reckon: Our numbers for annual gas demand are similar (although marginally higher), and our figures for number of customers are also identical to Reckon's.

We have chosen to exclude the period 2005/06 from our analysis, in line with Reckon (2011): This was the first year following the major restructuring within the industry, and the new owners may have taken time to adjust to the reporting requirements.

[65] In addition there are a number of smaller networks owned and operated by Independent Gas Transporters (IGTs), although these have been excluded from this analysis due to their size.

B3.2 Results

Table B3 below shows our RUOE results for gas distribution network operators in Great Britain, and compares the figures with Reckon's (2011) results.

Table B3 - RUOE results for gas distribution network operators in Great Britain

Report	Period	Average annual change in RUOE (%)	Output measure used
Reckon (2011)	06/07 - 09/10	-2.6	Throughput
	06/07 - 09/10	1.0	Number of customers
This report	06/07 - 09/10	-1.8	Throughput
	06/07 - 09/10	2.1	Number of customers

We note that in the main section of this report we have chosen to use "number of customers" as our output measure for gas distribution. Reckon (2011) state their results for both output measures (throughput and number of customers). The disadvantage of gas throughput is that it has decreased in recent years through greater energy efficiency efforts and rising prices. However, operating costs, particularly overheads, are likely to be dependent on the number of customers and length of the network. Oxera (2008) used annual demand forecast (throughput) as their output measure.

B2.3 Sensitivity analysis

In Table B2 below we show the results of sensitivity analysis around the cost elasticity used to adjust for economies of scale.

Table B2 - RUOE results under sensitivity analysis

Output measure used and period	Scenario	Cost Elasticity	Average change in RUOE (%)
Number of customers 92/93 - 09/10	Base Case	0.90	2.1
	Sensitivity 1	0.80	2.0
	Sensitivity 2	1.0	2.1

Overall, this suggests that the results are fairly unresponsive to the cost elasticity.

B4. GB National Grid electricity transmission

The electricity transmission network transports electricity in bulk from generating power plants to electrical substations located near demand centres (such as towns or industries). Transmission is distinct from the local wiring between high-voltage substations and customers, which is referred to as distribution.

There are three electricity transmission networks in GB, which are owned by three different groups (Transmission Owners, or TO). However, all three networks are operated by the same System Operator (SO), which is National Grid Electricity Transmission (NGET).

The SO and each TO are responsible for the whole of the electricity transmission in a certain region in GB, which makes them monopolies. In order to improve efficiency and to keep electricity transmission costs for customers low, the SO and TOs are subject to regular price controls, which are administered by Ofgem and typically last for five years.

B4.1 Data Inputs

We have sourced data for inputs to develop a RUOE metric for NGET (the System Operator) for the period 1990/91 - 2010/11. This section defines the data inputs, and provides details of their source.

We collected inputs from several sources. Controllable operating costs were sourced from NGET's regulatory accounts and from the data provided by Oxera; Annual electricity demand (GWh) was sourced from National Grid's website. However, given that several sources were available it was necessary to make certain assumptions.

- **Controllable Opex.** NGET's regulatory accounts provide opex figures back as far as 1997/98, and up to 2010/11; Oxera's data provided controllable opex for the period 1990/91 - 2006/07; therefore there is considerable overlap between these data sources.

  In order to get comparable data from NGET we needed to calculate a measure of controllable operating costs from their accounts. We did this by following Oxera's definition of controllable opex, which is: Total opex, minus various items which are deemed as uncontrollable (including depreciation and amortisation, rates, Balancing Service Incentive Scheme costs, any payments to Scottish transmission network owners, and any transmission service scheme direct costs).

  The NGET and Oxera data were almost identical, except that we have decided to exclude amortisation, and series were combined without the need for any adjustments or assumptions.

- **Outputs measures.** National Grid's website contains their annually-produced 'seven-year statement' back to 2003. These contain data on annual electricity demanded back to 1990/91 and up to 2010/11. Our starting point was the most recent (2011) seven-year statement which provided demand figures back to 2005/06. The seven-year statement from 2007 provides figures for 2001/02 to 2004/05. The 2003 statement's demand figures were of a magnitude different to the 2007 statement which and we have pro-rated the 2007 figure back to 1990/91 using the year-on-year movements from 2003.

- **Economies of scale.** In line with Reckon (2011) and Oxera (2008), we have used an elasticity figure of 0.721 to allow for economies of scale in the GB electricity transmission sector. This figure was previously applied to electricity distribution in a study for ORR by LEK/Oxera (2005), and Oxera applied this figure to electricity transmission in 2008. The original source for this 0.721 figure is a study by Burns and Weyman-Jones (1994), entitled 'The Performance of the Electricity Distribution Business: England and Wales 1971-1993'.

Our figures are lower than those stated in Reckon (see p70). Reckon's figures exclude depreciation and BSIS costs, as ours do, but it is possible that they may include some other aspects that are excluded from our analysis (in line with Oxera). These include 'rates', any payments to Scottish transmission network owners, and any transmission service scheme direct costs. In addition, Reckon source their data from Ofgem and a Frontier Economics report, so this may create differences.

In terms of output measures, our figures for electricity demand are slightly different from Reckon's (by 1-2%). This could be because Reckon used 'weather adjusted' annual demand figures, or possibly because Reckon used a different seven-year statement to us. Oxera (2008) used 'units of electricity transmitted' and it is not clear whether this was weather adjusted or not.

Please note that the results below exclude the years 1991/92 (because it is the first year after privatisation and the data appears to be an anomaly) and 2002/03 (because a change in reporting requirements means that National Grid Company start to include the whole of the GB in their reported electricity volumes). These two exclusions are in line with Oxera (2008). In addition we have also excluded 2008/09, there is a substantial jump in National Grid's "other" expenditure (30%) for which we cannot find an explanation.

B4.2 Results

Table B4 below shows our RUOE results for National Grid's electricity transmission business, and compares the figures with Reckon's (2011) results.

Table B4 - RUOE results for National Grid's electricity transmission business

Report	Period	Average annual change in RUOE (%)	Output measure used
Reckon (2011)	90/91 - 09/10 [66]	3.6	Annual electricity demand adjusted for weather (GWh)
This report	92/93 - 10/11	5.6	Annual electricity demand (GWh, not weather adjusted)

[66] Reckon (2011) provide an "update" figure for 06/07 - 09/10, and then combine this with Oxera's (2008) figure for 90/91 - 06/07 to get a weighted average figure for the period 90/91 - 09/10.

B4.3 Sensitivity analysis

In table B5 below we show the results of sensitivity analysis around the cost elasticity used to adjust for economies of scale. The main results use a cost elasticity of 0.72, and below we show the impact of varying this elasticity to both 0.66 and 0.88.

Table B5 - RUOE results under sensitivity analysis

Output measure used and period	Scenario	Cost Elasticity	Average change in RUOE (%)
Number of customers 92/93 - 10/11	Base Case	0.72	5.6
	Sensitivity 1	0.66	5.6
	Sensitivity 2	0.88	5.6

Overall, this suggests that the results are fairly unresponsive to the cost elasticity (although we might observe some small movements if the results were shown to more decimal places).

B5. National Grid Gas

In Great Britain the gas transmission network is known as the National Transmission System (NTS). It is the network of large-diameter gas pipelines that supply gas from several natural gas terminals (situated on the coast) to both power stations and the local gas distribution networks.

The whole of the NTS is owned by National Grid Gas (NGG), which is therefore a monopoly. In order to improve efficiency and to keep gas transmission costs for customers low, NGG is subject to regular price controls, which are administered by Ofgem and typically last for five years.

B5.1 Data Inputs

Data was sourced from NGG's regulatory accounts (which go back to 2005/06), Ofgem's website (transmission annual reports back to 2004/05), and NGG's ten-year statements.

- **Controllable Opex.** We used NGG's regulatory accounts to provide controllable opex, because this provides a breakdown of opex into its constituent parts. We have chosen to take payroll costs as our measure of costs as these seem broadly consistent with Ofgem's fairly narrow definition of controllable opex.
- **Outputs measures.** NGG's ten-year statements provide annual gas demand back to 1991/92. There are several different statements which seem to provide slightly different figures, so we combined the two series that seemed to give the most central figures (namely, the figures from NGG's ten-year statements from 2002 and 2011).
- **Economies of scale.** We have used an elasticity figure of 0.9 to allow for economies of scale in the Great Britain gas transmission sector. This has been applied to the gas distribution sector by Oxera (2008) and Reckon (2011), and so it seems reasonable to apply it as a proxy measure for gas transmission. For more information on the source of this figure see the section above on gas distribution.

We note that neither Oxera (2008) nor Reckon (2011) undertook an RUOE analysis for gas transmission, and so do not have a comparator study for our inputs or our results.

B5.2 Results

Table B6 below shows our RUOE results for National Grid's gas transmission business.

Table B6 - RUOE results for National Grid's gas transmission business

Report	Period	Average change in RUOE (%)	Output measure used
This report[67]	06/07 - 09/10	2.9	Annual gas demand (not weather adjusted)

[67] Reckon (2011) do not analyse gas transmission

B6. England and Wales water

The water companies in UK and Wales were privatised in 1989 and took over responsibility for the public water and wastewater industries. There are currently 21 major water companies in England and Wales: 10 of these provide sewerage and water services (see later section), whilst 11 provide only water services. There have been several mergers of water companies in the last 20 years, and the Ofwat website contains a useful diagram of all mergers up to 2003.[68]

B6.1 Data Inputs

We have sourced inputs to develop a RUOE metric for England and Wales water companies for the period 1992/93 to 2010/11. This section describes the data inputs and their source.

Ofwat's website provides annual returns (called June Returns) back to the financial year 1992/93. These returns contain a considerable amount of information on the performance of the England and Wales water companies, including opex and output measures.

Below we provide a definition of the data inputs which were collected:

- **Controllable Opex.** Calculated as the sum of total direct costs, general and support costs, and total business activities, minus any service charges by EA (Environmental Agency). This therefore excludes some items which would normally fall under "total" opex, which are local authority rates, doubtful debts, exceptional items and any opex for third party services.[69] These figures were originally sourced from Table 21 of the June Returns, although we received this information from three different sources.

- **Output measures.** Three output measures were collected: Water delivered (MI/d) and number of properties billed (households only). [70] Water delivered was collected from table 10 of the June Returns, and to maintain consistency between years the definition 'potable water delivered' was used. Connected population and properties billed was sourced from Table 7 of the June Returns.

- **Economies of scale.** In line with Reckon (2011) and Oxera (2008), we have used an elasticity figure of 0.96 to allow for economies of scale in the water sector. This was used in a previous study for ORR by LEK/Oxera (2005), which originally sourced this 0.96 figure a Competition Commission report in 2000 ('Mid Kent Water Plc: A Report on the References under Sections 12 and 14 of the Water Industry Act 1991').

B6.2 Variance to Methodology

The RUOE measure is calculated by taking the changes in real operating expenditure, and dividing by output to get a unit cost measure over time. For the other sectors, real operating expenditure is total controllable opex and a single output measure is used.

However, for the England and Wales water and sewerage sectors, a slightly different methodology is adopted. Total controllable opex is split into two parts, direct opex and indirect

[68] The Ofwat website contains a zip folder with data from 1993-2004. In each spreadsheet, see the "mergers" tab.

[69] In line with Reckon (2011), p65.

[70] Reckon (2011) collect data on water distributed (p66) and we have provided an additional output measure.

opex.[71] Direct opex (or "Operating costs less indirect costs") is defined as operating expenditure excluding depreciation/amortisation, environmental charges, local authority rates, doubtful debts and exceptional items. It includes any expenditure on maintenance that is not capitalised (also known as cash maintenance). Indirect opex includes general and support expenditure, as well as total business activities expenditure. Direct opex RUOE uses 'population connected' as the output measure, whilst indirect opex uses 'number of properties billed' as the output measure.

A RUOE metric is formed based on direct opex using water delivered as the output measure, and a second RUOE metric is formed based on indirect opex with the output measure being properties billed. Having created these two different RUOE metrics, they are then combined together to create a weighted average RUOE metric for total controllable opex.[72]

We have excluded the results for 2005/06 from our analysis, in line with Oxera (2008), due to accounting changes (relating to the pension deficit) and volatile energy costs. In addition, we identified a number of abnormal movements in some companies' estimates, likely the result of changes to reporting practises. We have removed these year-on-year movements from our total estimates. Oxera (2008) used water delivered as the output measure for its opex RUOE.

B6.3 Results

Table B7 below shows our RUOE results for water companies in England and Wales when total controllable opex is broken down into operations (direct opex) and general and support costs (indirect opex).

Table B7 - RUOE results for water companies in England and Wales (opex breakdown)

Cost breakdown	Period	Average change in RUOE (%)	Output measure used
Operations	92/93 - 09/10	0.1	Water delivered (Ml/d)
General and support costs	92/93 - 09/10	2.2	Number of properties billed

Table B8 below shows our RUOE results when the results for 'operating' and 'general and support' costs are weighted together to give a single RUOE figure for total controllable opex. The table also compares the RUOE figures in this report with Reckon's (2011) results.

Table B8 - Total controllable opex RUOE results for water companies in England and Wales

Report	Period	Average change in RUOE (%)	Output measure used
Reckon (2011)	02/03 - 09/10 [73]	1.4	Water delivered (Ml/d) and number of properties billed
This report	92/93 - 10/11	1.1	Water delivered (Ml/d) and number of properties billed

[71] This is in line with Oxera (2008) and Reckon (2011).

[72] The weightings are determined by the relative proportions of direct opex and indirect opex.

[73] Reckon (2011) provide an "update" figure for 05/06 - 09/10, and then combine this with Oxera's (2008) figure for 02/03 - 05/06 to get a weighted average figure for the period 02/03 - 09/10.

From these two tables above (tables B7 and B8) we derive the RUOE results used in the main body of this report. Namely:

- RUOE for total controllable opex = 1.1%
- RUOE for general and support costs = 2.2%

B6.4 Sensitivity analysis

In table B9 below we show the results of sensitivity analysis around the cost elasticity used to adjust for economies of scale, using the RUOE results for total controllable opex. The main results use a cost elasticity of 0.96, and below we show the impact of varying this elasticity to both 0.9 and 1.0.

Table B9 - Total controllable opex RUOE results under sensitivity analysis

Scenario	Cost Elasticity	Average change in RUOE (%)
Base Case	0.96	1.1
Sensitivity 1	0.9	1.0
Sensitivity 2	1.0	1.1

Overall, this suggests that the results are fairly unresponsive to the cost elasticity.

B7. England and Wales Sewerage

The water companies in UK and Wales were privatised in 1989 and took over responsibility for a public water and wastewater industry. There are 10 companies within England and Wales providing sewerage services. There have been several mergers of sewerage companies in the last 20 years, and the Ofwat website contains a useful diagram of all mergers up to 2003.[74]

B7.1 Data Inputs

We have sourced inputs to develop a RUOE metric for England and Wales sewerage companies for the period 1992/93 to 2010/11. This section describes the data inputs and their source.

Ofwat's website provides annual returns (called June Returns) back to the financial year 1992/93. These returns contain a considerable amount of information on the performance of the England and Wales sewerage companies, including opex and output measures.

Below we provide a definition of the data inputs which were collected.

- **Controllable Opex.** Calculated as the sum of total direct costs, general and support costs, and total business activities, minus any service charges by EA (Environmental Agency). This therefore excludes some items which would normally fall under "total" opex, which are local authority rates, doubtful debts, exceptional items and any opex for third party services.[75] These figures were originally sourced from Table 22 of the June Returns, although we received this information from three different sources.

- **Output measures.** Three output measures were collected: population connected to the sewerage service, and number of properties billed (households only).[76] Connected population and properties billed were sourced from Table 13 of the June Returns.

- **Economies of scale.** In line with Reckon (2011) and Oxera (2008), we have used an elasticity figure of 0.96 to allow for economies of scale in the sewerage sector. This was used in a previous study for ORR by LEK/Oxera (2005), which originally sourced this 0.96 figure a Competition Commission report in 2000 ('Mid Kent Water Plc: A Report on the References under Sections 12 and 14 of the Water Industry Act 1991').

B7.2 Variance to Methodology

As with the Water sector we estimate an indirect opex and direct opex RUOE. Direct opex (or "Operating costs less indirect costs") is defined as operating expenditure excluding depreciation/amortisation, environmental charges, local authority rates, doubtful debts and exceptional items. It includes any expenditure on maintenance that is not capitalised (also known as cash maintenance). Indirect opex includes general and support expenditure, as well as total business activities expenditure. Direct opex RUOE uses 'population connected' as the output measure, whilst indirect opex uses 'number of properties billed' as the output measure.

[74] The Ofwat website contains a zip folder with data from 1993-2004. In each spreadsheet, see the "mergers" tab.
[75] In line with Reckon (2011), p65.
[76] Reckon (2011) collect data on water distributed (p66) and we have provided an additional output measure.

We have excluded 2005/06 from our analysis, in line with Oxera (2008), due to accounting changes (relating to the pension deficit) and volatile energy costs. In addition, we exclude a small number of companies' annual RUOE movements from our total estimates where these movements were identified as resulting from data inconsistencies. Oxera (2008) used population connected as its output measure for its opex RUOE.

B7.3 Results

Table B10 below shows our RUOE results for sewerage companies in England and Wales when total controllable opex is broken down into operations (direct opex) and general and support costs (indirect opex).

Table B10 - RUOE results for sewerage companies in England and Wales (opex breakdown)

Cost breakdown	Period	Average change in RUOE (%)	Output measure used
Operations	92/93 - 09/10	-0.3	Population connected
General and support costs	92/93 - 09/10	1.0	Number of properties billed

Table B11 below shows our RUOE results when the results for 'operating' and 'general and support' costs are weighted together to give a single RUOE figure for total controllable opex. The table also compares the RUOE figures in this report with Reckon's (2011) results.

Table B11 - Total controllable opex RUOE results for sewerage companies in England and Wales

Report	Period	Average change in RUOE (%)	Output measure used
Reckon (2011)	92/93 - 09/10 [77]	1.6	Population connected and number of properties billed[78]
This report	92/93 - 10/11	0.2	Population connected and number of properties billed

Note: Reckon (2011) use both Population connected and number of properties billed for their 06/07-09/10 results. However, Oxera (2008) only use population connected.

From these two tables above (tables B10 and B11) we derive the RUOE results used in the main body of this report. Namely:

- RUOE for total controllable opex = 0.2%
- RUOE for general and support costs = 1.0%

The difference in table B11 between Reckon's results (1.6%) and our results (0.2%) arise through three key differences in the methodology: (i) Reckon (2011) only calculate an "update" figure for 06/07 - 09/10 (which they then combine with Oxera's (2008) figure for 92/93 - 06/07 to get a weighted average figure for 92/93 - 09/10); (ii) we exclude doubtful debts whereas Oxera

[77] Reckon (2011) provide an "update" figure for 06/07 - 09/10, and then combine this with Oxera's (2008) figure for 92/93 - 06/07 to get a weighted average figure for the period 92/93 - 09/10.
[78]

included this; and (iii) Oxera (2008) use a different output measure to this study and Reckon (2011).

When we compare our results for 06/07-09/10 with Reckon's results for this period, they are virtually the same. This means that the difference in table B11 above is being produced during the period 92/93-06/07, which is due to a difference between our figures and Oxera's (2008) results.

B7.4 Sensitivity analysis

In table B12 below we show the results of sensitivity analysis around the cost elasticity used to adjust for economies of scale. The main results use a cost elasticity of 0.96, and below we show the impact of varying this elasticity to both 0.9 and 1.0.

Table B12 - RUOE results under sensitivity analysis

Output measure used and period	Scenario	Cost Elasticity	Average change in RUOE (%)
Population connected and number of properties billed 92/93 - 10/11	Base Case	0.96	0.2
	Sensitivity 1	0.9	0.2
	Sensitivity 2	1.0	0.2

Overall, this suggests that the results are almost totally unresponsive to the cost elasticity (although we might observe some small movements if the results were shown to more decimal places).

B8. Scottish Water – water

Scottish Water is a public corporation that provides the vast majority of water and sewerage services in Scotland. It is accountable to the public through the Scottish Government. Although it has not been formally privatised, it is subject to price control regulation - this commenced in 2002/03, and Scottish Water is now in its second price control period.

B8.1 Data Inputs

We have sourced inputs to develop a RUOE metric for Scottish Water's water business for the period 2002/03 - 2009/10. This section defines the data inputs, and provides details of their source.

Scottish Water's website provides annual returns back to the financial year 2002/03. These contain a considerable amount of information on Scottish Water's performance, including opex and output measures for its water business.

- **Controllable Opex.** Calculated as the sum of total direct costs, general and support costs, and total business activities, minus any service charges by SEPA (Scottish Environmental Protection Agency). This therefore excludes some items which would normally fall under "total" opex, which are local authority rates, doubtful debts, exceptional items and any opex for third party services.[79] These figures were sourced from Table E of the Annual Returns.

- **Output measures.** Two output measures were collected from the Annual Returns: Water delivered (MI/d) and number of customers billed.[80] Water delivered was collected from table A2 of the Annual Returns, and to maintain consistency between years the definition 'potable water delivered' was used. Number of customers billed was taken from table A1.

- **Economies of scale.** In line with Reckon (2011) and Oxera (2008), we have used an elasticity figure of 0.96 to allow for economies of scale in the Scotland water sector. This was used in a previous study for ORR by LEK/Oxera (2005), which originally sourced this 0.96 figure a Competition Commission report in 2000 ('Mid Kent Water Plc: A Report on the References under Sections 12 and 14 of the Water Industry Act 1991').

It is useful to provide a sense check between these inputs and those used in Reckon (2011). The operating expenditure figures are exactly the same, although we note that the figures presented by Reckon in their report are nominal (p66); The figures used in our model have subsequently been adjusted for RPI inflation. The figures for water distributed are almost identical: Our figures are marginally lower, and so we think Reckon may have also included 'non-potable' water in their measure.

[79] In line with Reckon (2011), p65.

[80] Reckon (2011) collect data on water distributed (p66) and we have provided an additional output measure.

B8.2 Results

For consistency with our analysis for the England and Wales water companies, we have calculated an RUOE result for general and support costs, and then for total controllable opex.

Table B13 below shows our RUOE results for Scottish Water's water service when only looking at general and support costs (indirect opex).[81] We have used the output measure of 'number of properties billed' in order to maintain consistency with the earlier section for England and Wales water companies.

Table B13 - RUOE results for Scottish Water's water business (indirect opex only)

Cost breakdown	Period	Average change in RUOE (%)	Output measure used
General and support costs	02/03 - 09/10	3.6	Number of properties billed

Table B14 below shows our RUOE for the total controllable opex involved in Scottish Water's water service, and compares the figures with Reckon's (2011) results. In order to provide a comparison with Reckon (2011), we have used water delivered as the output measure, which has been applied to both operating and general/support costs. Oxera (2008) also used water delivered as its output measure.

Table B14 - RUOE results for Scottish Water - water service

Report	Period	Average change in RUOE (%)	Output measure used
Reckon (2011)	02/03 - 09/10 [82]	1.9	Water delivered (Ml/d)
This report	02/03 - 09/10	2.1	Water delivered (Ml/d)

B8.3 Sensitivity analysis

In table B15 below we show the results of sensitivity analysis around the cost elasticity used to adjust for economies of scale. The main results use a cost elasticity of 0.96, and below we show the impact of varying this elasticity to both 0.9 and 1.0.

Table B15 - RUOE results under sensitivity analysis

Output measure used and period	Scenario	Cost Elasticity	Average change in RUOE (%)
Water delivered (Ml/d) 02/03 - 09/10	Base Case	0.96	2.1
	Sensitivity 1	0.9	2.1
	Sensitivity 2	1.0	2.0

Overall, this suggests that the results are highly unresponsive to the cost elasticity.

[81] We have not shown the RUOE results for direct operating costs only because they are not used to calculate the RUOE results for total controllable opex (this is calculated separately using a different output measure).

[82] Reckon (2011) provide an "update" figure for 05/06 - 09/10, and then combine this with Oxera's (2008) figure for 02/03 - 05/06 to get a weighted average figure for the period 02/03 - 09/10.

B9. Scottish Water – Sewerage

Scottish Water is a public corporation that provides the vast majority of water and sewerage services in Scotland. It is accountable to the public through the Scottish Government. Although it has not been formally privatised, it is subject to price control regulation - this commenced in 2002/03, and Scottish Water is now in its second price control period.

B9.1 Data Inputs

We have sourced inputs to develop a RUOE metric for Scottish Water's sewerage business for the period 2002/03 - 2009/10. This section describes the data inputs and their source.

Scottish Water's website provides annual returns back to the financial year 2002/03. These contain a considerable amount of information on Scottish Water's performance, including opex and output measures for its sewerage business.

Controllable Opex is calculated as the sum of total direct costs, general and support costs, and total business activities minus any service charges by SEPA (Scottish Environmental Protection Agency). This therefore excludes some items which would normally fall under "total" opex, which are local authority rates, doubtful debts, exceptional items and any opex for third party services.[83] The opex figures were sourced from Table E of the Annual Returns.

We also excluded private finance initiative (PFI) costs, in line with Oxera 2008 (p42), because these costs are deemed to be "uncontrollable and expensed on the basis of long term contracts. We agree that it is right to exclude them. As stated by Oxera, PPP schemes represent long run contracts that cannot be controlled, and therefore it is not possible to make efficiency gains on them. In this case the opposite effect occurs: Because the contract comes to an end in 2004, Scottish Water is able to significantly reduce their operational expenditure without having achieved any genuine efficiencies in the way the company is run.

- **Output measures.** Two output measures were collected: Population connected and number of customers billed.[84] Connected population was collected from table A3 (2003-06) and table A2 (2007-11) of the Annual Returns; Number of customers billed was taken from table A3.
- **Economies of scale.** In line with Reckon (2011) and Oxera (2008), we have used an elasticity figure of 0.96 to allow for economies of scale in the Scotland sewerage sector. This was used in a previous study for ORR by LEK/Oxera (2005), which originally sourced this 0.96 figure a Competition Commission report in 2000 ('Mid Kent Water Plc: A Report on the References under Sections 12 and 14 of the Water Industry Act 1991').

[83] In line with Reckon (2011), p65.
[84] Reckon (2011) collect data on population connected (p66) and we have provided an additional output measure.

B9.2 Results

For consistency with our analysis for the England and Wales sewerage companies, we have calculated an RUOE result for general and support costs, and then for total controllable opex.

Table B16 below shows our RUOE results for Scottish Water's sewerage service when only looking at general and support costs (indirect opex).[85] We have used the output measure of 'number of properties billed' in order to maintain consistency with the earlier section for England and Wales sewerage companies.

Table B16 - RUOE results for Scottish Water's sewerage business (indirect opex only)

Cost breakdown	Period	Average change in RUOE (%)	Output measure used
General and support costs	02/03 - 09/10	6.5	Number of properties billed

Table B17 below shows our RUOE results for the total controllable opex involved in Scottish Water's sewerage service, and compares the figures with Reckon's (2011) results. In order to provide a comparison with Reckon (2011), we have used population connected as the output measure, which has been applied to both operating and general/support costs. Oxera (2008) also used population connected as its output measure.

Table B17 - RUOE results for Scottish Water - sewerage service

Report	Period	Average change in RUOE (%)	Output measure used
Reckon (2011)	02/03 - 09/10 [86]	5.4	Population connected
This report	02/03 - 09/10	5.3	Population connected

B9.3 Sensitivity analysis

In table B18 below we show the results of sensitivity analysis around the cost elasticity used to adjust for economies of scale. The main results use a cost elasticity of 0.96, and below we show the impact of varying this elasticity to both 0.9 and 1.0.

Table B18 - RUOE results under sensitivity analysis

Output measure used and period	Scenario	Cost Elasticity	Average change in RUOE (%)
Population connected 02/03 - 09/10	Base Case	0.96	5.3
	Sensitivity 1	0.9	5.3
	Sensitivity 2	1.0	5.3

Overall, this suggests that the results are highly unresponsive to the cost elasticity.

85 We have not shown the RUOE results for direct operating costs only because they are not used to calculate the RUOE results for total controllable opex (this is calculated separately using a different output measure).

86 Reckon (2011) provide an "update" figure for 05/06 - 09/10, and then combine this with Oxera's (2008) figure for 02/03 - 05/06 to get a weighted average figure for the period 02/03 - 09/10.

ANNEX C – CONTROLLABLE OPEX RUOE RANGES

In this Annex we provide the RUOE ranges per price control and years since privatisation for each industries controllable opex. This is in contrast to the ranges in the main body of the report which only include the estimates for the water and sewerage sectors covering operations and support opex. Table C.1 provides the per price control ranges and Table C.2 contains the ranges by years since privatisation.

Table 2.7: RUOE by control period, (average % change per annum)[87]

Control period	Range	Average
First	-0.5 to 13.4	4.7
Second	-3.2 to 13.2	3.1
Third	**-1.4 to 6.5**	**3.1**
Fourth	-0.8 to 4.2	0.7
Fifth	-1.1 to 2.5	0.9

Table 2.9: RUOE by years since privatisation (average % change per annum)

Years since privatisation	Range	Average
1-5	-0.6 to 14.7	4.7
6-10	-6.0 to 6.7	1.6
11-15	**-1.5 to 6.7**	**3.5**
15+	-2.3 to 0.5	-1.1

[87] Please note that we only have a limited number of annual data points available for the Fifth price control for a number of industries, namely electricity distribution, water and sewerage. This may distort the estimates for this time period, particularly as the regulators for these industries have required the companies to achieve all estimated catch-up efficiency over the price control.

ANNEX D – METHODOLOGICAL ISSUES AND ASSUMPTIONS – COMPARISON TO PREVIOUS STUDIES

D1. Comparators

D1.1. Introduction

The Total Factor Productivity (TFP) analysis utilises TFP statistics from comparator sectors ('comparators'), which are then combined to produce a hypothetical benchmark estimate for Network Rail's TFP. These comparators are chosen to be industries/sectors which have (some) similar characteristics to the UK rail industry.

As stated by Oxera (2008), "this approach ... is based on the assumption that the productivity performance of a particular industry (i.e. UK Rail) can be represented by a weighted average of the performance of a number of other industries".

D1.2. Previous studies for ORR

LEK/Oxera (2005)

LEK/Oxera use estimates of TFP growth to "identify frontier shift" (as opposed to "catch-up"), and identifies several "reasonable sectoral comparators for Network Rail". These are:

- Electricity, gas and water supply;
- Transport (part of transport, storage and communication); and
- Construction.[88]

These sectors were chosen because "they represent network industries that need to operate, maintain and renew their network - companies that undertake construction work, including civil engineering; or transport companies." However, these choices are followed by a caveat, which is that these comparators "may therefore be more indicative of the technology growth and thus long-term cost reduction trends that Network Rail may be able to achieve".

Oxera (2008)

Oxera highlight the importance of the "comparability of the industries", and note that some industries "have the potential to achieve high productivity growth", whilst for other industries "the productivity gains... may be less significant" (specifically in relation to technological development). This governs their choice of comparators.

When specifically looking at opex, Oxera identify four different business activities, and 'possible comparators' are mapped to each of these activities, as shown in the table below. (We also discuss the percentage weightings in section 3 below.)

[88] The report also utilises the TFP figures for 'the whole of the economy' and 'market sectors' (i.e. excluding the public sector) as more general comparators.

Table 2.1 - Network Rail's business activities and possible comparators, as specified by Oxera (2008)

Weights for OPEX	%	Possible comparators
Total operations and customer services		Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total other functions		Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total corporate services		Rental of machinery and equipment and other business activities
Total group activities (insurance and pensions)		Financial intermediation

Source: Oxera (2008), p28. Underlining by CEPA.

(We also note that when considering Operations, Maintenance and Renewals (OM&R) together, Oxera identify some additional industries/sectors which are relevant comparators: Namely: Transport and storage, Construction, and Post and telecommunications. However, because this report focuses on opex, we do not consider these sectors at this stage.)

Oxera then provide an explanation for their choice of possible opex comparators:

- Operations and customer services, other functions and corporate services: "Network Rail's operating functions are similar to those undertaken by other network utilities providing operations and customer services in these activities, as well as corporate activities. There is also an elements of professional services in these activities, and thus 'Rental of machinery and equipment and other business activities' was also included in the benchmarks."
- Group activities: "Total group activities relate mostly to insurance and pensions expenditure, and therefore the most relevant comparator is 'Financial intermediation'."

Reckon (2011)

TFP

Reckon have "taken the breakdown of activities used by Oxera [2008]" and have "applied the same comparator sectors to these activities".

LEMS

In Reckon's LEMS analysis, they do not specifically identify industries as 'comparators', but instead provide estimates for the 30 most disaggregated sectors for which relevant data are available from the EU KLEMS database.[89] Taken together, these sectors cover the entire UK economy, and so are not specific to Rail.

[89] As highlighted in the Reckon report (p.95), the researchers involved in the EU KLEMS database (O'Mahony and Timmer) state that "Gross output decompositions are most meaningful at the lowest level of aggregation".

D1.3. CEPA Analysis

Summary of previous studies

- The choice of comparators is based on assumptions made in Oxera 2008, which is a refined version of the choice made in LEK/Oxera (2005).
- Conclusion: At first glance, the explanation for Oxera's (2008) choice seems reasonable, although it is based on their own assumptions rather than any further academic studies. Further analysis should be undertaken to look at the definition of the comparator sectors, and whether an alternative choice of sectors might be more or less appropriate.

Further Analysis

Oxera (2008) present the industries "for which productivity growth data is available" in Appendix of their report. These industries correspond to the sectors in the EU KLEMS database for which variables are available to undertake growth accounting for all countries, according to the EU KLEMS methodology document.[90]

From an initial analysis of the comparators used by Oxera (2008), we consider that there may be other sectors which are marginally more relevant. For example, in relation to opex, Oxera have used the industry entitled "Renting of machinery and equipment and other business activities" (code 71t74 in the KLEMS database) as a comparator. However, the industry entitled "other business activities" (code 74) might have been more appropriate, as 'rental of machinery and equipment' would more likely fall under maintenance or capex than it would under opex.

However, from a further investigation, we found that this alternative code ("other business activities"), although existing in the EU KLEMS database, only has variables available for calculating labour productivity. Some of the variables required to calculate TFP growth do not provide figures under this industry (and others that potentially could have been relevant), and so this analysis is constrained to choosing comparators from the same sample of industries that was available to Oxera (2008).

In light of this, we do not see any strong reasons to change the sectors chosen by Oxera (2008), and so propose to use the same sectors as comparators for the TFP analysis.

With regards to the LEMS analysis, Reckon analyse the 30 most disaggregated industries (the same industries as Oxera, although slightly re-labelled). However, they compare all 30 industries individually, and do not bring these industry figures together to form a composite benchmark.

D2. Weightings

D2.1. Introduction

As stated above, the Total Factor Productivity (TFP) analysis utilises TFP statistics from comparator sectors ('comparators'). In LEK/Oxera (2005), these TFP statistics are used to identify frontier shift by taking a simple mean average of the different comparator sectors.

[90] See 'EU KLEMS Growth and Productivity Accounts, Version 1.0, Part I Methodology', March 2007, p10. The industries are then listed within the 'GA' column in table 2.3, on pages 11 and 12.

However, in Oxera (2008) and Reckon (2011) these comparator statistics are used to produce a weighted average benchmark TFP estimate. Therefore, weightings must be chosen in order to combine these TFP statistics into a single figure estimate (or 'composite benchmark').

This section on 'weightings' can be considered as an extension to the previous 'comparators' section, but applicable only to Oxera (2008) and Reckon (2011).

D2.2. Previous studies for ORR

Oxera (2008)

As stated in section 2.2.2 above, Oxera propose that a small sub-group of sectors are relevant, when specifically considering opex. These sectors, along with their weightings, are shown in the table below.

Table D.1 - Weightings for Network Rail's business activities, as specified by Oxera (2008)

Weights for OPEX	%	Possible comparators
Total operations and customer services	43	Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total other functions	19	Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total corporate services	15	Rental of machinery and equipment and other business activities
Total group activities (insurance and pensions)	23	Financial intermediation

Source: Oxera (2008), p28. Circling by CEPA.

In a footnote, Oxera state that these weightings "are based on total Network Rail projected CP4 costs", which were sourced from Network Rail's 2007 business plan and operating cost data.

Reckon (2011)

TFP

For opex, Reckon "agreed with ORR to retain the weights used by Oxera... due to a lack of data for a full update".[91] However, Reckon state that this is acceptable because the weights are unlikely to have a large impact on the results:

- "Firstly, several expenditure activities are mapped to the same sector of the UK economy." This is shown in table 3.1 above, as "Total operations and customer services" and "total other functions" have the same comparators. Therefore a change in the weightings between these two categories would have no impact on the composite (weighted average) benchmark. As such, Reckon state that "even large changes in weights would have a limited impact on the value of the composite benchmark".

[91] Reckon also retain the weights for maintenance and enhancement, but update the weights for renewals expenditure.

- "Secondly, we would not expect large changes in the proportion of activities that make up expenditure categories". Reckon's weightings are the same as those used by Oxera (2008), which were originally based on Network Rail's projected expenditure for CP4, so Reckon's assumption is that Network Rail's profile of expenditure between different activities is unlikely to vary significantly from that.

LEMS

In Reckon's LEMS analysis they compare the 30 individual sectors, but do not create a composite benchmark. Therefore weightings are not required.

D2.3. CEPA Analysis

Summary of previous studies

- The choice of weightings for TFP was made by Oxera (2008), and then replicated by Reckon (2011). As stated above, Oxera's weightings are based on Network Rail's total projected CP4 costs.
- Conclusion: We consider that Oxera's assumption in relation to the appropriate comparators was good. However, it would be worth updating the weightings based on Network Rail's projected expenditure for CP5, if available, or actual expenditure during CP4.[92] However, we would not expect the results to change very much as a result, for the reasons outlined above.

Further Analysis

As above, we propose to update the weightings to reflect Network Rail's costs for CP4. Table 3.2 below sets out the revised weights based on Network Rail's average expenditure for the activities from 2009/10 to 2010/11.

Table D.2 – Opex weightings

Weights for opex	%	Possible comparators
Total operations and customer services	47	Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total other functions	20	Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total corporate services	20	Rental of machinery and equipment and other business activities
Total group activities	12	Financial intermediation

Source: ORR, Network Rail Regulatory Accounts – Statement 7b.

[92] In addition, and if time permitting, it could be useful to review Network Rail's CP4 expenditure to endure that we would get the same weightings as Oxera (2008).

D3. Cost elasticities for economies of scale

D3.1. Introduction

Economies of scale exist where an increase in the scale of production (an increase in all factors of production) produces an even larger percentage increase in output, thus reducing unit costs. The extent to which unit costs decrease is determined by the 'cost elasticity'. The cost elasticity is the ratio of marginal cost to average costs, and measures the extent to which costs vary with output. For example, if output increases by 1%, and costs rise by the same proportion (1%), the industry is said to exhibit constant returns to scale, and the cost elasticity is unity. If costs rise by less than 1%, then the elasticity is less than unity, and the industry exhibits economies of scale. In this case, as output rises, unit costs naturally fall, even if there is no change in technology or changes in efficiency. If the converse is true, the industry is said to exhibit decreasing returns to scale.

By removing this reduction in costs due to Economies of Scale (i.e. efficiency from growth in inputs), it is possible to isolate the reduction in costs due to other sources (i.e. technical change or changes in efficiency over time).[93]

These cost elasticities are applied in the TFP analysis (as in the two previous sections on 'comparators' and 'weightings'), but are also applied in the Real Unit Operating Expenditure (RUOE) analysis.

D3.2. Previous studies for ORR

LEK/Oxera (2005)

RUOE

Costs elasticities are used in the RUOE analysis, and these elasticities vary by sector. The following table shows the elasticity and the source for each sector (as stated by LEK/Oxera), and additional information on the sources is provided below:

Table D.3 - RUOE weightings in LEK/Oxera (2005)

Sector	Elasticity	Page	Original Source*
Electricity Distribution	0.7	70	Burns and Weyman-Jones (1994)
Water / Sewerage	0.96	66	Competition Commission (2000)
BT	0.9	73	Oxera assumption: TFP elasticity figure

*Additional information on sources:

- Burns and Weyman-Jones (1994): 'The Performance of the Electricity Distribution Business: England and Wales 1971-1993', Centre for the Study of Regulated Industries.[94]
- Competition Commission (2000): 'Mid Kent Water Plc: A Report on the References under Sections 12 and 14 of the Water Industry Act 1991', p.267.

[93] See LEK/Oxera (2005) p.77 for this distinction.
[94] N.B. This source is not available for free online

- "Oxera assumption: TFP elasticity figure": No formal source is provided, but LEK/Oxera refer to the figure of 0.9 for TFP growth (see below).

TFP

Cost elasticities are also used in the TFP analysis:

Table D.4 - TFP weightings in LEK/Oxera (2005)

Sector	Elasticity	Page	Original Source*
All sectors	0.9	26	"Other consultants and academics"

*Additional information on sources:

- "Other consultants and academics". No formal source is provided, but LEK/Oxera state that: "The volume adjustment used is based on a conservative assumption of economies of scale of 0.9 for all sectors, used by other consultants and academics".[95]

Oxera (2008)

RUOE

Cost elasticities are used in the RUOE analysis. In the report they do not provide the actual elasticities used, but instead make a general statement that "Oxera used industry studies and academic papers, as well as precedents, to identify appropriate estimates of economies of scale for each industry."

However, Oxera have stated (via email) that "the [economies of scale] adjustments in 2008 were as per the [LEK/Oxera] 2005 report". Oxera's e-mails also provided some further minor details:

- The elasticity for electricity distribution was 0.721 (the 2005 report stated it as 0.7).
- The same elasticity number was used for NGC (i.e. electricity transmission) as for electricity distribution.
- For BT and the Gas Distributions there was "no obvious source" and so the TFP figure of 0.9 (from the 2005 report) was used.

The final elasticity figures are presented in the table below.

Table D.5 - RUOE weightings in Oxera (2008)

Sector	Elasticity	Page	Original Source
Electricity Distribution	0.721	-	LEK/Oxera (2005), refined by email
Electricity Transmission	0.721	-	Oxera assumption: Electricity distribution figure from LEK/Oxera (2005)
Gas Distribution	0.9	-	Oxera assumption: TFP elasticity figure from LEK/Oxera (2005)
Water / Sewerage	0.96	-	LEK/Oxera (2005)
BT	0.9	-	Oxera assumption: TFP elasticity figure from

95 LEK/Oxera (2005) also conducts sensitivities with elasticities of 0.8 and 0.95

			LEK/Oxera (2005)

TFP

Although cost elasticities were utilised in the *sensitivity* analysis for TFP, they were not used in the main TFP analysis. Oxera provide several reasons for not making any adjustments for economies of scale in the main TFP analysis:

- Utility companies can benefit from economies of scale "when there is excess capacity", but equally can incur high marginal costs "when capacity is constrained".
- "Due to the complexity of network economics, the estimation of scale effects is not straightforward. Hence, reliable estimates of returns to scale over different network capacities are difficult to identify in the literature, and what evidence is available is sometimes contradictory."[96]

For the TFP *sensitivity* analysis Oxera use an elasticity of 0.9, as per LEK/Oxera (2005).

Reckon (2011)

RUOE

Cost elasticities are used in the RUOE analysis, and these are sourced from LEK/Oxera (2005) and Oxera (2008).

Table D.6 - RUOE weightings in Reckon (2011)

Sector	Elasticity	Page	Original Source*
Electricity Distribution	0.721	67	Oxera (2008)
Electricity Transmission	0.721	70	Oxera (2008)
Gas Distribution	0.9	72	Oxera (2008)
Water / Sewerage	0.96	60	LEK/Oxera (2005) and Oxera (2008)
Network Rail	0	73	Reckon assumption

*Additional information on sources:

- Reckon assumption for Network Rail: Explanation not provided, although stated that "we have not made any adjustment for potential economies of scale".

TFP

Cost elasticities are not used in Reckon's TFP analysis, as in Oxera's (2008) main analysis.

LEMS

Reckon do not make an adjustments for economies of scale in their LEMS analysis.

D3.3. CEPA Analysis

[96] Oxera (2008) then note evidence from several studies, which includes some evidence of constant returns to scale. e.g. A report for Ofwat in 2004 found that larger water and sewerage companies actually display *diseconomies* of scale.

Summary of previous studies

- The elasticity figures are primarily those by LEK/Oxera (2005), although a few additional assumptions have also are made in Oxera (2008) and Reckon (2011).
- Conclusion: Overall, additional research in this area would be beneficial. The elasticity figures are robust in one sense, as two sectors have been sourced from academic studies (electricity distribution and water and sewerage). However, the other three sectors have required assumptions to obtain an elasticity figure:
    - Electricity Transmission: Oxera (2008) assume this to be the same as the elasticity for electricity distribution.
    - Gas Distribution: LEK/Oxera (2005) assume this to be the same as the TFP growth elasticity figure (0.9), which itself does not have a formal source (Oxera refer to "other consultants and academics").
    - Network Rail: Reckon (2011) simply state that they "have not made any adjustment for potential economies of scale".

  The following section presents some thoughts for possible further work in this area.

Further Analysis

There are several areas in which further analysis would be useful:

- Research should be undertaken for the elasticities of the three sectors mentioned above (electricity transmission, gas distribution and UK rail).

  We note that for rail, the variable access charge is based on how much M&R varies with respect to traffic. Operating costs are basically assumed constant with traffic, so there is a good reason to assume that the elasticity is zero. This means that Network Rail's unit costs will naturally fall as traffic grows even if they make no improvements. There has been other evidence from France suggesting that some aspects of operating costs could have an elasticity of 0.1 (10% variable with traffic), but this is just one study and so cannot be taken as fully authoritative on its own.
- The two elasticity figures with academic sources are from 2005, which may be slightly outdated by now, so further research in the interim period (2005-2011) would be useful.
- The gas transmission sector has not been assessed in previous RUOE analyses, so we will either need to undertake research or make an assumption (e.g. same as gas distribution).
- For gas distribution (elasticity of 0.9), the original source is the TFP elasticity figure from LEK/Oxera (2005) which is based on "other consultants and academics". It would be useful to find a formal source for this figure of 0.9.
- For the two latest reports, it is questionable why cost elasticities are applied in the RUOE analysis but not in the TFP analysis. In Oxera's (2008) TFP analysis they state that: "reliable estimates of returns to scale over different network capacities are difficult to identify in the literature, and what evidence is available is sometimes contradictory". So it

would be useful to understand why they should then be applied in the RUOE analysis. From our internal thinking, we suspect this is because analyses of operating costs are more plentiful and subject to fewer problems, whereas studies of total cost run into issues of how exactly to measure the capital input.

- Following from the point above, it is debatable whether elasticities should applies to the TFP analysis and /or the LEMS analysis. Reckon (2011) did not, but Oxera (2008) included an elasticity adjustment in a sensitivity scenario in its TFP analysis. The approach taken by Oxera (including economies of scale as a sensitivity) provides the most flexibility and so seems to be the preferable approach.

- Finally, it is interesting to consider whether economies of scale should be netted off from the efficiency gains. If a network operator is able to become more efficient by getting closer to the scale of production where it is most efficient (known as the Minimum Efficient Scale of Production, or MES), then (debatably) this is a "valid" way to become more efficient. If efficiency gains from economies of scale are netted off, then this removes the incentives for operators to produce at their most efficient scale of production.

  However, whilst we consider this to be an interesting point, the scale effects on costs are largely uncontrollable. Therefore, it is still useful to decompose the different sources of unit cost changes, because if a lot of the growth achieved by other industries has been achieved through scaling up, it is not feasible for rail to achieve the same efficiencies.

  In fact, as noted above, in reality it will be the other way round. Other industries have quite high elasticities (though whether these are relevant for opex, as opposed to all costs is not clear) whereas Network Rail has an elasticity close to zero. Therefore, we might expect Network Rail to have a *higher* unit cost reduction than those from other sectors. It would also be interesting to see whether the elasticities are related just to opex or maintenance, as that could affect the comparison.

D4. Business Cycles

D4.1. Introduction

The business cycle has the potential to affect productivity measures in a way that is exogenous to (or independent of) an industries level of efficiency. Productivity (defined as the change in the value of outputs divided by the change in the value of inputs) could increase significantly during an economic boom (from an increase in demand for outputs), but this would not necessarily reflect the industry's underlying efficiency.

In using total factor productivity (TFP) measures to create a composite benchmark for Network Rail's performance it is important to take account of exogenous factors to the extent possible. Therefore, when choosing the time period for the dataset, our analysis will need to consider the impact of the business cycle.

The three previous studies have considered this issue to greater or lesser degrees, and are discussed below.

D4.2. Previous studies for ORR

LEK/Oxera (2005)

Since the aim of LEK/Oxera's project was to "establish a *long-term* annual opex reduction benchmark" for Network Rail, they state that "any external benchmarks need to be constructed over reasonably long time periods to mitigate the impact of atypical performance". Therefore, they utilise data over a long time period (1973-99) and calculate TFP growth rates over three alternative periods: (i) 1973-99; (ii) 1979-99, and; (iii) 1989-99. The results are shown below.

Figure D.1 - LEK/Oxera's TFP results

Sectoral TFP growth adjusted for volume growth (average % pa)

	1989–99	1979–99	1973–99
Electricity, gas and water	3.2	2.7	2.7
Construction	0.7	1.7	1.2
Transport	2.3	3.0	2.4
Total market sectors	0.8	1.2	1.2
Total economy	0.9	1.1	1.1
Range	**0.7–3.2**	**1.1–3.0**	**1.1–2.7**
Average	**1.6**	**1.9**	**1.7**
Average using 0.8 as economies of scale	1.4	1.6	1.5
Average using 0.95 as economies of scale	1.7	2.1	1.8

Source: LEK/Oxera (2005)

The results above show that changing the data period does make a noticeable difference to the TFP benchmark results.

Oxera (2008)

Oxera highlight the importance of choosing data that ensures a "like-for-like comparison" with the data that is being benchmarked (i.e. UK rail). As part of this, they state the need to make TFP growth comparisons which "are made over complete business cycles to avoid misrepresenting the impact of recessionary or growth periods... or atypical performance".

To find data periods which consist of "at least one business cycle", Oxera analyse real value-added growth in the UK economy from 1970 to 2004. Their analysis concludes that:

- "1970-80 was characterised by sharp fluctuations in the level of value-added [economic growth]" and;
- "The 1981-2004 period covers two whole business cycles".

Therefore, Oxera created their TFP growth benchmarks based on the period 1981-2004. However, they also undertake further sensitivity analysis by assessing both the full dataset (1970-2004) and also a smaller recent period (1990-2004). Their results are shown below in figure 5.2.

Figure D.2 - Oxera's TFP results

Sensitivity analysis for the TFP growth benchmarks (% per year)	OPEX	Maintenance	Renewals	OM&R
Base case results	1.0	2.1	2.1	1.9
Expanding the period (1970–2004)	0.8	2.2	1.9	1.8
Reducing the period (1990–2004)	1.3	1.6	1.7	1.6

Source: Oxera (2008)

The results above show that changing the data period makes a fairly significant difference to the TFP benchmark results, particularly for opex.

Reckon (2011)

In contrast to Oxera (2008), Reckon do not analyse the business cycle to identify the time period for constructing the TFP composite benchmark. Reckon (2011) state that "we have not attempted to map our chosen data period to include a specific number of business cycles" because "we do not believe that we have a sufficient understanding of the nature of the business cycle to do this".

Instead, Reckon consider two time periods within their TFP analysis: Firstly, the whole period of available data from EU KLEMS, which is 1970-2007, and; Secondly, a marginally more recent subset, which is 1981-2007. This latter period is chosen as utilises more recent data (up to 2007) to provide an update of Oxera's 1981-2004 analysis. Therefore, although Reckon specifically note their intention to not analyse the business cycle, their choice of time periods closely reflects the Oxera report (albeit without choosing one particular period for Reckon's "main" analysis). Reckon's results are shown in figure 5.3 below.

Figure D.3 - Reckon's TFP results

TFP composite benchmarks for opex, maintenance and renewals	Opex	Maintenance	Renewals
Oxera (2008) benchmark 1981–2004	1.0	2.1	2.1
Updated benchmark 1981–2007	1.1	1.8	1.6
Updated benchmark 1970–2007	1.0	2.0	1.5

Source: Reckon (2011)

These results show a lower variation with respect to the time period (compared to the Oxera report), although this difference may be exaggerated due to rounding. In addition, Reckon do not analyse the smaller (more recent) time period (1990-2004), so we are unable to see how these compare.

In Reckon's main LEMS analysis, the time period 1970-2007 is used. However, they also undertake sensitivity analysis "to get a better understanding of how the choice of time period affects the estimates". These additional periods are 1987-2007 and 1997-2007.

Reckon find that the time period sometimes has an impact on the LEMS results, but not always. One hand, "the average annual growth in the LEMS cost measure over the last ten years appears lower for the majority of sectors (compared to the last 35 years), in some cases by as much as one percentage point". On the other hand, "the choice of time period seems to have less effect in the case of gross output TFP".

D4.3. CEPA Analysis

Summary of previous studies

- As an initial caveat, it should be noted that it is difficult to make precise judgements from a comparison of these studies because they only provide TFP results to one decimal place.
- In spite of this, the three studies show that the choice of time period can make a fairly significant difference. Ranking the three studies in terms of how large the impact of the time period is on the TFP results:
    1. Oxera (2008) show that the time period can have a fairly significant effect on the TFP opex benchmark;
    2. LEK/Oxera (2005) show a smaller, yet still noticeable difference from time period sensitivities (although they do produce an opex-specific benchmark).
    3. Reckon (2011) indicate a relatively small impact on opex from changing the time period (although they do show a large impact on their maintenance and renewals benchmarks).
- However, the studies do provide contrasting approaches to the time period analysis. Whilst Oxera (2008) specifically aim to provide benchmarks across "at least one business cycle", Reckon (2011) do not believe that they have a "sufficient understanding of the nature of the business cycle" to do this.[97]
- Conclusion: Overall, we think that the results in these studies show sufficient sensitivity to the time period to merit undertaking analysis across several time periods. We assess different time periods both in our TFP analysis and our LEMS analysis, in line with Reckon (2011).

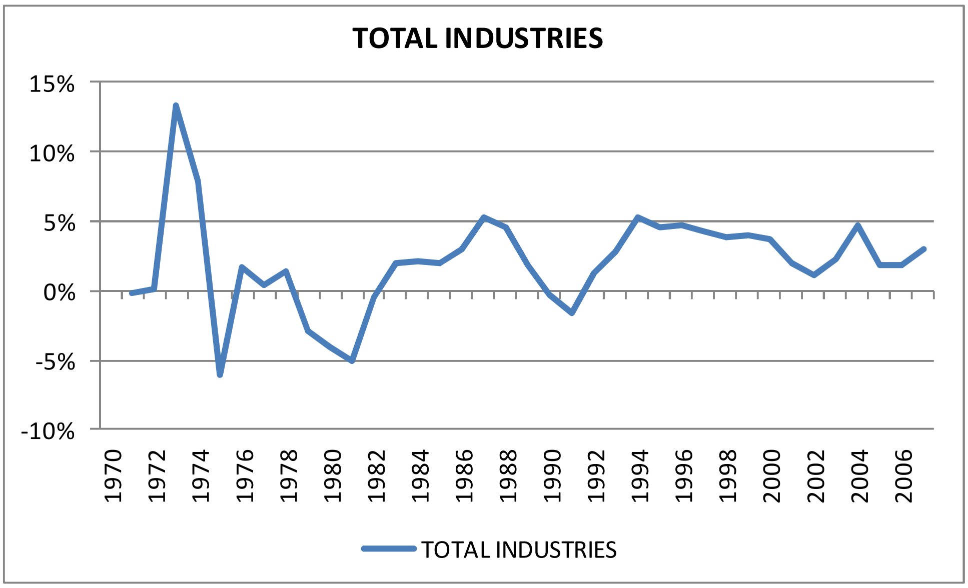
  In terms of the approach, it is useful that Oxera (2008) and Reckon (2011) have provided contrasting views to time period analysis (see above), with the former attempting to define business cycles and the latter not. We would suggest further research and analysis into the (potential) existence of business cycles.

Further Analysis

Firstly, we have calculated the annual change in UK real gross output (a measure of economic growth) using output and price-level inputs from the EU KLEMS database. The trend is shown in figure 5.4 below.

[97] The first study by LEK/Oxera (2005) simply analyses three time periods, but does not discuss the business cycle.

Figure D.4 - Annual change in UK real gross output, for all industries

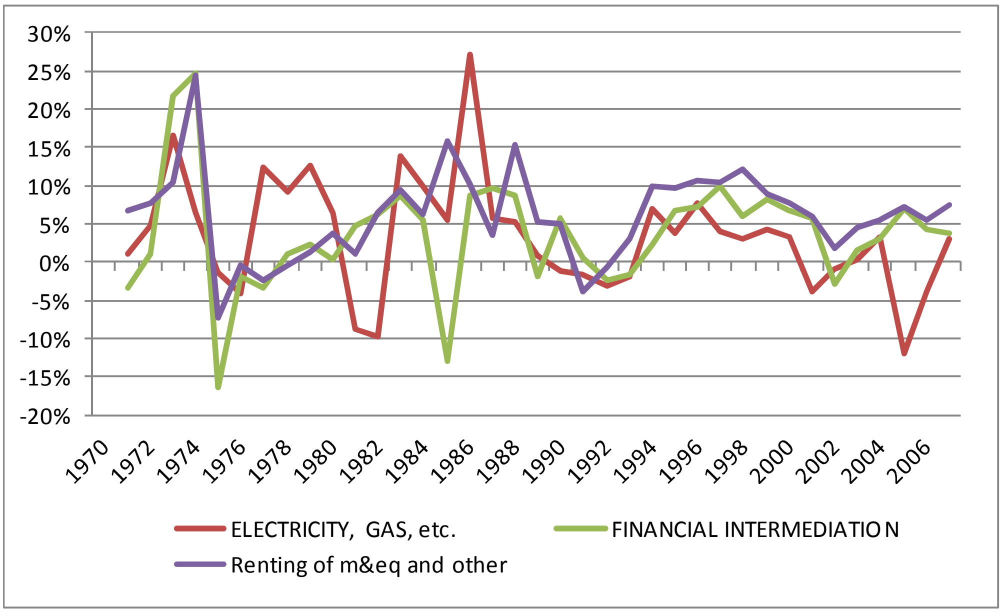


Source: EU KLEMS database

As identified by Oxera (2008), there do seem to be two fairly clear business cycles between 1980 and 2002 (both trough to trough). The periods either side of this (1970-1980 and post 2002) seem to involve more fluctuations, and the trend is less clear.

It is also useful to consider the industries that we might use to create the TFP composite benchmark. Figure 5.5 below shows the real annual growth in gross output for these industries.

Figure D.5 - Annual change in UK real gross output, for selected industries



Source: EU KLEMS database

The results seem to suggest a clear business cycle over the period 1992-2002, although the other potential cycle during the 1980s is less clear due to the large fall in Financial Intermediation output in 1985. Ideally, analysis of average growth rates should be done across a business cycle, peak-to-peak or trough-to-trough, which allows for the different utilisation of resources at different stages of the cycle to be taken into account. If only part of a business cycle is included in the time period analysed then the results can be affected by capacity utilisation.

Possible approaches would be:

- To undertake a primary analysis for the period 1980-2007, which is much in line with Oxera (2008) and Reckon (2011). This appears to include data for two business cycles (1980-2002), plus the most recent years (2003-07) where there have been some small (although not insignificant) fluctuations.
- To also undertake analysis for some other time periods, in order to get a sense of how the results might be affected by our choice of period. For example, such periods could include: (i) The whole dataset (1970-2007); A shorter dataset (1990-2007); and the period since Hatfield (2000-2007).

ANNEX E – COMPARISON OF OUTPUT AND VALUE-ADDED PRODUCTIVITY

In general, the data in the KLEMs database has higher value-added TFP growth than output TFP growth across various industries.[98] The formal relationship between TFP_O and TFP_{VA} can be shown as:

$$TFP_{VA}=1/S_{VA} * TFP_O \qquad (3)$$

where S_{VA} relates to the share of value-added in gross output. Since S_{VA} is less than one, TFP_{VA} is greater than TFP_O.

As discussed in Section 3.2.3, value-added TFP growth is a less intuitive measure at an organisation or industry level. A firm production function sees firms producing (gross) output using labour, capital and intermediate inputs. TFP measures based on value added impose restrictive (separability) assumptions on the production function. This implies, for example, that changes in the price of intermediate inputs does not affect the firm's decision on the relative use of the two primary inputs, capital and labour. As quoted in the OECD manual:

"Conceptually the [value added TFP measure] is not an accurate measure of technical change [at industry or firm level]. It is however an indicator of an industry's capacity to contribute to economy wide growth of income per unit of primary input" (OECD, 2001)

"Conceptually, KLEMS-MFP [gross output measure] is the most appropriate tool to measure technical change by industry as the role of intermediate inputs in production is fully acknowledged;

Finally, it should be noted that gross output TFP data are also less sensitive than value-added TFP to the degree of outsourcing within an industry or firm.[99]

[98] OECD 2001, Measurement of aggregate and industry level productivity growth p. 27.
[99] OECD (2001), p 31.

ANNEX F – CAPITAL SUBSTITUTION ESTIMATES

As gross output TFP includes intermediate inputs are assumed to contribute to productivity growth the calculation of the capital substitution adjustment is different from that used for value added TFP. The derivation of this calculation is shown below, starting from the standard log TFP equation (F.1):

$$(G.1) \qquad \Delta \ln TFP = \Delta lnY - s_K \Delta lnK - s_L \Delta lnL - s_M \Delta lnM$$

Where TFP is gross value-added productivity, intermediate inputs are denoted M, output is denoted Y, labour is denoted L, capital is denoted K, and s_L, s_K and s_M is are labour, capital and materials share of value respectively. Dividing both sides through by ΔlnL:

$$(G.2) \qquad \Delta \ln TFP - \Delta lnL = (\Delta lnY - \Delta lnL) - s_K \Delta lnK - s_L \Delta lnL - s_M \Delta lnM$$

Since $(\Delta lnY - \Delta lnL) = \Delta \ln(Y/L)$, we can substitute this into F.2 to get:

$$(G.3) \qquad \Delta \ln TFP - s_L \Delta lnL = \Delta \ln \left(\frac{Y}{L}\right) - s_K \Delta lnK - s_L \Delta lnL - s_M \Delta lnM$$

Which can be written as:

$$(G.4) \qquad \Delta \ln \left(\frac{Y}{L}\right) = \Delta \ln TFP + s_K \Delta lnK - (s_L - 1) \Delta lnL - s_M \Delta lnM$$

Since $(s_L - 1) = -(s_K + s_M)$, we can substitute this into F.4 to get:

$$(G.5) \qquad \Delta \ln \left(\frac{Y}{L}\right) = \Delta \ln TFP + s_K \Delta lnK - (s_K + s_M) \Delta lnL - s_M \Delta lnM$$

Rearranging F.5 gives us:

$$(G.6) \qquad \Delta \ln \left(\frac{Y}{L}\right) = \Delta \ln TFP + s_K \Delta \ln \left(\frac{K}{L}\right) + s_M \Delta \ln \left(\frac{M}{L}\right)$$

Which is equivalent to Equation 3.3:

$$(3.3) \qquad gLP = gTFP + S_k(g(K) - g(L)) + S_M(g(M) - g(L))$$

Table F.1 below provides our estimates for the capital substitution adjustments. These were calculated on the basis of the Equation 3, in Section 3.2.6.

Table G.1: Capital substitution adjustments

	Base case (1997-2006)	Two business cycles (1986-2006)	Three business cycles (1978-2006)	Four business cycles (1972-2006)
Economy-wide	0.4%	0.4%	0.5%	0.5%
Electricity, gas and water supply	0.7%	1.4%	0.9%	0.9%
Rental of machinery and equipment, and other business services	1.0%	0.8%	1.0%	1.0%
Financial intermediation	0.2%	0.5%	0.7%	0.7%
Composite benchmark	0.8%	0.9%	1.0%	0.9%

ANNEX G – LEMS COST MEASURE

The mathematical calculations for the LEMS cost measure draw on Reckon (2011), Appendix *to analysis of EU KLEMS data*. The annual growth in LEMS cost measure is defined as follows:

$$(H.1) \qquad \Delta\text{LEMS} = \Delta GO + ((\Delta KQ + \Delta GOP) \times {}^{K}/_{GO} - {}^{dK}/_{GO})/(1 - {}^{K}/_{GO})$$

Where: ΔLEMS is the logarithmic growth in LEMS cost in a sector ΔGOP is the logarithmic growth in the gross output price index for the sector; ΔKQ is the logarithmic growth in the flow of services from capital used in sector; K/GO is the proportion of gross output value accounted for by services from capital; and ${}^{dK}/_{GO}$ is the annual change in the value of services from capital, expressed as a proportion of the value of gross output.

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