



OFFICE OF RAIL REGULATION (ORR)

**UPDATE REPORT ON THE SCOPE FOR IMPROVEMENT IN THE
EFFICIENCY OF NETWORK RAIL'S EXPENDITURE OVER CP5**

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FINAL REPORT

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EXECUTIVE SUMMARY

This report has been prepared by Cambridge Economic Policy Associates (CEPA) for the Office of Rail Regulation (ORR) to provide updated estimates of productivity in relation to Network Rail's support and operations expenditure, maintenance and renewals expenditure, enhancement expenditure as well as total expenditure. These estimates are designed to help ORR set Network Rail's scope for efficiency improvement over Control Period 5 ('CP5', April 2014 to March 2019).

The work in this report is an update of our analysis in a previous report for ORR (CEPA 2012). The three key areas that this report addresses are:

- updates to previous productivity estimates to reflect latest data – Network Rail Strategic Business Plan (SBP);
- extended analysis to encompass enhancements expenditure; and
- estimates of total expenditure efficiency.

We have updated our previous total factor productivity (TFP) analysis using Network Rail's forecast CP5 data for support and operations, maintenance and renewals, and enhancement expenditure taken from Network Rail's Strategic Business Plan. We have estimated an overall ongoing efficiency estimate for Network Rail's total expenditure and have also provided ongoing efficiency estimates for support and operations under the assumption of constant capital.¹ These estimates provide a further comparison for the adjusted TFP measure presented in CEPA (2012) which allowed for capital substitution. We combined the estimates for support and operations with estimates for maintenance and renewals, and enhancement to derive a weighted total estimate for total expenditure. It should be noted that, as is the case for all benchmarking exercises, there are limitations to the level of comparability that can be achieved with Network Rail. However, in developing the frontier shift estimates we have taken a similar approach to previous ORR price controls and a consistent approach with other UK regulatory precedents.

Our chosen comparator sectors mainly include firms operating in competitive markets. Over a long period of time their performance should represent the performance of an efficient firm and hence we expect the catch-up efficiency component for these firms to be zero. However, our composite benchmark also includes regulated companies that may still be experiencing catch-up. Hence we have adjusted the TFP measure to exclude the component of catch-up efficiency, using estimates of 0.75 and 0.5 based on relevant academic work, previous studies and regulators' decisions within the industries included in the composite benchmark. Given that the regulated companies make a relatively small proportion of the comparator base (although this is somewhat higher for maintenance and renewals) we consider that these adjustments are conservative in relation to frontier shift. Therefore we have also presented the results without any adjustment for catch-up; that is, assuming 100% of efficiency change is due to frontier shift.

¹ The adjusted TFP at constant capital provides an estimate of the required changes in the volume of labour and intermediate to achieve the TFP, with no change in capital or output.

We carried out sensitivities around our base case results for different business cycles and for economies of scale, and while the results show some difference we do not consider these significant enough to deviate from the base case results. Therefore, for our base case we retained the time period from 1997-2006 (the most recent business cycle) and we made no adjustment for economies of scale.

Table E.1 below provides the average annual efficiency estimates and compound annual growth rates (CAGR) over CP5 for the three measures after adjusting for catch-up. We have presented the results under the different assumptions for catch-up; that is, assuming 50% (low case), 75% (median case) or 100% (high case) of efficiency change is frontier shift in the table below. We prefer using the 0.75 adjustment which is in between the two extremes of no adjustment or the 0.5 adjustment.

The figures in grey represent the annual percentage change in total expenditure which is calculated as a weighted average of the individual components. The weights are equal to the share of individual expenditure categories in total expenditure; this is 12% for support and operations, 53% for maintenance and renewals and 35% for enhancements.

Table E.1: Summary of estimates for ongoing efficiency gains over CP5

Expenditure	Low case (50% frontier shift)		Median case (75% frontier shift)		High case (100% frontier shift)	
	% p.a.	CAGR	% p.a.	CAGR	% p.a.	CAGR
Support and operations (TFP)	0.3	1.4	0.4	2.1	0.6	2.8
Support and operations (Adjusted TFP)	0.6	3.1	1.0	4.7	1.3	6.2
Support and operations (Adjusted TFP at constant capital)	0.3	1.7	0.5	2.5	0.7	3.4
Maintenance and renewals	0.2	0.9	0.3	1.4	0.4	1.8
Enhancement	0.3	1.3	0.4	1.9	0.5	2.5
Total expenditure (TFP for all)	0.2	1.1	0.4	1.6	0.5	2.2
Total expenditure (Adjusted TFP for support and operations)	0.3	1.3	0.4	2.0	0.6	2.6
Total expenditure (Adjusted TFP at constant capital for support and operations)	0.2	1.1	0.4	1.7	0.5	2.3

*Note: Estimated TFP estimates are gross, i.e. **not** net of economy TFP.²*

There are differences in the CAGR as they are based on unrounded figures.

² Economy wide TFP (or real price effects) is usually netted off from the gross frontier shift. This is done to avoid a double count as RPI implicitly captures economy wide inflation as it reflects the changes in price of inputs less productivity gains.

The choice between the approaches provided in Table E.1 above depends on how ORR estimates Network Rail's expenditure requirements for CP5. The approaches presented in Table E.1 rely on different assumptions relating to the underlying data and the interactions between different parts of the price control, which are set out briefly below:

- **Adjusted TFP.** The 'adjusted TFP' measure (which is a labour and intermediate inputs productivity measure) takes account of operations and support expenditure excluding capex, this results in capital substitution appearing as productivity changes. To maintain consistency with overall TFP, where capital substitution is captured in the adjusted TFP estimate appropriate allowances for capex should be made to avoid double counting productivity changes. We note that the adjusted TFP measure was used by ORR for operations and support expenditure in PR08.
- **Adjusted TFP at constant capital.** The 'adjusted TFP at constant capital' measure relies on the assumption is that, for support and operations expenditure, Network Rail is able to achieve the same level of measured TFP in the comparator sectors by changing its opex (labour and intermediate inputs) only and not through changes to opex and/or capex. This measure assumes no change in the volume of capex and output and therefore provides an estimate of the change in the volume of labour and intermediate inputs required to achieve the measured TFP change. While this measure was used by Ofgem in its recent RIIO-GD1 and T1 price controls we have some concerns with the assumptions required in adjusting the comparator sectors' data for constant capital.
- **TFP.** The TFP measure captures the change in the volume of outputs that are not attributed to changes in all the (measured) volume of inputs. If ORR is setting a total expenditure productivity frontier shift for Network Rail then this approach may be the most appropriate as it avoids some of the consistency requirements, from the interactions between the different parts of the price control, and assumptions of the adjusted TFP approaches.

We have presented gross estimates in Table E.1, that is, without the economy wide TFP growth subtracted, to be consistent with CEPA (2012). The estimates, however, can be converted by subtracting the economy wide TFP (0.1% per annum).

1. INTRODUCTION

1.1. Aim of study

This report has been prepared by Cambridge Economic Policy Associates (CEPA) for the Office of Rail Regulation (ORR) to provide updated estimates of productivity in relation to Network Rail's support and operations expenditure, maintenance and renewals expenditure, enhancement expenditure as well as total expenditure. These estimates are designed to help ORR set Network Rail's scope for efficiency improvement over Control Period 5 ('CP5', April 2014 to March 2019).

The work in this report is an update on our analysis in a previous report for ORR (CEPA 2012). The three key areas that this report addresses are:

- updates to previous productivity estimates to reflect latest data – Network Rail Strategic Business Plan (SBP);
- extended analysis to encompass enhancements expenditure; and
- estimates of total expenditure efficiency.

1.2. Structure of report

Following this introduction the report is structured as follows:

- Section 2 provides CEPA's methodology for estimating total factor productivity (TFP), the formation of the composite benchmark and our estimates including sensitivity analysis.
- Section 3 sets out CEPA's conclusions and estimates for Network Rail's scope for total expenditure efficiency improvements as well as support and ops, maintenance and renewals and enhancement expenditure efficiency improvements over CP5.

Annex A provides a comparison of the weights used in the 2012 study and the updated weights used in this study. Annex B provides a summary of recent regulatory decisions for comparisons. Annex C provides the formula for the adjusted TFP measure.

2. TFP

2.1. 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. Although as noted above they also reflect other differences, such as variation in the scale of production. They can be used both to compare firms/ industries at a specific point in time and over time. TFP is a measure that is commonly used by regulators in the UK and internationally to determine ongoing efficiency ('frontier shift') targets for regulated companies.

A common type of TFP measure is based on a Törnqvist index which is a geometric index using the component's share of total value to weight its movement e.g. the movement in the volume of labour is weighted using labour's value share of GDP. Hereafter, when we refer to "TFP" we are referring to a Törnqvist TFP index (as opposed to, for instance, a Malmquist TFP index which is discussed below).

The approach quantifies TFP change based on the residual or 'unexplained' component of output growth once the growth in inputs has been accounted for. In other words if output increased by 5%, but inputs only increased by 4% then TFP represents the growth in outputs over and above the growth in inputs i.e. 1% in this example. This residual does not identify whether the improvement in TFP is due to the firm(s) catching up to the frontier or the frontier itself moving (or indeed due to changes relating to scale effects). Instead, it is necessary to attribute the TFP 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 the efficiency improvement is likely to relate to frontier shift.

We note that there are two types of frontier shift that can be considered - *gross* frontier shift and *net* frontier shift. These are discussed in Text Box 2.1 below.

Text Box 2.1: Gross frontier shift and net frontier shift

Some consideration needs to be given to determining whether a gross or net frontier shift should be applied in the X-factor. Gross frontier shift means the productivity gains that can be achieved by a firm or industry resulting from technical change, whilst net frontier shift refers to the difference between the technical change achieved in the firm or industry and that achieved by the economy as a whole.

Input prices need to be taken into account as well as productivity gains associated with frontier shift in order to get at cost-based trend measures. The equations for expressing cost trends (which can also be referred to as output price movements) for both a particular business and the economy are well established and can be represented in the following equations for the firm and the economy, respectively:

$$\text{Firm: } P_{FB} = P_{IB} - TFP_B \quad (\text{i})$$

Where variables in *italics* denotes growth rates, P is price movements, TFP refers to total factor productivity movements, B refers to a business, F refers to final outputs and I refers to intermediate inputs/outputs.

The economy-wide measure of inflation, represented by RPI, captures both changes in input prices and TFP across the economy and this can be subtracted from both sides of equation (i):

$$P_{FB} - RPI = P_{IB} - TFP_B - RPI \quad (\text{ii})$$

Rearranging, we have:

$$P_{FB} - RPI = (P_{IB} - RPI) - TFP_B \quad (\text{iii})$$

The first term on the right hand side of (iii) is termed differential inflation (or ‘real price effects’). The remaining term is a measure of the gross efficiency improvements that the regulated company can be expected to achieve. Therefore, the productivity adjustment term in the X-factor should reflect the difference between the sector’s productivity and that of the economy as a whole. Equation (iii) can also be represented as (where E refers to the whole economy):

$$P_{FB} - RPI = (P_{IB} - P_{IE}) - (TFP_B - TFP_E) \quad (\text{iv})$$

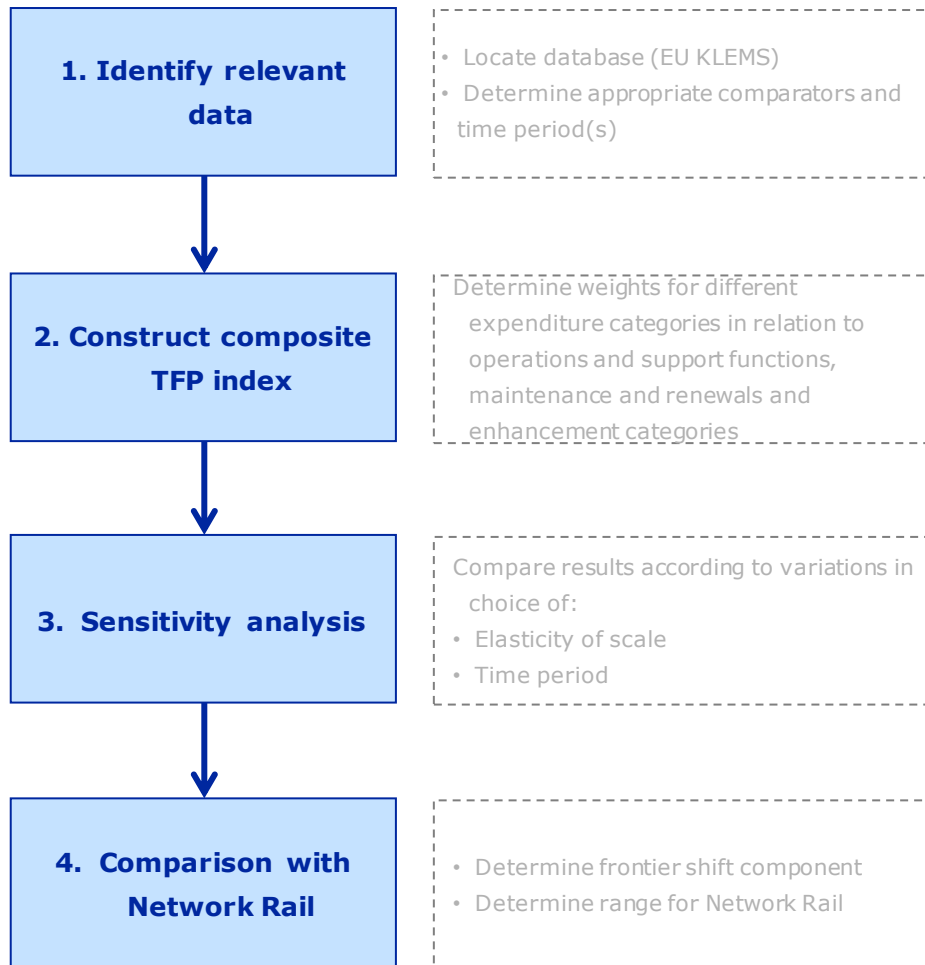
The first term on the right hand side shows the difference in the input prices between the economy and the sector, while the second term represents net TFP.

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.

2.2. Methodology

Our methodology for estimating a composite TFP index for Network Rail is summarised in Figure 2.1 below.

Figure 2.1: Summary of methodology for composite TFP index



It is to be noted that we adopted this methodology to construct TFP indices for each of the three Network Rail's expenditure categories :

- Support and operations expenditure.
- Maintenance and renewals expenditure.
- Enhancement expenditure.

The three estimates are then combined to give a weighted average TFP index for total expenditure.

2.2.1. 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.³

³ EU KLEMS website: <http://www.euklems.net/>

Based on the HM Treasury analysis, the following full economic cycles⁴ 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 (one of our key comparators). We have also undertaken sensitivity analysis covering the following whole business cycles:

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

There are two different types of TFP statistics: Growth output TFP and Value-added TFP. Value-added TFP uses the output and less inputs (value added) as the ‘output measure’, whereas gross output TFP treats intermediate inputs as a factor of production in the same way as labour and capital are treated. This latter approach 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 that, “*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*”.⁵ Gross output measures of TFP growth are the preferred concept for industry specific studies because “*the role of intermediates in production is fully acknowledged*”.⁶

We consider that the gross output measure is more appropriate as it better reflects the business decisions made by the companies. A brief summary of the difference between the two metrics is set out in Text Box 2.2 overleaf.

⁴ 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. Also see, OBR, *Estimating the UK’s historical output gap*, Working paper no.1., Nov 2011

⁵ OECD (2003), p 19.

⁶ Ibid, p 18.

Text Box 2.2: Gross output versus value added

Generally it is considered that the gross output measure better reflects the business decisions taken by companies as it identifies intermediate inputs as a controllable factor of production.

An alternative argument proposed by First Economics, is that value-added is a better measure of productivity for vertically integrated companies since it is not impacted by changes in the vertical structure of the industries. For example, a change in the vertical structure of a firm which begins to outsource its labour force, thus replacing labour with intermediate inputs, will not show a significant change in a value added measure of productivity as it will in a gross output measure of productivity. This is because such a substitution between labour and intermediate inputs will cause a fall in both value added and labour used, which have opposite impact on total productivity, hence making the measure less sensitive to such changes. However, a counter argument can be made that a switch from in-house to outsourced labour in the gross output formula would result in no change in output, and the change in inputs would capture both the fall in labour and the increase in intermediate inputs appropriately weighted via the cost share weights. For the value added formula, there would be a fall in value added as intermediate inputs would rise, whilst there would also be a fall in labour inputs, but this fall would be weakened by the cost share weight. Thus productivity could appear to fall, even though all that has happened is a simple switch from in-house to outsourced labour.

In its RIIO-GD1/TD1 proposals Ofgem used both value added and gross output measures and comparing the results with other indicators of ongoing efficiency in order to arrive at the final figure. Reckon (2011) used gross output to calculate the TFP.

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.

*Source: First Economics, The Scope for future productivity Growth, prepared for Northern Gas Networks, August 2011
Ofgem(2012), RIIO-T1/GD1: Real price effects and ongoing efficiency appendix, Final Decision
Reckon (2011), Productivity and unit cost change in UK regulated network industries and other UK sectors: initial analysis for Network Rail's periodic review.*

A new EU KLEMS dataset is available, with data to 2010, but it does not yet contain TFP gross output, although we note that this is to be added. As such we have not used the new dataset in our analysis. In this respect we note that, a full business cycle has not been completed since 2006, therefore, as discussed above we would still use the 1997 to 2006 business cycle as our base case even if we were using the new data.

2.2.2. 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 create a performance benchmark with which to compare Network Rail. We have taken the approach, in line with our previous report and Oxera (2008) of creating a 'composite' TFP performance benchmark.

TFP gross output measures are available for a wide range of sectors, some of which undertake similar activities to those of Network Rail. The most appropriate sectors are selected for inclusion in

the benchmark and the TFP measures for these sectors are weighted together on the basis of their applicability to Network Rail's expenditure activities. This produces a single figure (composite) benchmark for Network Rail.

We split operations and support costs, maintenance and renewals, and enhancements expenditure into more disaggregated activities in order to match more accurately with comparator sectors. For operations and support costs, and maintenance and renewals we have chosen the same comparators as in CEPA(2012) and Oxera(2008).⁷ For enhancement expenditure we have used similar comparators to those used for maintenance and renewals expenditure as the activities undertaken within enhancements are similar to those undertaken for renewals. We provide these splits and the chosen comparator sectors in the tables below. Table 2.1 provides the breakdown for support and operations activities, Table 2.2 for maintenance and renewals and Table 2.3 for enhancements.

Table 2.1: Selected comparators for Network Rail's support and operations activities

Support & operations 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

Table 2.2: Selected comparators for Network Rail's maintenance and renewals activities

Maintenance and Renewals activities	Selected comparators
Track	Transport and storage Electricity, gas and water supply
Signals	Transport and storage Electricity, gas and water supply
E&P	Transport and storage Electricity, gas and water supply
Telecoms	Post and communications
Maintenance – other	Transport and storage Electricity, gas and water supply
NDS	Transport and storage
IT and Other	Transport and storage Electricity, gas and water supply

⁷ In CEPA (2012) we 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.

Maintenance and Renewals activities	Selected comparators
	Rental of machinery and equipment, and other business activities
Civils	Construction
Operational Property	Construction
Plant and Machinery	Electricity, gas and water supply

Table 2.3: Selected comparators for Network Rail's enhancement activities

Enhancement activities	Selected comparators
Track	Transport and storage Electricity, gas and water supply
Signals	Transport and storage Electricity, gas and water supply
Civils	Construction
Telecoms	Post and communications
Electrification	Transport and storage Electricity, gas and water supply
Plant and Machinery	Electricity, gas and water supply
IT and other	Rental of machinery and equipment, and other business activities

These comparator sectors involve:

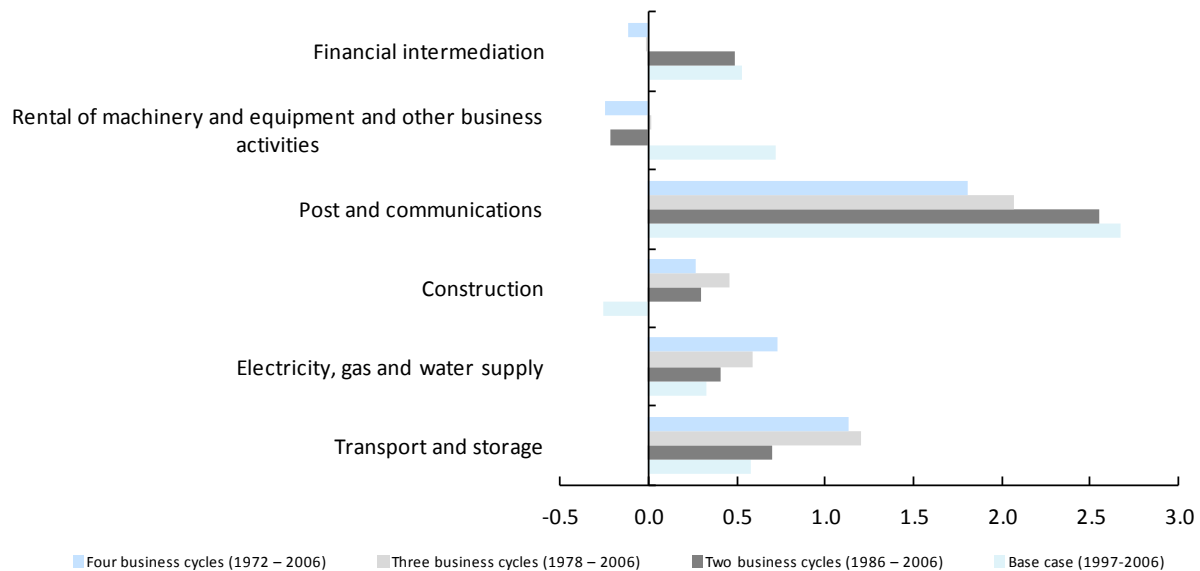
- **Electricity, gas and water supply.** Includes activities related to the production and distribution of electricity and gas, and the collection and treatment of water and sewerage.
- **Construction.** Includes activities related to: site preparation; building of complete constructions or parts thereof; 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.
- **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 2.2 below shows gross output TFP estimates for the relevant comparators. The estimates are shown as averages over varying time periods: 1997-2006, 1986-2006, 1978-2006, and 1972-2006. Note to maintain consistency with previous reports, a positive number reflects a decrease in unit expenditure relative to RPI, while a negative number reflects an increase in unit expenditure relative to the RPI.

Figure 2.2 – Average annual % gross output TFP growth in selected sectors



We note that Oxera (2008) undertook a sensitivity for maintenance and renewals that placed a greater than 90% weight on the construction sector. This was done on the basis of allocating the comparators to the standard industrial classification (SIC) category in which the costs would be recorded. We accept that a significant proportion of the activities for renewals and enhancements may be construction related, but in line with Oxera (2008) we considered that our base case, in

which comparator choices are made on the basis of mapping Network Rail’s activities to a range of sectors carrying out similar activities (which include construction like activities), is appropriate.⁸

2.2.3. Comparator sector weights

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

Our weights are based on Network Rail’s CP5 business plan expenditure for support and operations, maintenance and renewals and enhancement. The weights assigned to these activities differ from those used in CEPA (2012), this reflects the new data in the business plan. Weights have been discussed and agreed with ORR. Refer to Annex A for the weights used in CEPA (2012) calculated using actual expenditure.

Tables 2.4, 2.5 and 2.6 below set out our weights based on Network Rail’s average forecast expenditure for the activities from 2014/15 to 2018/19. For activities with more than one comparator, the weight percentage is divided equally between the comparators as we have no further information on which to take a more detailed view.

Table 2.4: CEPA weightings for support and operations activities

Support and operations activities	Weight	Selected comparators
Total Operations and Customer Services	48%	Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total Other Functions	17%	Electricity, gas and water supply Rental of machinery and equipment and other business activities
Total Corporate Services	22%	Rental of machinery and equipment and other business activities
Total Group Activities	14%	Financial intermediation

Table 2.5: CEPA weightings for maintenance and renewals activities

Maintenance and renewals activities	Weight	Selected comparators
Track	29%	Transport and storage Electricity, gas and water supply
Signals	23%	Transport and storage

⁸ Ofgem, for R110 T1 and GD1 used construction as the principle, but not sole, comparator for capex and replacement expenditure, it had excluded sectors which contained utilities in order to avoid the ‘catch-up’ adjustment (which is discussed in Section 2.4 below) which limited its available range of comparators.

Maintenance and renewals activities	Weight	Selected comparators
		Electricity, gas and water supply
E&P	7%	Transport and storage Electricity, gas and water supply
Telecoms	3%	Post and communications
Maintenance – other	1%	Transport and storage Electricity, gas and water supply
NDS	1%	Transport and storage
IT and Other	12%	Transport and storage Electricity, gas and water supply Rental of machinery and equipment, and other business activities
Civils	14%	Construction
Operational Property	7%	Construction
Plant and Machinery	3%	Electricity, gas and water supply

Table 2.6: CEPA weightings for enhancement activities

Enhancement activities	Weight	Selected comparators
Track	13%	Transport and storage Electricity, gas and water supply
Signals	14%	Transport and storage Electricity, gas and water supply
Civils	20%	Construction
Telecoms	6%	Post and communications
Electrification	20%	Transport and storage Electricity, gas and water supply
Plant and Machinery	4%	Electricity, gas and water supply
IT and other	23%	Rental of machinery and equipment, and other business activities

2.2.4. Adjusted TFP for support and operations

TFP as its name suggests, includes the productivity of all (i.e. the "total") factors of production - namely labour, capital and intermediate inputs.⁹ Activities which have a relatively balanced mix between capital inputs and, labour and intermediate inputs are therefore better suited to indirect

⁹ Intermediate inputs are also considered as inputs under the gross output measure, but not under the value-added measure.

comparisons with industry wide TFP. However, support and support activities' costs predominantly comprise labour and intermediate input costs. As such, we create an 'adjusted TFP' which captures the labour and intermediate inputs productivity only.

Two different assumptions can be made when calculating the adjusted TFP (i) allow for capital substitution, or (ii) assume constant capital. The 'adjusted TFP' measure is a partial productivity measure rather than a TFP measure and is also referred to as LEMS productivity as it covers labour, energy, materials and services (LEMS).¹⁰ The 'adjusted TFP at constant capital' assumes no change in the volume of capex and output and therefore relies on the assumption that the measured TFP change can be achieved by reduction in the volume of labour and intermediate inputs only. Reckon (2011) set out a formula for estimating LEMS productivity at constant capital (adjusted TFP at constant capital) for the comparator sectors and we have used this methodology in this report.¹¹ We do note however, that the formula requires relatively strong assumptions about the comparator sectors' underlying data.

The choice of estimate depends on how capital expenditure is treated in determining an allowance over the price control. If the 'adjusted TFP' were used then an allowance would need to be made for capital substitution in the capex allowance and the scope for frontier shift in the capex categories may be reduced as some of their contribution to TFP has been captured in the opex target.¹² If adopting the 'adjusted TFP at constant capital' then the assumption is that, as support and operations expenditure does not include capital, Network Rail is able to achieve the same level of TFP growth by changing its opex only, and not through changes to both its opex and capital. This estimate does not require a specific adjustment to the capex allowance, but does rely on the strong assumption that the measured TFP change can be achieved by reduction in the volume of labour and intermediate inputs only. As maintenance and renewals expenditure and enhancement expenditure includes capital expenditure we assume that the effects of factor substitution in the comparator industries is similar. Therefore, we have not made an adjustment for capital substitution for these expenditure categories.

While the decision on the appropriate choice of indices to use as the frontier shift estimate is dependent on ORR's approach to setting the allowance over CP5, given that the frontier shift can be applied at the total expenditure level and the assumptions required for either of the 'adjusted TFP' measures using the unadjusted TFP measure at the total expenditure level may be the most appropriate approach.

2.3. Results

2.3.1. Base case

¹⁰ It is to be noted that Oxera (2008) also made an adjustment for capital substitution to their value added TFP measure and arrived at a (pseudo) labour productivity measure. However since we use a gross output rather than a value added measure, we arrive at a LEMS (labour and intermediate inputs productivity measure) instead of a labour productivity measure.

¹¹ Reckon (2011), page 140-141.

¹² The formulas for the adjusted TFP are given in Annex B.

The estimates for the gross output TFP benchmarks are provided in Table 2.7 below. Note, a positive number reflects a decrease in unit expenditure relative to RPI, while a negative number reflects an increase in unit expenditure relative to the RPI. We include an estimate for economy wide TFP growth as well as an estimate for adjusted TFP (at variable and constant capital) for support and operations expenditure. Our estimate for the growth in the composite benchmark; that is, performance that might be expected from a company carrying out similar activities as Network Rail, is between 0.4%-0.5% per annum (including both frontier shift and catch-up).

As shown in Table 2.7, the TFP estimates for the total expenditure are a weighted average of the TFP estimates of support and operations (12%), maintenance and renewals (53%), and enhancement activities (35%).

Table 2.7: Gross output TFP growth, 1997-2006 (% per annum)

	Support and operations	Maintenance and renewals	Enhancement	Total expenditure
Economy wide TFP	0.1			
Composite TFP benchmark*				
TFP change	0.6	0.4	0.5	0.4
Adjusted TFP change for support and operations	1.3	0.4	0.5	0.5
Adjusted TFP change at constant capital for support and operations	0.7	0.4	0.5	0.5

Source: CEPA

* Estimated TFP benchmark is **not** net of economy

As seen in the Table 2.7 there are three possible estimates for efficiency change in the total expenditure based on the measure of TFP used for support and operating expenditure. The choice between the two adjusted TFP measures depends on the approach ORR takes to assessing Network Rail's expenditure.

If ORR is setting allowances without explicitly making an allowance for capital expenditure that reduces operating expenditure then a gross TFP estimate for totex (before an adjustment for catch-up) of 0.5% could be used or 0.3% net of economy wide TFP.

If allowances are made specifically for capital substitution then a similar estimate of 0.5% is still applicable (this is the same at one decimal place due to the low weight on support and operations). This figure will be 0.4% net of economy.

2.3.2. Sensitivities

We 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. In order to test the robustness of our key results we have conducted sensitivities around these assumptions. We also conducted sensitivities to take into account 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 adjustment difficult.

However we have conducted sensitivities to allow for a volume adjustment for economies of scale using the following formula:

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

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. 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.

Results

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

- economies of scale; and
- the time period.

The estimates for these sensitivities are presented in Table 2.8, 2.9 and 2.10 below. The three tables correspond to the different measures of efficiency used for support and operations expenditure. Table 2.8 displays the results using unadjusted TFP, Table 2.9 displays the results using adjusted TFP and Table 2.10 displays the results using adjusted TFP at constant capital.

Table 2.8: Sensitivity results for % p.a. efficiency forecasts calculated using TFP estimates for all expenditure categories

Sensitivities	Support and operations	Maintenance and renewals	Enhancement	Weighted total
Base case results	0.6	0.4	0.5	0.4
Assuming 0.9 elasticity of scale	0.5	0.4	0.5	0.4
Assuming 0.8 elasticity of scale	0.5	0.3	0.4	0.4
Two business cycles (1986 – 2006)	0.1	0.5	0.4	0.4

Sensitivities	Support and operations	Maintenance and renewals	Enhancement	Weighted total
Three business cycles (1978 – 2006)	0.2	0.8	0.7	0.7
Four business cycles (1972 – 2006)	0.1	0.8	0.6	0.6

Source: CEPA

Table 2.9: Sensitivity results for % p.a. efficiency forecasts calculated using adjusted TFP estimates for support and operations

Sensitivities	Support and operations	Maintenance and renewals	Enhancement	Weighted total
Base case results	1.3	0.4	0.5	0.5
Assuming 0.9 elasticity of scale	1.2	0.4	0.5	0.5
Assuming 0.8 elasticity of scale	1.2	0.3	0.4	0.5
Two business cycles (1986 – 2006)	0.7	0.5	0.4	0.5
Three business cycles (1978 – 2006)	0.7	0.8	0.7	0.7
Four business cycles (1972 – 2006)	0.6	0.8	0.6	0.7

Source: CEPA

Table 2.10: Sensitivity results for % p.a. efficiency forecasts calculated using adjusted TFP at constant capital estimates support and operations

Sensitivities	Support and operations	Maintenance and renewals	Enhancement	Weighted total
Base case results	0.7	0.4	0.5	0.5
Assuming 0.9 elasticity of scale	0.7	0.4	0.5	0.4
Assuming 0.8 elasticity of scale	0.6	0.3	0.4	0.4
Two business cycles (1986 – 2006)	0.1	0.5	0.4	0.4
Three business cycles (1978 – 2006)	0.2	0.8	0.7	0.7
Four business cycles (1972 – 2006)	0.1	0.8	0.6	0.6

Source: CEPA

The difference between the base case and the cost elasticity sensitivities is small, approximately 0.1 percentage points. This indicates that varying our assumption on the elasticities of scale at the margin would not have a significant impact. This is true for all the three measures of efficiency in the tables above.

The sensitivity analysis around the time periods shows varying results for the different expenditure categories. All three efficiency estimates for support and operating expenditure are larger in the base period (1997-2006) than in the longer time periods comprising two or more business cycles. The

results are exactly opposite for maintenance and renewals expenditure with the efficiency estimates for the base period being smaller than the corresponding estimates over two or more business cycles. For enhancement expenditure the base period estimates are larger than the estimates for the time period comprising two business cycles but smaller than the estimates for the time period comprising three and four business cycles.

This indicates that TFP growth over the most recent business cycles has been slower than was experienced previously for sectors carrying out similar activities to maintenance and renewals and enhancement in Network Rail but has been larger for sectors carrying out similar activities to support and operations in Network Rail.

The sensitivity analysis shows that the TFP composite benchmark estimates for the weighted total expenditure are relatively stable over the different time periods, but increase slightly as more time periods are added.

2.4. Frontier shift versus catch-up

TFP, as discussed previously, 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.

Splitting catch-up from frontier shift in the TFP estimates is difficult and there is no robust evidence or studies as to the extent that catch-up is captured in the TFP for sectors containing regulated companies. Therefore, some proxy estimates or judgement is required. The adjustment for catch-up made in CEPA (2012) studies is based on:

- 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.

It is also to be noted that in its recent regulatory decisions, Ofgem¹³ decided not to make any adjustment for catch-up. It stated that Fäire et al (1994) calculates the 75% adjustment figure when

¹³ Ofgem (2012), RII0-T1/GD1: *Real price effects and ongoing efficiency appendix*, Final Decision

comparing the UK economy to the global frontier, and hence it sees no reason why the same figure should be used when calculating an efficiency index based on the UK economy sectors alone.¹⁴ In addition, Ofgem had excluded regulated sectors from its comparator set, this further mitigating the risk of capturing catch-up in its TFP estimates.

Our TFP composite benchmark on the other hand contains industries in the UK economy 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, the post and telecommunications sector and the transport and storage sector so some adjustment for catch up seems prudent.

For the purpose of our calculations of the composite TFP, the total weight given to the sectors which include regulated companies in the different expenditure categories is shown in Table 2.11 below.

Table 2.11: Sectors with regulated industries

	Support and Operations	Maintenance and Renewals	Enhancement
Electricity, gas and water	32%	37%	28%
Post and telecommunications	0%	3%	6%
Transport and storage	0%	35%	25%
Total	32%	75%	59%

Given the above weights, it is clear that these sectors represent a reasonable proportion of the total, and a high proportion for maintenance and renewals, of the comparator group for Network Rail. However within each of these sectors there are many companies which either have not been subject to regulation or have been deregulated for a reasonably long period (that is, energy retail and wholesale was privatised in the early 90's). Therefore, only a proportion of the three sectors listed in Table 2.11 above should require an adjustment for catch-up. For example, within the electricity, gas and water sector only the distribution and transmission activities are regulated, most of post and telecom sector has been privatised except for some functions performed by Royal Mail that are still regulated. Similarly within the transport and storage sector airports and Network Rail are regulated.

On the basis of the above arguments and evidence we consider that an adjustment for catch-up is appropriate but we cannot exactly determine the proportion that the regulated companies contribute to each of the sectors based on the weights given to the sectors. We are of the view however that a 0.75 adjustment is conservative in relation to frontier shift, that is, an adjustment factor greater than 0.75 (between 0.75 and 1.0) may be more appropriate.

¹⁴ Färe et al investigated the efficiency in 17 OECD countries and split this into two components, technical change (global frontier shift) and efficiency change (catch-up). Based on their estimates, it has been assumed that in the UK 75% of the overall change was attributable to frontier shift.

2.5. Conclusion

In Table 2.12 we set out our estimates, based on the gross output TFP estimates, for Network Rail's scope for efficiency savings over CP5 from frontier shift only. We present estimates with a 0.5 (low case), 0.75 (median case) and no applied (high case).

Table 2.12: Estimates for ongoing efficiency (frontier shift), based on gross output TFP (% per annum)

Expenditure	Low case (50% frontier shift)	Median case (75% frontier shift)	High case (100% frontier shift)
Support and operations (TFP)	0.3	0.4	0.6
Support and operations (Adjusted TFP)	0.6	1.0	1.3
Support and operations (Adjusted TFP at constant capital)	0.3	0.5	0.7
Maintenance and renewals	0.2	0.3	0.4
Enhancement	0.3	0.4	0.5
Total expenditure (TFP for all)	0.2	0.3	0.4
Total expenditure (Adjusted TFP for support and operations and TFP for others)	0.3	0.4	0.5
Total expenditure (Adjusted TFP at constant capital for support and operations and TFP for others)	0.2	0.3	0.5

Source: CEPA

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

The results from the table above show that a 0.2% to 0.5% p.a. efficiency range for total expenditure can be used for CP5 based on the performance of comparator sectors in the UK economy depending on the assumption relating to capital for support and operations.

Table 2.13 below presents the ongoing efficiency estimates from our previous report. We did not estimate the efficiency for enhancements previously and we provided separate estimates for maintenance and renewals.

Table 2.13: Summary of estimates for ongoing efficiency gains over CP5 – estimates from CEPA (2012) (% per annum)

Expenditure	Low case (50% frontier shift)	Median case (75% frontier shift)	High case (100% frontier shift)
Support and operations (Adjusted TFP)	0.6	0.9	1.3
Maintenance	0.3	0.5	0.6
Renewals	0.3	0.4	0.5

Source: CEPA

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

A comparison of Tables 2.12 and 2.13 reveals that the updated analysis estimates are not significantly different from the estimates in our previous report. In CEPA (2012) renewals expenditure was approximately twice maintenance expenditure so a greater weight would have been placed on the renewal estimates. The changes result from slight changes in comparator sector weights e.g. for maintenance and renewals greater weight has been placed on comparators with lower TFP growth.

3. CONCLUSION

For this project ORR asked us to:

- update our previous productivity estimates to reflect latest data – Network Rail Strategic Business Plan (SBP);
- extend our previous analysis to encompass enhancements expenditure; and
- estimate total expenditure efficiency.

In this report we have updated our previous TFP analysis using forecast CP5 data for support and operations, maintenance and renewals, and enhancement expenditure taken from Network Rail’s Strategic Business Plan. We have estimated an overall ongoing efficiency estimate for Network Rail’s total expenditure and have also provided ongoing efficiency estimates for support and operations under the assumption of constant capital. These estimates provide a further comparison for the adjusted TFP measure presented in CEPA (2012) which allowed for capital substitution. We combined the estimates for support and operations with estimates for maintenance and renewals, and enhancement to derive a weighted total estimate for total expenditure. 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.

We have updated our previous total factor productivity (TFP) analysis using Network Rail’s forecast CP5 data for support and operations, maintenance and renewals, and enhancement expenditure taken from Network Rail’s Strategic Business Plan. We have estimated an overall ongoing efficiency estimate for Network Rail’s total expenditure and have also provided ongoing efficiency estimates for support and operations under the assumption of constant capital.¹⁵ These estimates provide a further comparison for the adjusted TFP measure presented in CEPA (2012) which allowed for capital substitution. We combined the estimates for support and operations with estimates for maintenance and renewals, and enhancement to derive a weighted total estimate for total expenditure. It should be noted that, as is the case for all benchmarking exercises, there are limitations to the level of comparability that can be achieved with Network Rail. However, in developing the frontier shift estimates we have taken a similar approach to previous ORR price controls and a consistent approach with other UK regulatory precedents.

Our chosen comparator sectors mainly include firms operating in competitive markets. Over a long period of time their performance should represent the performance of an efficient firm and hence we expect the catch-up efficiency component for these firms to be zero. However, our composite benchmark also includes regulated companies that may still be experiencing catch-up. Hence we have adjusted the TFP measure to exclude the component of catch-up efficiency, using estimates of

¹⁵ The adjusted TFP at constant capital provides an estimate of the required changes in the volume of labour and intermediate to achieve the TFP, with no change in capital or output.

0.75 and 0.5 based on relevant academic work, previous studies and regulators' decisions within the industries included in the composite benchmark. Given that the regulated companies make a relatively small proportion of the comparator base (although this is somewhat higher for maintenance and renewals) we consider that these adjustments are conservative in relation to frontier shift. Therefore we have also presented the results without any adjustment for catch-up; that is, assuming 100% of efficiency change is due to frontier shift.

We carried out sensitivities around our base case results for different business cycles and for economies of scale, and while the results show some difference we do not consider these significant enough to deviate from the base case results. Therefore, for our base case we retained the time period from 1997-2006 (the most recent business cycle) and we made no adjustment for economies of scale.

Table 3.1 below provides the average annual efficiency estimates and compound annual growth rates (CAGR) over CP5 for the three measures after adjusting for catch-up. We have presented the results under the different assumptions for catch-up; that is, assuming 50% (low case), 75% (median case) or 100% (high case) of efficiency change is frontier shift in the table below. We prefer using the 0.75 adjustment which is in between the two extremes of no adjustment or the 0.5 adjustment.

The figures in grey represent the annual percentage change in total expenditure which is calculated as a weighted average of the individual components. The weights are equal to the share of individual expenditure categories in total expenditure; this is 12% for support and operations, 53% for maintenance and renewals and 35% for enhancements.

Table 3.1: Summary of estimates for ongoing efficiency gains over CP5

Expenditure	Low case (50% frontier shift)		Median case (75% frontier shift)		High case (100% frontier shift)	
	% p.a.	CAGR	% p.a.	CAGR	% p.a.	CAGR
Support and operations (TFP)	0.3	1.4	0.4	2.1	0.6	2.8
Support and operations (Adjusted TFP)	0.6	3.1	1.0	4.7	1.3	6.2
Support and operations (Adjusted TFP at constant capital)	0.3	1.7	0.5	2.5	0.7	3.4
Maintenance and renewals	0.2	0.9	0.3	1.4	0.4	1.8
Enhancement	0.3	1.3	0.4	1.9	0.5	2.5
Total expenditure (TFP for all)	0.2	1.1	0.4	1.6	0.5	2.2
Total expenditure (Adjusted TFP for support and operations)	0.3	1.3	0.4	2.0	0.6	2.6
Total expenditure (Adjusted TFP at constant capital for support and operations)	0.2	1.1	0.4	1.7	0.5	2.3

*Note: Estimated TFP estimates are gross, i.e. **not** net of economy TFP¹⁶
There are differences in the CAGR as they are based on unrounded figures*

The choice between the approaches provided in Table 3.1 above depends on how ORR estimates Network Rail's expenditure requirements for CP5. The approaches presented in Table E.1 rely on different assumptions relating to the underlying data and the interactions between different parts of the price control, which are set out briefly below:

- **Adjusted TFP.** The 'adjusted TFP' measure (which is a labour and intermediate inputs productivity measure) takes account of operations and support expenditure excluding capex, this results in capital substitution appearing as productivity changes. To maintain consistency with overall TFP, where capital substitution is captured in the adjusted TFP estimate appropriate allowances for capex should be made to avoid double counting productivity changes. We note that the adjusted TFP measure was used by ORR for operations and support expenditure in PR08.
- **Adjusted TFP at constant capital.** The 'adjusted TFP at constant capital' measure relies on the assumption is that, for support and operations expenditure, Network Rail is able to achieve the same level of measured TFP in the comparator sectors by changing its opex (labour and intermediate inputs) only and not through changes to opex and/or capex. This measure assumes no change in the volume of capex and output and therefore provides an estimate of the change in the volume of labour and intermediate inputs required to achieve the measured TFP change. While this measure was used by Ofgem in its recent RIIO-GD1 and T1 price controls we have some concerns with the assumptions required in adjusting the comparator sectors' data for constant capital.
- **TFP.** The TFP measure captures the change in the volume of outputs that are not attributed to changes in all the (measured) volume of inputs. If ORR is setting a total expenditure productivity frontier shift for Network Rail then this approach may be the most appropriate as it avoids some of the consistency requirements, from the interactions between the different parts of the price control, and assumptions of the adjusted TFP approaches.

We have presented gross estimates in Table 3.1, that is, without the economy wide TFP growth subtracted, to be consistent with CEPA (2012). The estimates, however, can be converted by subtracting the economy wide TFP (0.1% per annum).

¹⁶ Economy wide TFP (or real price effects) is usually netted off from the gross frontier shift. This is done to avoid a double count as RPI implicitly captures economy wide inflation as it reflects the changes in price of inputs less productivity gains.

ANNEX A – Comparator weights used in CEPA (2012)

The tables below provide a comparison of the weights used in this report (CP5 weights) and those used in CEPA (2012), based on actual expenditure.

Table A.1 - Comparators and weights for Network Rail's support and operations expenditure

Expenditure activity	CP5 weights	Previous weights
Total operations and customer services	48%	47%
Total other functions	17%	20%
Total corporate services	22%	20%
Total group activities	14%	12%
Total	100%	100%

Table A.2 - Comparators and weights for Network Rail's maintenance expenditure

Expenditure activity	CP5 weights	Previous weights
Track	46%	42%
Signals	17%	16%
E&P	10%	6%
Telecoms	2%	6%
Maintenance – other	4%	3%
Overheads and engineering		23%
NDS	5%	1%
Other	15%	3%
Total	100%	100%

Table A.3 - Comparators and weights for Network Rail's renewals expenditure

Expenditure activity	CP5 weights	Previous weights
Track	24%	29%
Signals	24%	18%
Civils	18%	16%
Operational property	9%	11%
Telecoms	3%	11%
Electricification	6%	4%
Plant and machinery	4%	4%
IT and other	11%	7%
Total	100%	100%

ANNEX B – Regulatory precedents

Table B.1 below draws together recent determinations for frontier shift efficiency targets by various UK regulators. While it is not clear for all regulators decisions we have tried to set these out as gross frontier shifts i.e., before economy-wide efficiency has been removed and/ or real price effects.

Table B.1: Summary of ongoing efficiency targets

Regulator	Country	Sector	Price control	Expenditure	Frontier-shift efficiency target
CAA	GB	Airports	2008-13	Opex	1.0%
CAA	GB	Air traffic control (NATS)	2011-15	Opex	1.3%*
ORR	GB	Rail	2008-13	Opex	1.0%
Ofgem	GB	Electricity distribution	2010-15	Opex	1.0%
Ofgem	GB	Transmission and gas distribution	2013-21	Opex	1.0%
				Capex	0.7%
				Totex	0.8%
Ofwat	Eng/Wales	Water & sewerage	2010-15	Opex	0.9%
				Capex	0.4%
Ofcom	GB	Telecoms	2009-14	Opex	2.0%
Range					0.4% - 2.00%

* Some catch-up may be included in this estimate.

ANNEX C – Adjusted TFP (LEMS productivity) formula

The formula for the adjusted TFP measure unadjusted for capital is gives as:

$$\Delta adj. TFP = \Delta GOQ - s_L \cdot \Delta LQ - s_{II} \cdot \Delta IIQ$$

Where:

$$s_L = \frac{L/GO}{\left(\frac{L}{GO} + \frac{II}{GO}\right)}$$

$$s_{II} = \frac{II/GO}{\left(\frac{L}{GO} + \frac{II}{GO}\right)}$$

ΔGOQ is the change in gross output quantity indices from one year to the next

ΔLQ is the change in labour quantity indices from one year to the next and

ΔIIQ is the same as above for intermediate inputs.

The formula for the adjusted TFP measure at constant capital is gives as:

$$\Delta adj. TFP_{constant K} = \Delta TFPGO / \left(1 - \frac{K}{GO}\right)$$

Where:

$\Delta TFPGO$ is the change in gross output total factor productivity from one year to the next

$\frac{K}{GO}$ is the share of capital in gross output

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