Reckon LLP
Data analysis | Economic regulation | Competition law

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Productivity and unit cost change in UK regulated network industries and other UK sectors: initial analysis for Network Rail's periodic review

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1 Introduction and summary

1.1 At its last periodic review, the Office of Rail Regulation (ORR) set a price control on the access charges that Network Rail can charge users of its rail network over the period 2009/2010 to 2014/2015.

1.2 In its *Determination of Network Rail's outputs and funding for 2009-14*, ORR explained that its efficiency assessment for Network Rail covered three elements: "catch-up efficiency", "frontier-shift efficiency" and input price inflation. The catch-up element related to the expectation that Network Rail could achieve cost savings by catching up to the levels of performance of more efficient companies. The frontier-shift element related to the expectation that, in addition to any catch-up, Network Rail should be able to improve its efficiency over time.

1.3 ORR's decisions on frontier-shift and catch-up elements were made in light of reports it had commissioned from consultants, which provided analysis of historical changes in measures of unit costs and productivity for other UK companies and sectors.

1.4 In January 2011, ORR commissioned Reckon LLP to carry out an update of that analysis. Our report does the following:

(a) We provide estimates of historical changes in measures of unit operating expenditure for some regulated network industries in the UK. We use recent data to update an analysis of unit operating expenditure that was carried out by ORR's consultants at the last periodic review. We also provide some further analysis using alternative data sources and output measures.

(b) We provide estimates of historical changes in measures of productivity growth, based on data for sectors of the UK economy. We use recent data to update an analysis of "TFP composite benchmarks" for Network Rail which was carried out by ORR's consultants at the last periodic review. We also provide estimates for some alternative measures of productivity growth for sectors of the UK economy.

(c) We review the way in which ORR and its consultants used this type of information at the last periodic review, drawing on the approaches used by other

UK regulators. We suggest potential improvements. In light of these suggestions, we have carried out some further quantitative analysis.

1.5 We provide a brief summary below. It is essential not to rely on this summary in isolation from the more detailed explanations and discussion in the main report.

Operating expenditure for regulated network companies

1.6 Oxera (2008) provided estimates of changes over time in real unit operating expenditure (RUOE) for a number of regulated network industries other than rail. The estimates showed that industries such as electricity distribution had experienced substantial reductions in measures of operating expenditure per unit of output, relative to the RPI.

1.7 We have carried out an update of these estimates. Table 1 provides a summary of updated estimates of growth rates relative to the RPI. A negative number indicates a reduction in costs relative to the RPI. We find that the large reductions in unit operating expenditure seen in Oxera (2008) have not been repeated over the last four or five years. We suspect that at least some of the estimates in Oxera (2008) were affected by a period of high productivity gains following privatisation and/or a period in which companies shifted away from operating expenditure and towards capital expenditure in response to the price control regulation that they faced.

Table 1 Summary of growth rates in RUOE (average annual percentage change)

	Estimate from Oxera (2008)	Update for last four or five years	Weighted average over period
Great Britain electricity distribution	–4.0	4.0	–2.7
National Grid Electricity Transmission	–4.9	2.5	–3.6
England and Wales water	–1.8	0.2	–1.4
England and Wales sewerage	–1.7	–1.2	–1.6
Scottish water	–8.8	3.3	–1.9
Scottish sewerage	–14.3	1.3	–5.4

1.8 The estimates are sensitive to the output measure used to calculate the change in operating expenditure per unit of output. For example, in the case of electricity distribution, the average annual increase in RUOE over the last four years is 4.0 per cent if the units of electricity distributed is taken as the output measure (as in table 1) and 2.4 per cent if, instead, the number of customers is taken as the output measure. This difference reflects a drop in the volume of electricity distributed since 2006/2007, which may be explained in part by contractions in economic activity in the UK. The main report provides estimates of changes in measures of operating expenditure over the last four years using alternative output measures.

Estimates of productivity growth for sectors of the UK economy

1.9 Oxera (2008 and 2008b) provided an analysis of "TFP composite benchmarks" for Network Rail. Separate benchmarks were calculated for four different categories of Network Rail's expenditure: operating expenditure, maintenance, renewals and enhancements. Each benchmark was calculated using a weighted average of the estimates of the historical growth in total factor productivity (TFP) for selected sectors of the UK economy, using data from the EU KLEMS database. At the last periodic review, ORR drew on these TFP composite benchmarks in its decisions about the frontier-shift elements of Network Rail's price control.

1.10 We have calculated updated values for the TFP composite benchmarks, using the most recent version of the EU KLEMS database, which runs to 2007. The updated estimates are similar to those produced previously.

1.11 We have concerns with the TFP composite benchmarks. The method may provide a misleading impression of the extent to which the estimates take account of the details of Network Rail's business.

1.12 The TFP composite benchmarks are based on estimates of what is known as "value added" total factor productivity growth. The concept of "value added" has a role in macroeconomic studies but seems less useful in making projections above the costs of specific companies. Estimates of total factor productivity growth on a "gross output" basis are more common in microeconomic studies, especially ones that concern the productivity improvements achieved by specific companies. We have provided estimates of total factor productivity growth for different sectors of the UK economy on both a gross output basis and a value added basis. The gross output estimates are systematically smaller in magnitude.

Further analysis of changes in unit costs and output price indices

1.13 In addition to our update of the specific strands of analysis summarised above, we have considered how projections about Network Rail's future expenditure requirements were made at the last periodic review. We have identified some risks that arise under the previous approach and we suggest potential improvements.

1.14 We have made some specific suggestions about the way in which estimates relating to productivity growth are combined with adjustments for input price inflation. There are risks of double-counting that need to be addressed. We have also identified risks of inconsistency if Network Rail's price control is calculated using efficiency projections for separate categories of expenditure, such as operating expenditure, maintenance and renewals. We set out one possible way to address these risks.

1.15 We also question whether it is necessary for ORR to place emphasis on estimates of productivity growth and then to combine these with input price adjustments. We have highlighted above that we have concerns about the method involving TFP composite benchmarks. Leaving these aside, the estimates of productivity growth we have calculated using the EU KLEMS database seem susceptible to measurement error. A number of sectors show negative productivity growth even over long periods of time; this may reflect measurement problems rather than what has happened, on average, to the productivity of suppliers within these sectors.

1.16 Rather than collating estimates of productivity growth, ORR could focus on estimates of changes over time, relative to the RPI, in measures of unit costs and in output price indices. Such estimates should capture the combined effects of historical productivity growth and changes, relative to the RPI, in input prices.

1.17 We have produced estimates of the growth rates, relative to the RPI, in construction output price indices. These estimates may be relevant to regulatory projections about Network Rail's future maintenance, renewals and enhancement expenditure requirements. Using the EU KLEMS database we have calculated a long-term average annual growth rate for the UK construction sector. We have also estimated the growth rates in several output price indices for the construction sector, using the BIS output price indices available from BCIS which provide more detailed and more recent data. Table 2 provides a summary.

Table 2 Growth rates in selected construction output price indices relative to RPI

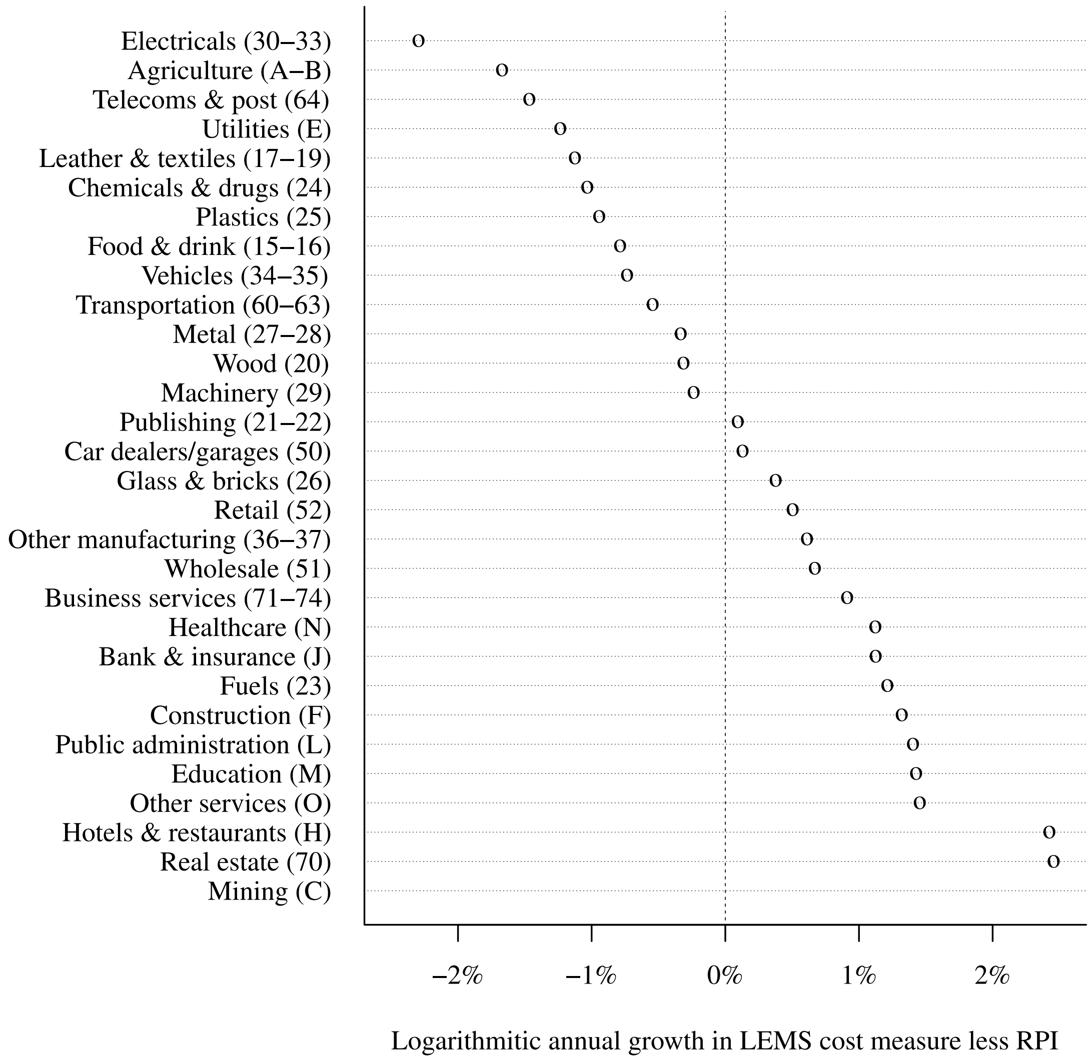
	Time period	Logarithmic annual growth rate (%)
EU KLEMS output price index for construction sector	1970 to 2007	1.1
Selected construction output price indices from BCIS	1990Q1 to 2009Q4	–0.4 to 0.3
Selected construction output price indices from BCIS	1995Q1 to 2010Q3	0.0 to 1.0

1.18 The growth rate of RPI plus 1.1 per cent over the period 1970 to 2007 is relatively high compared to output price indices for other sectors of the UK economy.

1.19 The output price indices for the construction sector are sensitive to the time period over which they are calculated and will reflect variations over time in the profits achieved by construction companies. For instance, between 1995 and 2007 the price index for "all new construction" grew at a faster rate than the RPI. This price index has fallen in nominal terms since 2007 — a period which has seen the credit crunch and the first UK recession since the early 1990s.

1.20 We have also used the EU KLEMS database to estimate changes over time in measures of labour and intermediate input costs (relative to the RPI) per unit of output for 30 sectors of the UK economy. These estimates may be relevant to regulatory projections about Network Rail's future operating expenditure requirements. Figure 1 shows estimates for the logarithmic annual growth rate in one of these measures, relative to the RPI, over the full period of available data, 1970 to 2007. The sectors shown are the most disaggregated sectors for which data are available. These sectors differ in size and a simple average or median across them would not necessarily be representative of the UK economy as a whole.

Figure 1 Growth rate in LEMS cost measure (relative to RPI) 1970 – 2007



1.21 The main report provides more information on how this unit cost measure is calculated and on the variation over different periods of time. For example, across the 30 sectors of the UK economy that we cover, the median value for the logarithmic annual growth rate for the unit cost measure in figure 1 is 0.3 over the period 1970 to 2007 and –0.6 over the period 1997 to 2007. We have also examined the variation in average growth rates across consecutive five-year periods, which correspond to the length of Network Rail's price control.

Structure of this document

1.22 The remainder of this document is structured as follows.

1.23 Section 2 discusses potential implications of our updated analysis for decisions that ORR may make about the efficiency improvements open to Network Rail. It starts with a summary of relevant aspects of ORR's decisions at the last periodic review. We have provided updates to some of the analysis that ORR drew on, using more recent data, and we discuss the potential implications of these updates. In addition, we have carried out analysis of alternative measures which relate to changes in productivity and unit costs which seem relevant and we discuss the potential implications of these.

1.24 Section 3 highlights some interactions between the estimates set out in this report and the frontier-shift, catch-up and input price elements that ORR considered at the last periodic review. It also highlights potential interactions between Network Rail's various expenditure categories. We provide suggestions for ways in which ORR might revise or adapt its use of information about frontier-shift, catch-up and input price inflation in light of the estimates and analysis in this report.

1.25 Sections 4 to 8 provide supporting information. Section 4 provides more information on our update of the analysis of changes in measures of operating expenditure per unit of output for regulated network companies, including a description of the data sources and methods used. Section 5 explains our update of the analysis of total factor productivity (TFP) composite benchmarks, including a description of the data sources and methods used. Section 6 provides our additional analysis of productivity growth and changes in measures of unit costs for different sectors of the UK economy. Section 7 provides some further analysis of output price indices for the construction sector. Section 8 summarises relevant aspects of recent decisions by UK regulators and other recent literature.

1.26 At the end of the document we provide an appendix to the analysis presented in section 6 and then a list of references.

2 Potential implications of the updated analysis

2.1 This section discusses some potential implications of the analysis and estimates which are described in sections 4 to 7 of this report. It is structured as follows:

(a) We summarise our understanding of ORR's decisions on efficiency for the price control period from April 2009 to March 2014.

(b) Against this background, we discuss the potential implications of our updated RUOE analysis and updated productivity analysis.

(c) We discuss the potential implications of further analysis we have carried out relating to changes over time in measures of unit costs and output prices for different sectors of the UK economy.

(d) We provide some thoughts on the evolution, over time, in the estimates of RUOE for regulated network companies. We then discuss the potential implications of RUOE estimates for these companies if focus is placed on data from more recent years.

Summary of ORR's decisions on efficiency at the last periodic review

2.2 The last periodic review for Network Rail took place in 2008. We set out below our understanding of the way in which ORR set the efficiency assumptions for Network Rail over the price control period from April 2009 to March 2014 (ORR calls this period CP4). This is based upon ORR (2008) *Determination of Network Rail's outputs & funding for 2009-14* and some further clarification from ORR.

2.3 ORR made separate decisions for four expenditure categories: controllable operating expenditure, maintenance expenditure, renewals expenditure and enhancement expenditure. In each case, ORR's decision was based on the combination of three elements: catch-up efficiency, frontier-shift efficiency and an input price adjustment. Taken together, these provided the overall efficiency assumptions for each expenditure category. We set out our understanding of ORR's approach to each expenditure category in turn below.

Controllable operating expenditure

2.4 As with the other expenditure categories, controllable operating expenditure efficiency projections were composed of three elements: catch-up, frontier-shift and an adjustment for input price inflation.

2.5 The annual catch-up efficiency projection was set at 4.9 per cent for each of the financial years from 2009/2010 to 2013/2014. ORR had identified in its draft determinations that by March 2009 Network Rail would have an estimated efficiency gap in controllable operating expenditure of 35 per cent, and that two thirds of this gap could be closed by March 2014 with the remainder to be closed by March 2019.

2.6 ORR's view on the efficiency gap was informed by analysis which involved a comparison between Network Rail's actual operating expenditure and two extrapolations of what Network Rail's controllable operating expenditure would have been had this reduced by a certain amount per year in every year since rail privatisation (though ORR made an upwards adjustment of £105 million for additional operating expenditure associated with the Hatfield accident). The rates of annual reduction used for these two extrapolations were 2.8 per cent and 5 per cent. These figures were chosen in light of estimates of the reductions in real unit operating expenditure achieved by other regulated industries in the UK since privatisation, drawing on estimates from Oxera (2008) and also from a report LECG prepared for Network Rail.

2.7 ORR (2008, page 157) says the following about the 35 per cent efficiency gap:

> "For opex, the study Oxera carried out for us has shown that other regulated utilities have achieved, over an extended period, efficiencies averaging 4% to 6.2% per annum. Our updated analysis of historical controllable opex using 2.8% per annum (from the LECG study for Network Rail) as a lower bound and 5% per annum (the approximate central point in the Oxera range) as an upper bound, and taking into account our reasonable adjustment for justified post-Hatfield cost increases (of £105m) gives an efficiency gap at the end of CP3 that ranges between 23% and 43%. On this basis we consider that our estimate from the draft determinations, of 35%, remains robust. Our bottom up assessment of insurance, total employment costs and the operations function confirms that Network Rail faces a significant efficiency gap at the end of CP3."

2.8 In addition to the catch-up efficiency of 4.9 per cent per year, ORR assumed a frontier-shift efficiency element which would contribute a reduction in controllable operating expenditure of 0.2 per cent per year. The figure of 0.2 was, we understand, based upon the estimate of the total factor productivity (TFP) composite benchmark for operating expenditure in Oxera (2008). The value of 0.2 per cent was for productivity outperformance of the composite benchmark against the economy-wide productivity growth. The calculation of the composite benchmark involved weighting different elements of operating expenditure according to their relative proportion of Network Rail's operating expenditure and then mapping each type of expenditure to sectors of the UK economy for which estimates of total factor productivity growth were available. The composite benchmark included an adjustment for capital substitution and an adjustment intended to strip out the impact of catch-up productivity gains.

2.9 ORR also provided an allowance for the expectation that Network Rail would face input price inflation above RPI. ORR drew on information from a study prepared for Network Rail. The input price adjustment contributed an uplift to controllable operating expenditure of 2.1 per cent per year for 2009/2010 and 2010/2011 and then an uplift of 0.9 per cent per year for the remaining three years of the price control.

Maintenance and renewals expenditure

2.10 ORR's figures for catch-up efficiency were based upon an assessment that there was an efficiency gap of 31 per cent for maintenance expenditure and 36 per cent for renewals expenditure. The catch-up assumption was based on the view that Network Rail could reduce the efficiency gap over the same timeframe as for controllable operating expenditure, with two thirds to be closed by March 2014 and the remainder to be closed by March 2019. This led to annual catch-up assumptions of between 4.3 and 4.6 per cent for maintenance expenditure and between 4.9 and 5.7 per cent for renewals expenditure.

2.11 ORR's analysis of these efficiency gaps included international benchmarking between Network Rail and other rail network companies.

2.12 The catch-up assumptions were combined with frontier-shift efficiency assumptions and input price adjustments. The frontier-shift assumptions were for 0.7 per cent cost reductions per year for both maintenance expenditure and for renewals expenditure. This was, we understand, on the basis of TFP composite benchmarks (outperformance against whole-economy productivity) from Oxera (2008). ORR set the annual input price adjustments in light of submissions from Network Rail. These varied between maintenance and renewals, and across the five-year period of the price control, ranging between an uplift to expenditure of 2.1 per cent and a reduction of 0.1 per cent.

Enhancements

2.13 ORR used a different method for enhancement expenditure. ORR made adjustments to capital expenditure projections on the basis of catch-up efficiency expectations which varied by category: 12.5 per cent for platform costs; 7.5 per cent for power supply costs; 5 per cent for other non-specified enhancement projects; and no adjustment in the case of specific projects.

2.14 In addition to these catch-up assumptions, a subset of projects was subject to a frontier-shift efficiency assumption which implied expenditure reductions of 0.7 per cent per year relative to the RPI. This was, we understand, based on a TFP composite benchmark for enhancements provided in Oxera (2008b). ORR also included adjustments for input price inflation above RPI, drawing on submissions from Network Rail.

Potential implications of our update to the analyses used at PR08

2.15 In this report we provide an update for two strands of analysis carried out by Oxera that ORR drew on at PR08:

(a) The first concerns estimates of the changes over time in measures of real unit operating expenditure (RUOE) experienced in other regulated network industries in the UK. ORR drew on these estimates as part of its assessment of the efficiency gap for Network Rail's controllable operating expenditure.

(b) The second concerns TFP composite benchmarks based on productivity growth estimates for various sectors of the UK economy. ORR drew on these benchmarks in setting frontier-shift elements.

Update to RUOE analysis

2.16 Table 3 summarises the estimates from our update to the analysis of operating expenditure in other regulated network industries. It shows how the original Oxera estimate and our estimate over the more recent period combine to give a weighted average growth rate in RUOE over the entire period. Our analysis has excluded BT.

2.17 For consistency with other parts of this report, we present all our estimates of RUOE in terms of the growth in unit operating expenditure relative to the RPI (in contrast, Oxera's estimates were presented as annual rates of reductions in expenditure relative to the RPI). Under our presentation, a negative number indicates that the measure of unit operating expenditure decreased relative to the RPI.

Table 3 Summary of growth rates in RUOE (average annual percentage change)

	Period	Estimate from Oxera (2008)	Update for last four or five years	Weighted average over whole period
GB electricity distribution	1990/1991–2009/2010	–4.0	4.0	–2.7
National Grid Electricity Transmission	1990/1991–2009/2010	–4.9	2.5	–3.6
England and Wales water	1992/1993–2009/2010	–1.8	0.2	–1.4
England and Wales sewerage	1992/1993–2009/2010	–1.7	–1.2	–1.6
Scottish water	2002/2003–2009/2010	–8.8	3.3	–1.9
Scottish sewerage	2002/2003–2009/2010	–14.3	1.3	–5.4

2.18 The table above shows that the average annual reduction in RUOE for these regulated industries over the whole period covered in Oxera (2008) and our update was less than the average annual reduction in the period covered Oxera (2008).

2.19 As described above, at the last periodic review ORR carried out analysis of the potential efficiency gap for Network Rail's controllable operating expenditure. This included a calculation of how Network Rail's controllable operating expenditure would have evolved over time had it reduced by 5 per cent per year relative to the RPI (this included an adjustment made in relation to the Hatfield incident). ORR took the figure of 5 per cent from the central range of RUOE estimates provided in Oxera (2008). The central range reported in Oxera (2008) was based on the estimates of RUOE reductions in electricity distribution, electricity transmission and by BT.

2.20 Our update suggests that if a similar efficiency gap calculation were to be used in the future, involving an extrapolation from operating expenditure in 1996/1997, then an average annual rate of reduction in unit operating expenditure of 5 per cent would be too high. This is for a number of reasons, including:

(a) In the four-year period since the Oxera (2008) analysis, electricity distribution has seen an average annual increase in RUOE of 4 per cent — if the same output measure is used as in Oxera (2008). The average annual growth in RUOE over the last nineteen years is –2.7 per cent.

(b) The average change in the RUOE measure for the England and Wales water and sewerage industry was –1.4 and –1.6 per cent over the period since 1992/93. These sectors were excluded from the central range presented by Oxera. We do not see the basis for a similar exclusion in the future. Particularly in light of the more recent data for electricity distribution and transmission, the water industry does not seem an outlier as Oxera found in 2008.

2.21 In addition to the update to the estimates from Oxera (2008) we have also produced estimates of changes in measures of operating expenditure over more recent periods of time using different output measures (e.g. the number of connected customers rather than units distributed in the case of electricity distribution). We summarise and discuss this analysis towards the end of this section.

Update of TFP composite benchmarks

2.22 At the last periodic review, the efficiency projections for Network Rail comprised catch-up efficiency, frontier-shift efficiency and an adjustment for input prices. For the frontier-shift element, ORR drew on estimates of total factor productivity (TFP) composite benchmarks from Oxera (2008, 2008b). The figures used by ORR related to productivity growth for the benchmark less an estimate of whole-economy productivity growth.

2.23 We have updated the Oxera benchmarks using the latest version of the EU KLEMS dataset, which provides data to 2007. We used the same method as Oxera as far as possible. The benchmarks are calculated using data for different sectors of the UK economy on value added total factor productivity growth. We have not updated the weights that are used to map different elements of the benchmarks to different categories of Network Rail data. We have used the same value for the capital substitution adjustment as in Oxera (2008). We describe our analysis in more detail in section 5.

2.24 We calculate the benchmarks over two time periods. The first is based upon a three year extension to the period of 1981 to 2004 that Oxera used. The second spans the entire period of data available from the EU KLEMS dataset, 1970 to 2007. Table 4 summarises our estimates and compares them with Oxera (2008) and Oxera (2008b).

Table 4 TFP composite benchmarks (average annual percentage growth)

	Opex	Maintenance	Renewals	Enhancement	Enhancement alternative
Oxera estimate 1981–2004	1.0	2.1	2.1	2.0	1.8
Updated estimate 1981–2007	1.1	1.8	1.6	1.6	1.5
Updated estimate 1970–2007	1.0	2.0	1.5	1.6	0.6

2.25 The updated benchmarks are similar to the benchmarks calculated by Oxera, with the exception of the alternative enhancement expenditure benchmark which falls from 1.8 to 0.6 if we use data over the full period 1970 to 2007. The alternative TFP benchmark for enhancement expenditure is predominantly based on estimates of productivity growth for the construction sector, and these seem particularly sensitive to the change in time period.

2.26 The EU KLEMS data for the UK economy as a whole show a growth rate in value added total factor productivity growth of 0.8 per cent for the period 1981 to 2007, which compares to a corresponding figure for 1981 to 2004 of 0.7 per cent from Oxera (2008). Over the period 1970 to 2007, we calculate the growth rate in value added total factor productivity growth for the UK economy as 0.4 per cent, which reflects a period in the 1970s when, according to the EU KLEMS data, value added total factor productivity fell in the UK.

2.27 These updated estimates suggest that if the method used at the last periodic review were to be repeated with updated numbers across the entire data period, then there could be a slight increase in the allowance for frontier-shift for opex and maintenance expenditure due to the decrease in total industry TFP. Renewals expenditure frontier-shift would be similar, with a decrease in total industry TFP offset by a reduction in the benchmark. The figure for enhancement expenditure would depend significantly upon the choice of benchmark as well as on the data period chosen. The changes would be smaller if the period of data used was 1981 to 2007 rather than 1970 to 2007, particularly for enhancement expenditure.

2.28 However, we have some serious reservations about the use of the estimates for TFP composite benchmarks to set frontier-shift elements.

2.29 First, the approach ORR used at the last periodic review involved the combination of a frontier-shift element with separate adjustments for input prices. We have not examined in any detail the analysis underpinning the input price adjustments. However, it seems possible that they are intended to capture the extent to which the prices of the inputs that Network Rail uses (including labour) will increase relative to the RPI. If so, then we do not see the basis for subtracting an estimate of economy-wide productivity growth from the TFP composite benchmarks. This approach risks double counting the potential for Network Rail to face input price inflation in excess of the growth in the RPI.

2.30 Second, there are two different concepts of total factor productivity (TFP) growth: TFP growth calculated on a "value added" basis and TFP growth calculated on a gross output basis. These are not different ways of estimating the same thing; they are different things entirely. The TFP composite benchmarks are based on estimates of TFP growth on a value added basis. The concept of "value added" relates to the difference between the value of output produced in a sector and the expenditure of that sector on intermediate inputs (e.g. materials and services but not labour). Whilst this concept is useful in growth accounting and macroeconomics, it is not well suited to be reconciled with accounting or business concepts such as operating expenditure or with the changes over time in the efficiency and costs of particular companies. We have not identified a good reason to use a measure of total factor productivity growth that is based on the value added concept. We compare estimates for gross output TFP and value added TFP below. There are systematic differences, with estimates for gross output TFP growth being of a smaller magnitude.

2.31 Third, the TFP composite benchmarks rest on the idea that Network Rail can be decomposed into a number of parts, with each part expected to experience the same productivity growth as one or two selected sectors of the UK economy. This idea allows us to take estimates of the productivity growth experienced by different sectors of the UK economy and to produce a single productivity growth estimate for Network Rail. This is, at best, overly-ambitious. At worst, the method may provide a misleading impression of the extent to which the estimate of productivity growth for Network Rail takes account of the details of Network Rail's business.

2.32 For instance, within the maintenance expenditure category, track maintenance is mapped to the productivity improvements in the sectors labelled "Transport and storage" and "Electricity, gas and water supply" in the EU KLEMS database. It is not hard to think of differences between track maintenance activities and the economic activities within these two sectors that could lead to differences in productivity growth rates. Nor is it hard to find other sectors that seem no less plausible comparators for track maintenance (e.g. construction).

2.33 In addition to our update of the value-added TFP composite benchmarks, we have carried out a different type of analysis of the data available from EU KLEMS, in an attempt to address these problems.

Gross output TFP and LEMS productivity growth

2.34 We have estimated two separate measures of productivity growth for a range of different sectors using EU KLEMS data. The first of these measures is gross output TFP over the period 1970 to 2007.

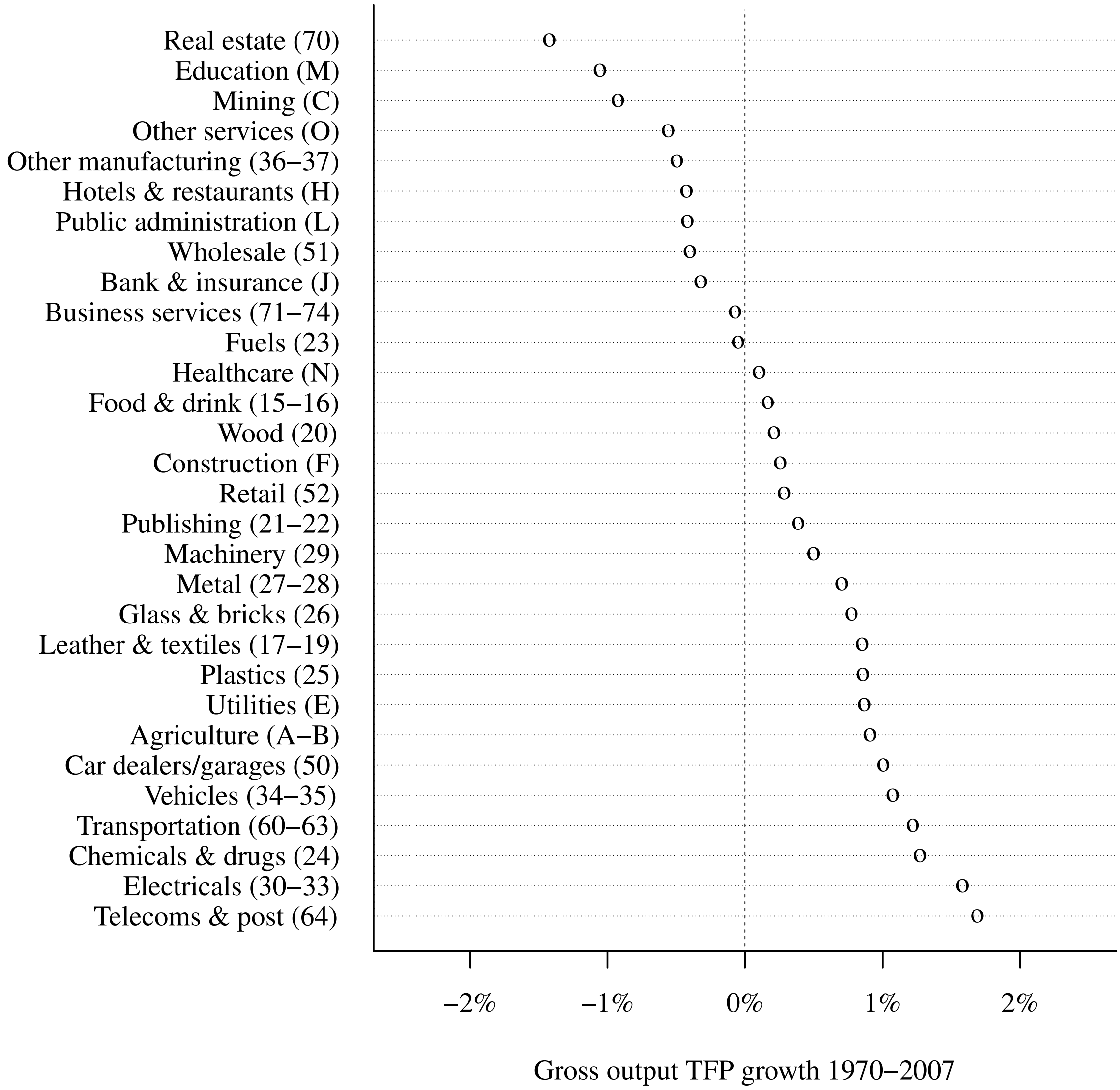
2.35 The growth in gross output total factor productivity can be seen as an estimate of the increase in the annual volume of gross output that might be obtained from using a constant volume of labour inputs, services from capital and intermediate inputs. It can also be seen as the growth rate in the volume of gross output that is not attributed to growth in the volume of inputs used.

2.36 Figure 2 shows the estimates of the logarithmic annual growth rate in gross output TFP for the 30 most disaggregated sectors of the UK economy for which data are available from EU KLEMS. We provide more information on the calculation of logarithmic annual growth rates in the appendix at the end of this document.

2.37 For most sectors, the estimates of gross output TFP growth range from around –1 to 1 per cent per year. Only two sectors show TFP growth rates much above 1 per cent.

2.38 The estimates for the TFP composite benchmarks reported earlier in table 4 seem relatively high compared to the estimates of gross output TFP growth for these sectors. The estimates for the benchmarks range from around 1 per cent for operating expenditure to around 2 per cent for enhancement expenditure. This difference can be explained, in part, by the use of value added measures of productivity growth in the composite benchmarks, since value added TFP growth for a sector will be of a greater magnitude than gross output TFP growth for that sector.

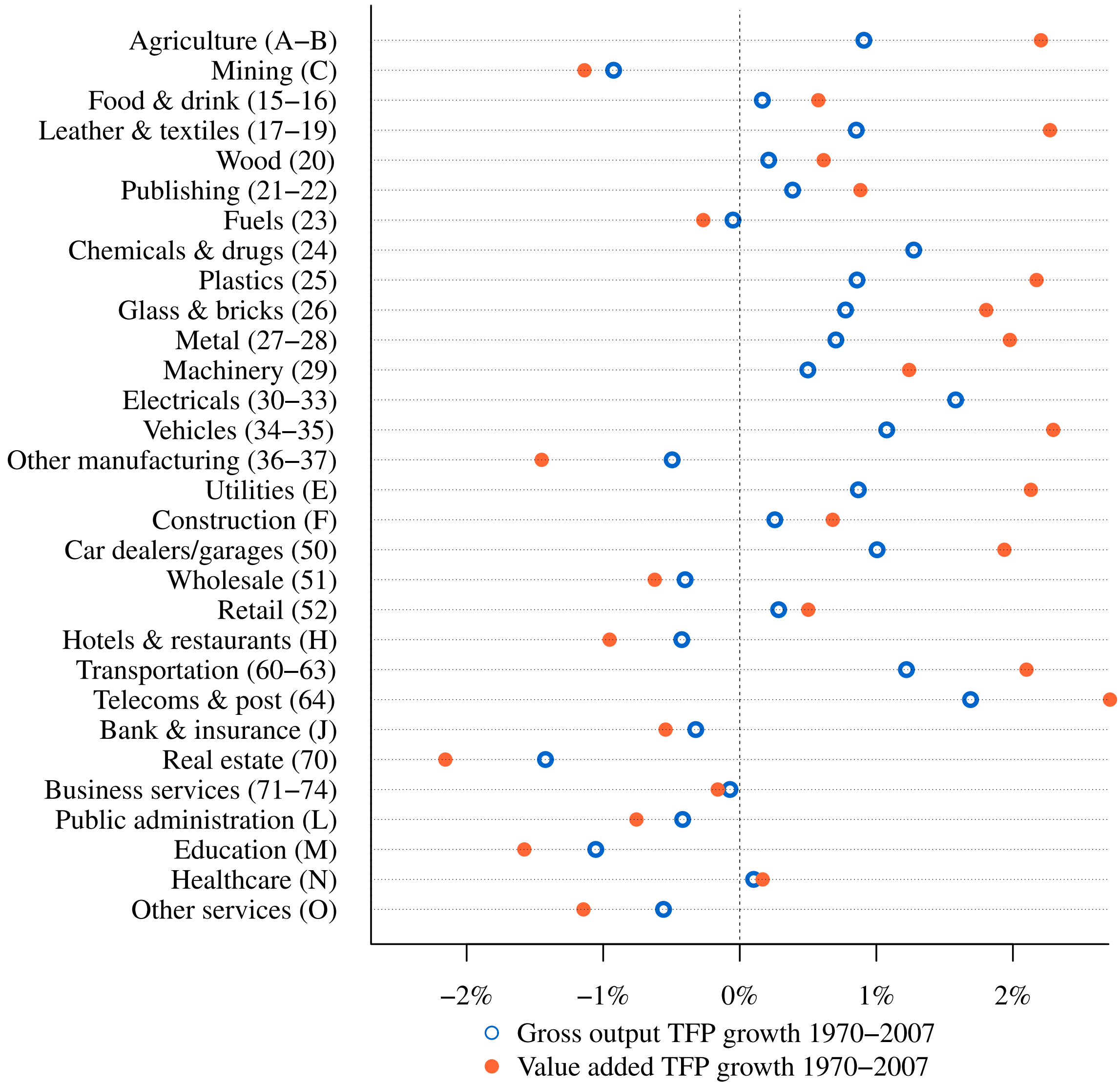
Figure 2 Growth rate in gross output productivity measure 1970 – 2007



2.39 Figure 3 provides a comparison between TFP growth calculated on a gross output versus a value added basis for the sectors above over the same period. Across both gross output TFP and value added TFP, we see that a number of sectors are estimated to have experienced negative productivity growth. We would not expect industries, especially competitive private sector industries, to experience negative productivity growth over long periods of time. These estimates may reflect measurement error. However, it is possible that some sectors have experienced negative productivity growth for reasons unconnected with measurement error — for instance, some

Government regulations or laws may reduce productivity (e.g. this is possible for some health and safety or employment legislation).

Figure 3 Comparison of value added and gross output TFP growth 1970 – 2007



2.40 In addition to gross output TFP growth, we have calculated estimates of productivity growth for a measure that we call LEMS productivity (at constant capital). LEMS stands for labour, energy, materials and services. This measure is described in more detail in section 6. The growth rate in LEMS productivity (at constant capital) provides an estimate of the decrease in the volume of labour and intermediate inputs that might be expected from past productivity trends, if there was to be a constant volume of output and a constant volume of services from capital. This can be calculated by taking an estimate of gross output total factor productivity growth achieved and making an estimate of what would have happened if that total factor productivity growth had only been manifest through reductions in the volume of labour and intermediate inputs.

2.41 Figure 4 shows the estimates for the growth in LEMS productivity at constant capital for 30 sectors of the UK economy over the period 1970-2007. The figure also shows a measure called the LEMS productivity growth without capital adjustment. This is calculated as the growth in a measure of the volume of output produced by a sector minus the growth in a measure of the volume of labour and intermediate inputs used in that sector. This measure may be particularly sensitive to changes, over time, in the amount of capital employed in the sector relative to labour and intermediate inputs.

2.42 The LEMS productivity growth estimates may be relevant to assumptions about frontier-shift for operating expenditure, or operating and maintenance expenditure. There are a number of issues that would need to be considered if measures of LEMS productivity were used to provide information about frontier-shift for Network Rail's operating and maintenance expenditure. These include:

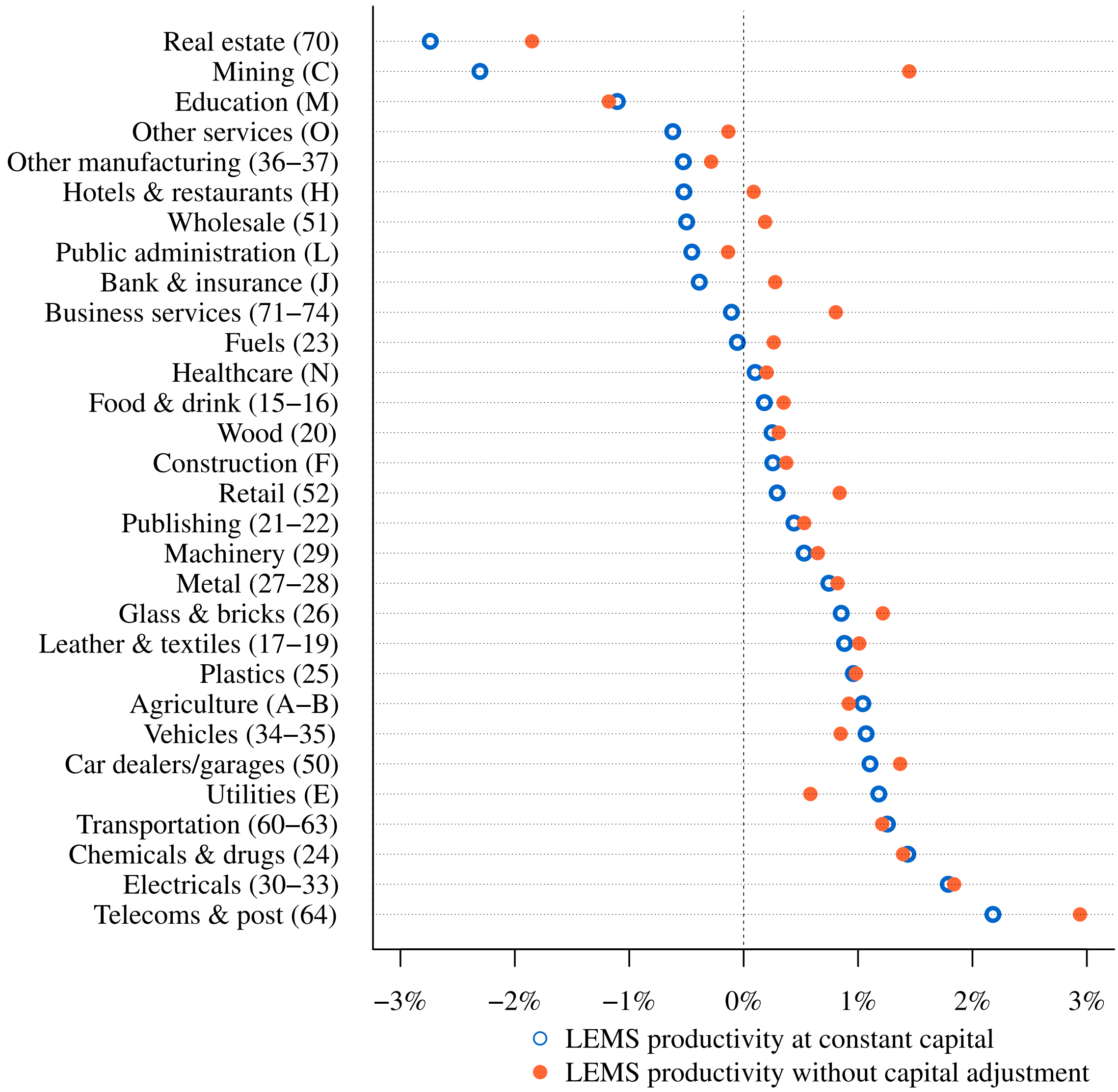
(a) The LEMS productivity estimates will likely include a degree of catch-up productivity improvements that can be considered a normal part of business activity.

(b) The relatively high rates of productivity growth for the utilities sector and the telecommunications and post sector may reflect the transitory impacts of privatisation in these sectors.

(c) The effect of capital substitution will need to be considered. For instance, the LEMS productivity (at constant capital) provides an estimate of the productivity gains that would have occurred had the sector operated with a level of constant capital inputs per unit of output. It would be important to ensure that assumptions made about productivity for other expenditure categories are compatible with this assumption about the volume of capital (see the discussion towards the end of section 3).

2.43 As we discuss in section 3, it does not seem necessary to examine estimates of productivity growth. It may better to focus on changes in unit costs directly, without decomposition into productivity and input price effects.

Figure 4 Growth rate in LEMS productivity measures 1970 – 2007



Further analysis of unit cost measures and output prices

2.44 We have used data from the EU KLEMS dataset to calculate historical growth rates in output price indices for 30 sectors of the UK economy and historical growth rates in a unit cost measure which is intended to be comparable with operating expenditure. We have also examined some more detailed data on output price indices for the construction sector.

2.45 Estimates of changes over time in unit cost measures and output price indices should reflect the effects of both productivity growth and input price inflation, so the estimates from this part of our analysis are most comparable to the combined effect of frontier-shift and input price effects. At the last periodic review, ORR made separate decisions about frontier-shift and input price effects, and the input price adjustment varied from year to year over the price control period. Table 5 shows our understanding of the combined impact of the frontier-shift and input pride elements, expressed as a logarithmic annual growth rate over the period. The logarithmic annual growth rate shown indicates a single annual growth rate that would lead to the same level of expenditure by March 2014 as implied by the various frontier-shift and input price adjustments. We provide more information on the calculation of logarithmic annual growth rates in the appendix at the end of this document.

Table 5 Combined impact of frontier-shift and input price adjustment

Expenditure category	**Logarithmic annual growth rate between April 2009 and March 2014implied by input price adjustment less frontier-shift**
Controllable opex	RPI + 1.4%
Maintenance	RPI + 0.6%
Renewals	RPI + 0.0%

2.46 In the table above, RPI plus 1.4 per cent implies an expectation of controllable operating expenditure increasing by 1.4 per cent more than RPI inflation in each year of the price control period. The increase above RPI arises from a view that the productivity gains from frontier-shift are not sufficient to offset the expectation of input price growth in excess of the growth in the RPI.

2.47 A number of limitations and vulnerabilities apply to any attempt to draw inferences about frontier-shift and input price effects for Network Rail from our analysis of unit cost measures and output price indices for other sectors of the UK economy. Notwithstanding these concerns, we highlight that:

(a) The growth rate of RPI plus 1.4 per cent seems relatively high compared to the historical data for different sectors of the UK economy. For instance, over the period 1970 to 2007 the growth rates, relative to RPI, in the LEMS cost measure for the majority of the 30 sectors are spread between –1.5 and 1.5 per cent.

(b) The figures of RPI plus 0.6 per cent for maintenance and RPI plus 0 per cent for renewals align better with our updated analysis. For instance, there are grounds to compare these elements with the rates of change in output prices in the construction sector. The output price indices for construction sector will reflect both the productivity improvements achieved by construction companies and the input price inflation that they face (e.g. wage growth and materials prices). Using the EU KLEMS dataset we estimate a long-term growth rate for the construction output price index of 1.1 per cent between 1970 and 2007 (this is relatively high compared to output price indices for other sectors). We have also estimated the growth rates in several output price indices for the construction sector, using the BIS Output price indices database published by BCIS. Over the period 1990 to 2009, the average annual growth rates for the construction price indices which seem most relevant lie between –0.4 and 1 per cent.

2.48 We discuss the LEMS cost measure below. It is described more fully in section 6.

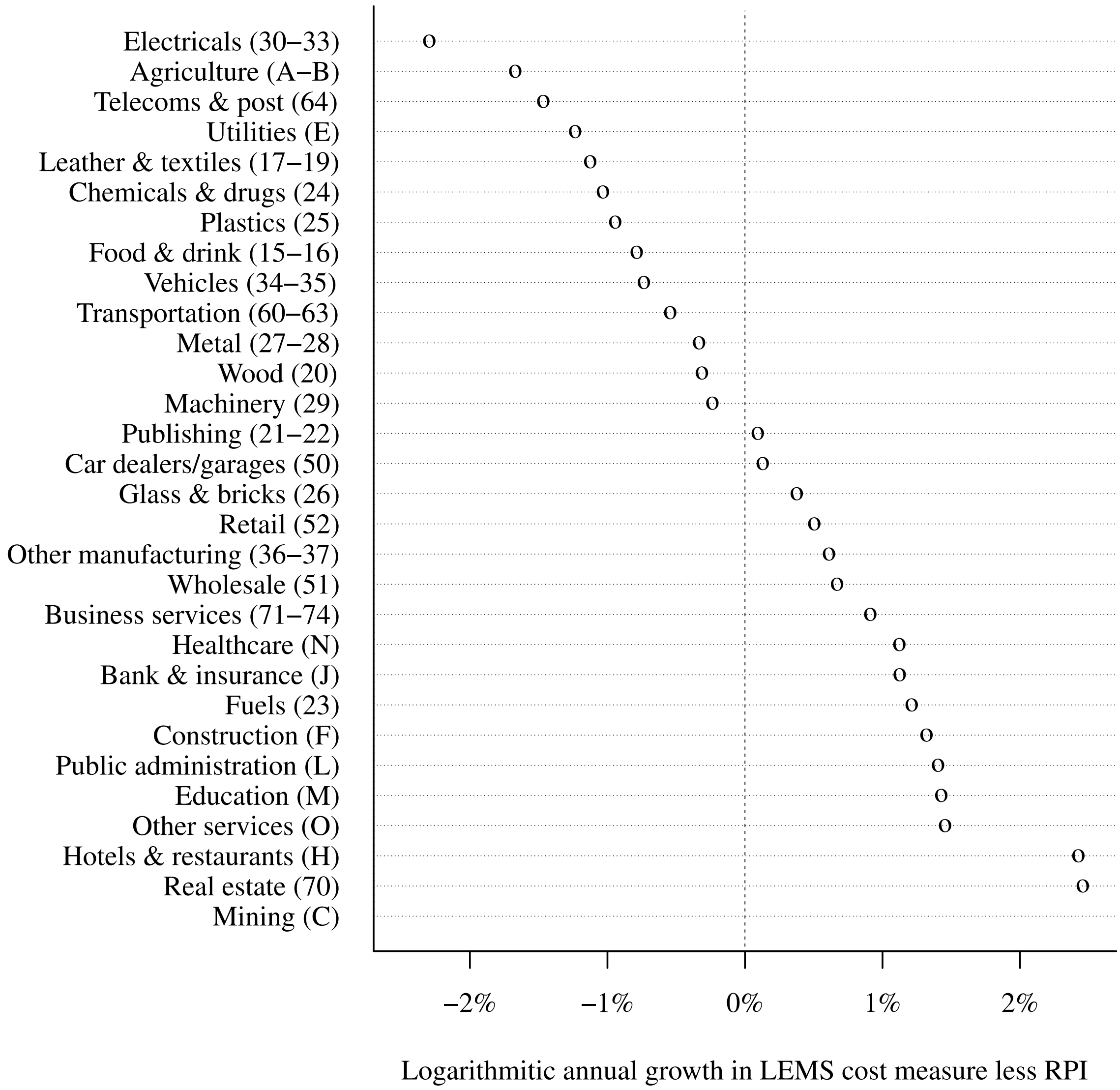
Comparisons with the LEMS cost measure

2.49 We have used the EU KLEMS dataset to produce estimates for each sector of the UK economy of the growth rate, relative to RPI, in what we call the LEMS cost measure. The LEMS cost measure captures labour costs and expenditure on intermediate inputs and excludes the purchases of capital by a sector. This seems similar, in some ways, to the concept of operating expenditure (excluding depreciation). However, there are several reasons why changes over time in the LEMS cost measure are not the same as measure of changes in operating expenditure. The LEMS cost measure is discussed further in section 6.

2.50 The estimates for the LEMS cost measure should reflect the impact of productivity growth in each sector and of changes, relative to the RPI, in the prices of labour inputs and of intermediate inputs (e.g. the prices of materials and energy used for production).

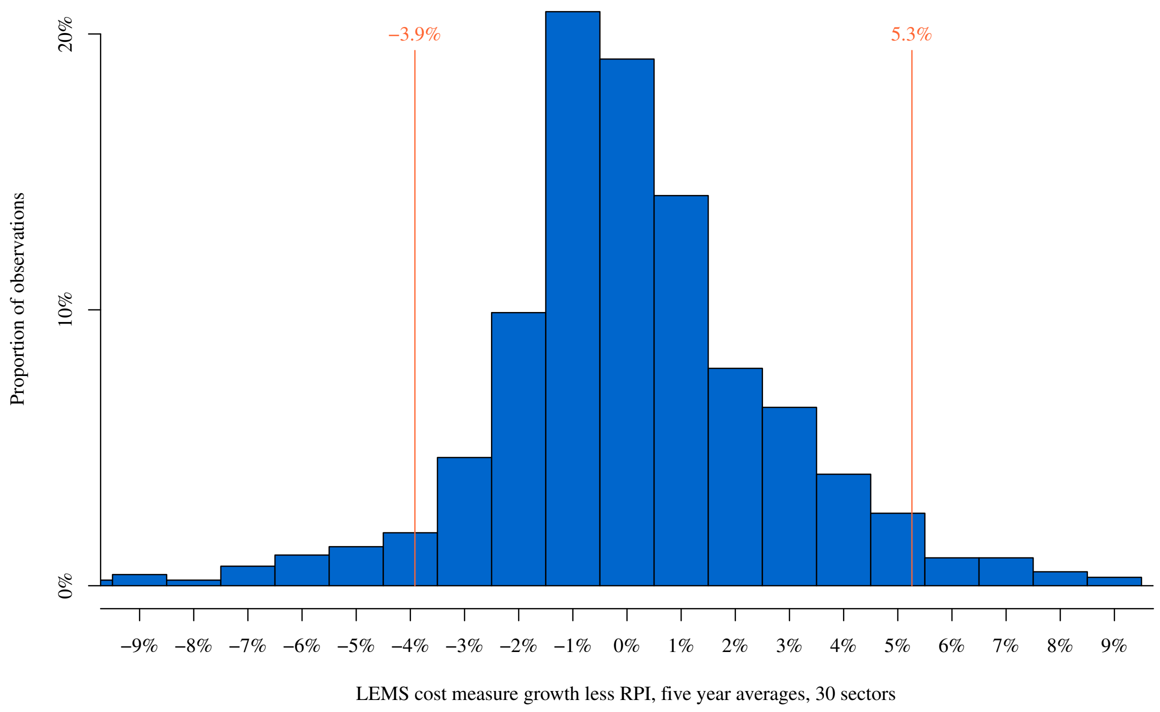
2.51 Comparisons might be made between the figure of RPI plus 1.4 per cent for "controllable opex" in table 5 and the estimates for the LEMS cost measure. The growth rate in the LEMS cost measure is, in our view, the most comparable thing to the growth rate in operating expenditure per unit of output (under a constant capital hypothesis) that can be calculated from the EU KLEMS dataset. The growth in the LEMS cost measure for a sector should not be taken as a perfect guide to the changes in operating expenditure, per unit of output, for companies in that sector. Figure 5 shows estimates for the logarithmic annual growth rate (relative to RPI) in the LEMS cost measure. A positive number indicates costs rising relative to the RPI.

Figure 5 Growth rate in LEMS cost measure (relative to RPI) 1970 – 2007



2.52 Figure 6 provides a histogram which indicates the variation in the growth rates of the LEMS cost measure over five-year periods, taking all sectors together. We use five-year averages as this is the current duration of the Network Rail price control. The histogram shows the frequency distribution of the 1,020 observations corresponding to each combination of a sector (there are 30 sectors) and a period of five consecutive years (there are 34 such periods between 1970 and 2007). For each observation, the annual average growth in output prices less RPI is calculated, and is placed in the "band" corresponding to the nearest integer percentage value. The height of each bar on the histogram is proportional to the proportion of the observations in the relevant band.

Figure 6 Distribution of annual growth rates for LEMS cost measure relative to RPI (five-year averages, all sectors)



2.53 The mean of the five-year averages is 0.3 per cent and the median is –0.1 per cent. The vertical lines in the histogram enclose 90 per cent of the observations. In 90 per cent of cases for which we have data, the average growth rate of the LEMS cost measure over a five-year period was between –3.9 per cent and 5.3 per cent.

2.54 The LEMS cost measure includes expenditure on intermediate input that is treated, for the purposes of National Accounts data, as it is "consumed" in production in the year incurred, rather than contributing to "capital formation". It seems likely to include expenditure that would be treated as maintenance expenditure under the definitions applied to Network Rail. This raises the question of whether the growth rate in the LEMS cost measure is best compared with Network Rail's operating expenditure including or excluding maintenance expenditure. Because Network Rail is likely to have a relatively high amount of non-capitalised maintenance work, compared to other sectors of the UK economy, there is an argument that comparisons with other sectors may be better if maintenance is excluded. ORR separated maintenance expenditure from operating expenditure as part of the work at the last periodic review.

2.55 There are a number of potential problems with comparisons with between the LEMS cost measure and the figure for "controllable opex" in table 5:

(a) The LEMS cost measure will reflect the productivity growth achieved by companies in the sector. Some of this may have taken place through imitation and adoption and might be seen to overlap with catch-up.

(b) The LEMS cost measure is a unit cost measure. It is intended to capture the rate of growth in labour and intermediate input costs per unit of output produced in each sector. If Network Rail is expected to provide a greater or lesser quantity or quality of services in the future then this could affect its operating expenditure requirements.

(c) The LEMS cost measure is calculated to provide an estimate of a growth rate in labour and intermediate input costs that is compatible with a company maintaining a constant volume of services from its capital assets. If Network Rail experiences a large increase in the volume of its capital assets, relative to the volumes of its outputs, it may face less growth in operating expenditure.

(d) There may be differences between the growth rates in the LEMS cost measure and the growth rates in Network Rail's "controllable" operating expenditure that arise because some other (presumably "uncontrollable") elements of operating expenditure will feature in the LEMS cost measure.

2.56 We provide more information about how the LEMS cost measure might be relevant to ORR's work on Network Rail price controls in section 3.

The evolution of operating expenditure in regulated network industries

2.57 Oxera (2008) shows substantial reductions in measures of the unit operating expenditure of regulated network companies, relative to the RPI. Oxera gave particular emphasis to estimates of reductions in RUOE in for electricity distribution companies in Great Britain, National Grid's electricity transmission business in England and Wales and BT. Oxera also provided estimates for water and sewerage companies in England, Wales and Scotland.

2.58 Our update covers these companies with the exception of BT. In addition, we have produced RUOE estimates for gas distribution companies in the period since National Grid sold some of the gas distribution networks and separate price controls were established for gas distribution. In contrast to the estimates in Oxera (2008), we find that these industries have either experienced smaller reductions in RUOE over the four- or five-year period of our update than in the earlier period covered by Oxera (2008) or that they have experienced significant increases in RUOE.

2.59 This section provides some additional context that may be relevant to the estimates of RUOE for regulated network industries.

Speculation on the impacts of privatisation and price control regulation

2.60 When looking at the estimates of changes over time in measures of operating expenditure for regulated network companies in the UK since privatisation, we suggest that the following ideas are kept in mind:

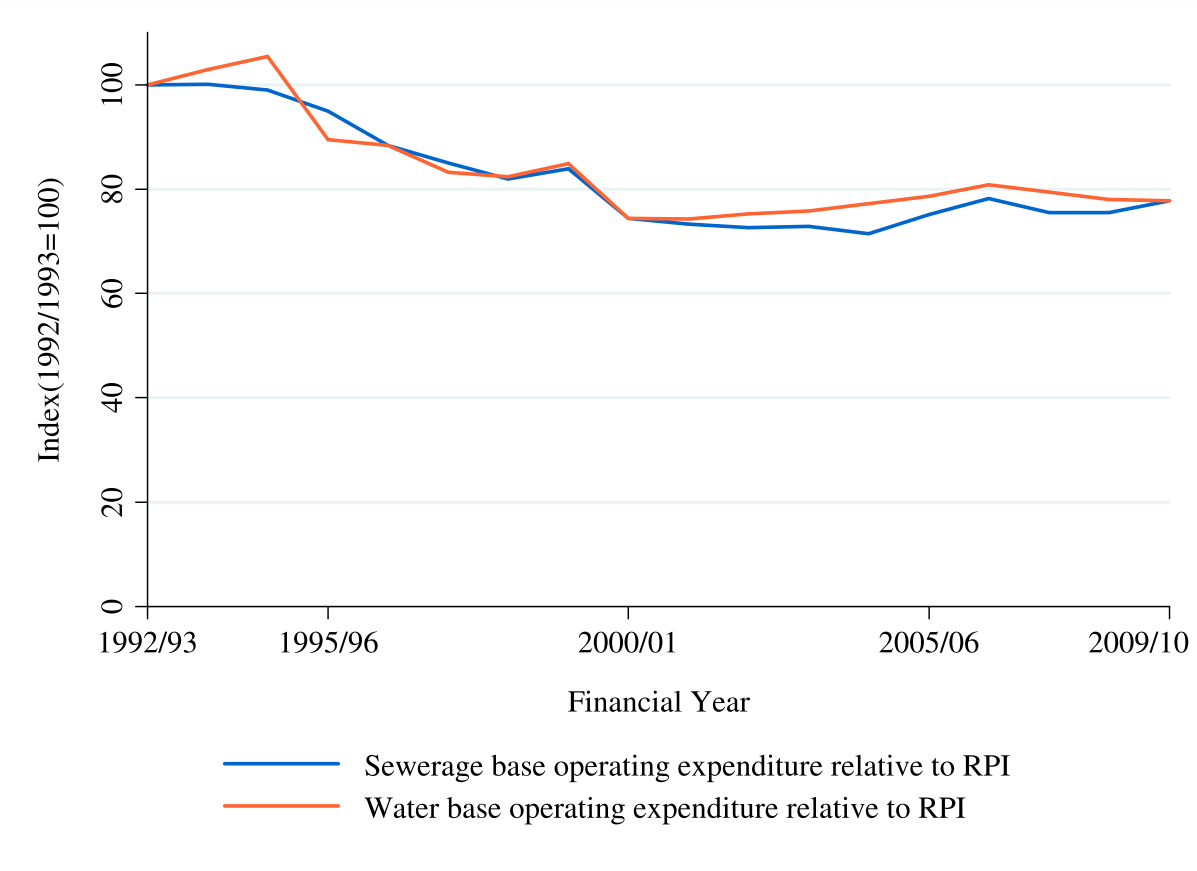
(a) **Low-hanging fruit following privatisation**. Apart from some of the smaller water companies, and Scottish Water, the companies in our sample of regulated network companies were previously in public sector ownership and then privatised. Public sector ownership may have led to a situation in which there were particularly large opportunities for productivity improvements (low-hanging fruit) which companies took following privatisation and the introduction of price control regulation.

(b) **Shift in favour of capital expenditure**. The form of price control regulation that has been applied to water and sewerage companies, to electricity network companies and to gas network companies has involved differences in the treatment of operating expenditure and capital expenditure. Companies have faced clear profit opportunities from making reductions to operating expenditure where possible. The profits that companies could make from reductions to capital expenditure have been more limited. Indeed, it is possible that some companies may have taken the view that reducing capital expenditure would not be a profitable strategy, because this would lead to a lower regulatory asset base (or regulatory asset value) in the future which would, in turn, reduce the profits that the company would be allowed in future price control periods. In these circumstances, companies may have achieved substantial reductions in operating expenditure as a result of changes to working practices that placed an emphasis on capital expenditure rather than operating expenditure (and, perhaps, through capitalisation policies that increased the proportion of expenditure treated as capital expenditure).

2.61 These factors may have led to a period in which the operating expenditure of regulated energy and water network companies reduced at a rapid rate that would not be maintained over the longer-term.

2.62 For example, this view would be consistent with the sharp reductions, relative to the RPI, in base service operating in the water industry up to around 2000/2001, after which there have been no sustained decreases in base operating expenditure relative to the RPI. This is illustrated in figure 7 (see section 4 for more information).

Figure 7 Water and sewerage base service operating expenditure relative to RPI



2.63 The issues above have been recognised by economic regulators in the UK. For instance, Ofgem carried out a review of its approach to energy network regulation in Great Britain which was completed in 2010 (the "RPI-X@20" review). In a consultation paper early in the review, Ofgem (2009, page 20) pointed to the substantial reductions in unit operating expenditure experienced since privatisation but suggested that it does not necessarily expect to see similar rates of reduction in the future:

> "There is evidence to suggest that operating efficiency has increased [over the last couple of decades], for example real unit operating expenditure has fallen by approximately 5.5% p.a. across the electricity distribution networks since privatisation, and we continue to set incentives to encourage the energy network companies to improve their operating efficiency. […]
>
> "In recent years, however, we have observed changes. At the most recent price reviews, we have allowed stable (RPI+0) or increasing (RPI+X) prices. Companies continue to

have incentives to reduce costs, for example through the adoption of new business models, but the scope for further large-scale reductions may be limited."

2.64 In relation to the second point above, Ofgem (2010, page 10) says that stakeholders had suggested that the existing regulatory frameworks led to a bias towards "capex" solutions. Ofgem is implementing changes to reduce the extent to which operating expenditure is treated differently from capital expenditure in its price controls. This includes Ofgem's new policy on what it calls the "efficiency incentive rate", which is a risk-sharing mechanism through which the maximum revenue that a regulated energy network company is allowed to collect from consumers is adjusted in light of its actual expenditure during the price control period. Ofgem (2010, page 84) says:

> "The same efficiency incentive rate will also apply to operating expenditure and capital expenditure. This will reduce the risk that expenditure decisions may be distorted in favour of capital expenditure solutions."

2.65 Ofwat is also carrying out to a review of the way that it regulates the water and sewerage companies in England and Wales. As part of a discussion paper in 2010, Ofwat (2010, page 48) raised the following questions about the "capex bias" and said that it will be doing more work on these issues:

> "To what extent is there a preference for capital expenditure solutions? What role do our incentives play in this (in combination with incentives from other aspects of regulation, company culture and the interests of investors)?"

More recent changes in the regulatory regime

2.66 It is possible that the recent increases in operating expenditure for regulated energy and water network companies reflect changes over time in regulatory arrangements that companies operate under. There are usually a number of substantial changes from one price control period to the next and it is possible that some of these may have affected the strength of financial incentives that companies face to reduce (or restrain) operating expenditure or affected companies' preferences between operating expenditure and capital expenditure.

2.67 We have looked through the headline points made in the price control decisions by Ofgem and Ofwat for the periods from 2005. We did not identify any major changes to the price controls applying in the period 2005 to 2010, compared to earlier price controls, which would explain the impacts above. However, the price control arrangements for regulated energy network and water and sewerage companies are very complicated and we have not had an opportunity, as part of this project, to review in detail changes made that may have affected the financial incentives related to companies' operating expenditure.

2.68 The most significant developments that we are aware of in this area are the changes to the "efficiency incentive rate" introduced by Ofgem as part of its most recent review of electricity distribution network price controls and developed further in its RPI-X@20 review (see previous sub-section). These changes reduce the extent to which operating expenditure is treated differently from capital expenditure as part of the price control. It is possible that we will see increases in operating expenditure as companies have less reason to favour capital expenditure. These changes were implemented in the period after the end of the data period used for our RUOE estimates and do not seem relevant to the estimates we present in this report. They may be relevant as part of any future work on RUOE estimates for energy network companies in Great Britain.

Comparisons with estimates from the EU KLEMS dataset

2.69 We have used the EU KLEMS dataset to produce estimates for each sector of the UK economy of the growth rate, relative to RPI, in what we call the LEMS cost measure.

2.70 As far as we are aware, the growth rate in the LEMS cost measure is the most comparable thing to the growth rate in operating expenditure per unit of output (under a constant capital hypothesis) that can be calculated from the EU KLEMS dataset. We describe the measure further in section 6.

2.71 We have provided summary information for the LEMS cost measure above. The histogram for the LEMS cost measure shows that in 90 per cent of cases for which we have data, the average growth rate of the LEMS cost measure index over a five-year period was between –3.9 per cent and 5.3 per cent. An average growth rate in the LEMS cost measure of around –4 or –5 per cent is a rare event in the sectors covered by the EU KLEMS data.

2.72 This comparison is consistent with the view that the relatively rapid reductions in measures of unit operating expenditure, relative to the RPI, for some regulated network industries arose from special circumstances — such as privatisation and the introduction of price control regulation — and that we should not expect them to be sustained over the long-term.

Regulatory precedent

2.73 Regulatory precedent is consistent with the view that the relatively rapid reductions in unit operating expenditure relative to the RPI, experienced in industries subject to price control regulation, was a transitory rather than long-term phenomenon.

2.74 In previous rounds of price control decisions, UK regulators tended to set out expectations that regulated companies could achieve substantial reductions in operating expenditure relative to the RPI. For instance, between 1991 and 2001, around twenty price control decisions for privatised energy, water, telecommunications and airport companies were made which included assumptions that the companies could reduce some measure of operating expenditure by between two and five per cent per year relative to the RPI.[1] More recent price control decisions seem to be based on a view that there is now less opportunity for operating expenditure reduction relative to the RPI. We summarise a number of recent regulatory decisions in section 8.

The estimates for regulated network companies for more recent years

2.75 In light of the discussion above, it seems probable that the estimates in Oxera (2008) reflect a transitory period of high productivity gains and/or a period in which companies shifted away from operating expenditure and towards capital expenditure. The full period of data does not seem likely to provide a good guide to future operating expenditure in these industries.

2.76 Table 5 above set out our understanding of the combined impact of ORR's frontier-shift and input price adjustment elements, for each category of Network Rail expenditure over the period 2009/2010 to 2014/2015. For controllable operating

[1] Based on the summary of efficiency assumptions adopted by UK regulators provided at Table D.4 of Mazars Neville Russell (2001).

expenditure, this works out as a logarithmic annual growth rate in controllable operating expenditure of around RPI plus 1.4 per cent. To the extent that the regulated network industries covered in our RUOE analysis can be taken as relevant comparators to Network Rail, the estimates of changes over time in RUOE for more recent periods of time provide information that could be relevant to any update of this figure for CP5.

2.77 Table 6 provides estimates of RUOE for the last four years using a number of different output measures. This includes RUOE estimates for Network Rail, which was not covered in Oxera (2008). The table also shows the growth in operating expenditure relative to RPI — i.e. a growth rate before any adjustment for growth in outputs. The figures in table 6 are averages of the logarithmic annual growth rates over the period 2006/2007 to 2009/2010, rather than averages of the annual percentage changes from year to year as presented in Oxera (2008). A logarithmic growth rate makes more sense in circumstances in which there may be a time lag of more than a year between a change in the volume of output and the associated change in operating expenditure requirements. Due to data availability, there are some differences across the estimates in terms of the expenditure coverage (e.g. whether business rates or local authority rates are included). More information on the methods used is presented in section 4.

2.78 We have provided estimates for alternative output measures. Whilst none of these output measures is anywhere near perfect, when RUOE is calculated over short periods of time we suggest that an output measure for electricity and gas distribution networks that is based on the number of customers is more suitable than an output measure based on the volume of energy distributed (with or without adjustments for economies of scale). If the output measure for electricity and gas distribution is taken as the number of customers, rather than measures of energy distributed, then the range across the RUOE estimates excluding Scottish Water is –1.5 to 1.9 per cent.

Table 6 Average logarithmic annual growth rates between 2006/2007 and 2009/2010

Industry	Growth in operating expenditure relative to RPI (%)	Output measure(s)	Adjusted for economies of scale?	Growth in RUOE (%)
Electricity distribution in Great Britain	2.8	Units distributed	Yes	3.9
		Units distributed	No	4.4
		Customer numbers	No	2.4
England and Wales water	–0.3	Water delivered and households billed	Yes	–0.1
		Water delivered and households billed	No	0.0
		Base service	No	–0.1
England and Wales sewerage	–0.8	Population connected and population billed	Yes	–1.5
		Population connected and population billed	No	–1.4
		Base service	No	–1.3
Gas distribution in Great Britain	–0.6	Annual demand	Yes	2.6
		Annual demand	No	2.9
		Customer numbers	No	–1.0
National Grid Electricity Transmission	1.0	Annual demand	Yes	2.4
		Annual demand	No	3.0
Scottish Water water service	3.2	Water delivered	Yes	5.8
		Water delivered	No	5.9
Scottish Water sewerage service	1.0	Population connected	Yes	0.7
			No	0.7
Network Rail	–0.7	Length of lines	No	–0.6
		Passenger train kilometres	No	–3.3

2.79 If taken at face value, these estimates might imply a growth rate for Network Rail's controllable operating expenditure (excluding catch-up efficiencies) of somewhat less than the figure of RPI plus 1.4 per cent from table 5. However, it is not straightforward to use these numbers to set frontier-shift and input price inflation for Network Rail:

(a) The estimates are for a relatively short periods of time. It may not be sensible to make long-term forecasts solely on the basis of four years' data. This is particularly true for expenditure data taken from regulated companies, since regulatory arrangements may distort the profile of expenditure between years.

(b) The changes over time in operating expenditure for regulated network industries are likely to include catch-up elements. At least some of the productivity improvements achieved by companies in each industry are likely to have been through imitation and adoption of practices and technologies used by other companies.

(c) At the last periodic review, ORR applied a frontier-shift assumption to a measure of Network Rail's controllable operating expenditure which excluded cumulo rates. There is an argument that changes over time in Network Rail's operating expenditure requirements and the operating expenditure requirements of other regulated network companies are more comparable if cumulo rates and similar taxes are excluded. However, we did not find data on these rates for the gas and electricity network companies. Most of the RUOE estimates summarised above relate to a measure of operating expenditure that include cumulo rates or similar taxes (e.g. network rates or local authority rates).

(d) The RUOE numbers have been adjusted for changes in volume. When applying these estimates to any projection for Network Rail it will be important to consider the impact that changes in the quantity and quality of the services that Network Rail provides may have on its expenditure requirements.

(e) Expenditure data from other regulated industries can inform expectations on Network Rail's expenditure if there is a degree of comparability between the sectors. Whilst there some good grounds for drawing comparisons between the

Network Rail and the industries above (e.g. asset management functions) there remain substantial differences between these industries. For this reason, it seems sensible to also look at estimates from other industries, such as those covered by our analysis of the EU KLEMS data.

2.80 In respect of the first point above, we recognise that the estimates of RUOE growth presented in this report are, in most cases, limited to either (i) the last four years or (ii) a weighted average over recent years and the preceding period covered in Oxera (2008). It was beyond the scope of this update study to collect and examine data on the operating expenditure of regulated network companies in the period already covered in Oxera (2008). This means that we are not in a position to provide, for example, estimates of the changes in RUOE for electricity distribution companies over the last ten years. As part of its future work, ORR may wish to examine estimates of the changes in RUOE over alternative time periods. Where this requires looking further back in time, it would be necessary to consider potential changes to accounting policies and the nature of scope of the regulated businesses.

2.81 We provide further information about how RUOE estimates might be relevant to ORR's work on Network Rail price controls in section 3.

3 Interactions between efficiency elements of the price control

3.1 We set out in section 2 our understanding of the methods used by ORR at the last periodic review (PR08). In this section we provide some thoughts on the interactions between the estimates provided in this study and other elements that are relevant to ORR's judgements about Network Rail's future opportunities for efficiency improvements — input price adjustments and catch-up.

3.2 The section takes the following points in turn:

(a) Interactions with input price adjustments.

(b) Potential focus on unit cost measures rather than productivity.

(c) Interactions with catch-up concepts.

(d) Compatibility of efficiency elements across expenditure categories.

3.3 This section relates to aspects of the methods that may be used to set price controls. It does not cover more specific issues about how changes in productivity or unit costs can be estimated for particular companies, industries or sectors.

Interactions with input price adjustments

3.4 ORR (2008, page 112) combined three elements as part of its assumptions about efficiency at the last periodic review:

> "**catch-up efficiency**: the efficiency improvement that Network Rail should make in order to close the gap between itself and the best (or better) performing companies against which we have benchmarked the company;
>
> **frontier-shift efficiency**: the continual improvement in efficiency (above that reflected in RPI) that would be expected from even the best (or better) performing companies; [footnote: We use the retail price index (RPI) to rebase annually Network Rail's access charges and revenue requirement. RPI already reflects general, economy-wide productivity growth]; and

input price inflation. the impact of expected input price inflation on Network Rail's cost base (above that reflected in RPI) which reduces the effective level of efficiency improvement possible."

3.5 We suggest that ORR uses a different method in the future or at least refines the treatment of input prices within this method.

3.6 The way in which ORR defined and combined the three elements above creates a risk of double-counting the potential for the input price inflation faced by Network Rail to grow at a faster rate than the RPI. Such double-counting could lead to Network Rail being allowed to set higher track access charges than necessary.

3.7 The risk of double-counting arises from the combination of an input price adjustment which is defined by reference to the RPI with a frontier-shift element which seems to be defined as being "above [the continual improvement in efficiency] reflected in the RPI". We are not aware of any theoretical basis for combining such frontier-shift and input price elements, nor of its use by other UK regulators (see section 8 for a summary of approaches used by some other regulators).

3.8 One possible way to address the risk of double-counting input price inflation is to combine two elements:

(a) A frontier-shift productivity element that is defined to be net of some estimate of the UK economy-wide productivity growth rate.

(b) An adjustment for input price inflation (if any) that is intended to capture the potential for Network Rail to face more (or less) input price inflation than the average input price inflation faced in the UK economy.

3.9 The adjustment under (b) is quite different to an adjustment for input price inflation whose purpose is to capture the potential for Network Rail's input prices to grow by more or less than the RPI over the price control period. However, this approach is unnecessarily complex and is vulnerable to a number of criticisms (see, for example, our summary of First Economics (2010) in section 8).

3.10 If ORR wants to combine a productivity growth element with an input price adjustment, then it would be more straightforward to combine estimates of:

(a) the productivity growth that Network Rail can achieve; and

(b) the input price inflation that Network Rail will face relative to the RPI.

3.11 This combination avoids the risks of double-counting input price inflation that arise under the approach taken at ORR's last periodic review. An important difference is that, under this approach, there is no need to subtract some estimate of economy-wide productivity growth from the productivity element in (a).

3.12 Nonetheless, there remain some other issues that arise in seeking to combine estimates of productivity growth with input price adjustments.

3.13 Productivity growth is calculated as the rate of change in a volume index for output minus a rate of change in a volume index of inputs. It seems important to ensure that the estimates of productivity growth relate to comparable inputs to those for which the input price index forecast. This may raise problems in the context of productivity estimates from the EU KLEMS dataset.

3.14 For instance, the EU KLEMS dataset uses measures of the volume of labour inputs that are based on hours worked adjusted for changes in the composition of the workforce (e.g. using a measure of educational attainment and age, which is taken as a proxy for work experience).[2] Because of this feature of the EU KLEMS dataset, it does not seem straightforward to combine an estimate of total factor productivity growth with an input price index that is based on estimates of the growth in wages or annual earnings. There is a risk of inconsistency if productivity estimates calculated on this basis are combined with estimates of input price growth that are calculated from forecasts of the growth in wages per hour worked or annual earnings per employee.

3.15 It does not seem necessary to combine separate estimates of productivity growth and input price inflation. We discuss an alternative approach below.

[2] O'Mahony, M and M P Timmer (2009) page F379.

Potential focus on unit cost measures rather than productivity

3.16 Rather than adding together a productivity growth assumption and an input price adjustment, ORR could adopt a more direct approach. ORR could make regulatory judgments about the rate of change in measures of Network Rail's costs (e.g. the rate of change in operating expenditure required to run a rail network of a constant scale). These rates of change could be specified to exclude any additional catch-up effects.

3.17 Regulatory judgments on the rate of change in measures of costs could be made in light of historical information on:

(a) **Output price indices for sectors of the UK economy**. The estimates of changes over time in output price indices, relative to the RPI, for a sector will reflect the combined impact of the productivity improvements achieved by companies in that sector and the input price inflation faced by companies in that sector. The output price indices for the construction sector may be particularly relevant to the maintenance, renewals and enhancements expenditure categories.

(b) **LEMS cost measure for sectors of the UK economy.** The estimates of changes over time in the LEMS cost measure will reflect the combined impact of the productivity improvements achieved by companies in that sector and the input price inflation faced by companies in that sector. These may be particularly relevant to Network Rail's operating expenditure.

(c) **RUOE estimates for regulated network industries**. The estimates of changes over time in measures of RUOE for an industry will reflect the combined impact of the productivity improvements achieved by the companies in that industry and the input price inflation they have faced relative to RPI. The RUOE estimates may be particularly relevant to Network Rail's operating expenditure, and potentially to operating and maintenance expenditure taken together. As discussed in section 2, it would be important to take account of the argument that for several regulated network industries there was a transitory period of substantial expenditure reductions (relative to RPI) in the initial period after privatisation due to privatisation and the introduction of incentive regulation and that estimates calculated over that period may not be a good guide to the likely changes in RUOE in such industries in the future.

3.18 A potential limitation of a focus on estimates such as these is that, in each case, input price inflation is only taken into account indirectly, through its influence on the costs of companies covered by the historical cost and price data. There might be views that the input price inflation that Network Rail will face over the price control period, relative to the RPI, could be different to that reflected in the historical data. This might call for adjustments as follows:

(a) If there is an expectation that input price inflation will be greater in the future than it has been over the period of the historical data, a separate adjustment could be made for this.

(b) If there is an expectation that the input price inflation faced by Network Rail will be greater than the input price inflation faced by the companies covered by the sample of historical data, a separate adjustment could be made for this.

3.19 This approach has possible advantages compared to a method which involves separate estimates of productivity growth and input price effects:

(a) It avoids the potential for inconsistency between the measures of input volumes used to calculate productivity growth and the measures of input volumes to which estimates of input price inflation apply. For instance, the data on the volume of labour inputs on which productivity estimates from EU KLEMS are based are adjusted for the skills and age composition of the workforce. It may not be appropriate to combine this directly with data on the average growth in wages per hour worked or annual earnings of employees.

(b) In addition, there are some grounds to believe that the estimates of the growth rates for measures of unit costs and for output price indices are less vulnerable to measurement error than estimates of productivity growth. For instance, the LEMS cost measure should be less sensitive than a gross output total factor productivity estimate to the methods used to produce estimates of the volumes of intermediate inputs used in a sector and the volumes of labour employed in a sector, both of which could involve measurement error.

Interactions with catch-up concepts

3.20 This section identifies interactions between the productivity and unit cost estimates presented in this report and concepts of catch-up. It discusses the method used in Oxera (2008) to decompose estimates of productivity growth from EU KLEMS into frontier-shift and catch-up elements. It provides an alternative method to combine estimates of sector-level or industry-level growth rates in unit costs or productivity with catch-up estimates derived from comparative efficiency or benchmarking analysis.

Interactions between estimates from EU KLEMS and concepts of catch-up

3.21 The EU KLEMS dataset provides data for sectors of the UK economy. It does not provide data for individual companies. Some tentative links can be drawn between the sector-level estimates calculated using the EU KLEMS data and the companies within each sector:

(a) The measure of gross output total factor productivity growth for a sector provides an estimate of the weighted average of the gross output productivity growth achieved by companies in that sector, with weights given by each company's share of gross output in that sector.

(b) The measure of the growth in output price indices for a sector provides an estimate of the weighted average of the growth in prices of the goods and services produced by companies in that sector, with weights given by each company's share of gross output in that sector.

(c) The measure of the growth in the LEMS cost measure for a sector provides an estimate of the weighted average of the growth in the LEMS cost measure for each company, with weights given by each company's share of gross output in that sector.

3.22 Each of these measures has a link with catch-up.

3.23 Catch-up can be seen as a process through which the difference in a measure of relative efficiency or unit costs between companies is reduced over time – e.g. through imitation and the adoption of working practices and production processes used by other companies. We expect that each of the measures listed above is affected by this form of catch-up.

3.24 In the case of the productivity measures for a sector, at least some of the productivity improvements experienced by companies within that sector will have been achieved through processes of imitation and adoption that can be seen as catch-up.

3.25 In the case of the output price and LEMS cost measures for a sector, these are affected by both productivity improvements achieved in that sector and the input price inflation experienced in that sector. As above, some of the productivity improvements experienced by companies within that sector will have been achieved through processes of imitation and adoption that can be seen as catch-up. In addition, some companies may have experienced relatively less input price inflation than others, as they have "caught up" with companies who had previously been getting a relatively good deal on input prices (e.g. wages and prices paid to suppliers).

3.26 These links between concepts of catch-up and the estimates from the EU KLEMS dataset should be recognised if price controls for Network Rail are to be set in light of efficiency comparisons between Network Rail and other companies and sector-level estimates calculated from the EU KLEMS dataset.

Interactions between RUOE estimates and concepts of catch-up

3.27 The changes over time in measures of RUOE for an industry will be affected by both the productivity improvements achieved in that industry and the input price inflation (relative to RPI) experienced in that industry. As with the sector-level estimates of the LEMS cost measure:

(a) Some of the productivity improvements experienced by companies within that industry will have been achieved through processes of imitation and adoption that can be seen as catch-up.

(b) Some companies may have experienced relatively less input price inflation than others in that industry, as they have "caught up" with companies who had previously been getting a relatively good deal on input prices (e.g. wages and prices paid to suppliers).

The Oxera (2008) decomposition between frontier-shift and catch-up

3.28 Oxera (2008) considers the potential for the estimate of the TFP composite benchmarks, which are calculated using sector-level data from EU KLEMS, to include an element of catch-up. Oxera (2008, page iii) states:

> "As these estimates come from firms operating in competitive markets over long time horizons, theory would suggest that their performance represents that of an efficient firm (i.e. they do not include an element of catch-up). This assumes that all firms are operating efficiently and productivity growth is seen from advances in new technology and management practice. In reality, there may be transition costs and structural inefficiencies that have an impact on this estimate. A more conservative view, based on academic evidence, is that, on average, 75% of economy-wide productivity gains are the result of pure frontier-shift."

3.29 Oxera (2008, page 32) says:

> "The TFP growth estimates produced in this study can be equated to frontier-shift improvements only under the hypothesis of no technical inefficiency or no change in technical or allocative inefficiency over time. Although both assumptions do not conform to empirical evidence, it could be argued that, due to the long timeframe of the analysis, the contribution of improvements in technical efficiency to productivity growth would be limited in light of the competitive nature of the industries that make up the composite benchmark. Nevertheless, an academic study examining the overall productivity performance of the UK economy found that, on average, 75 % of the economy-wide TFP growth is due to frontier-shift. This estimate is a lower bound because it includes the contribution from non-market sectors, which are less competitive than the market sectors forming the composite benchmark".

3.30 The academic paper referred to in Oxera (2008) is Färe et al (1994), which provides an analysis of country-level productivity for 17 OECD countries over the period 1978 to 1988. The output measure is GDP. The paper provides estimates, for each country, of annual changes in productivity which can be decomposed into a "technical change" component and an "efficiency change" component.

3.31 The link between the results from the academic study cited by Oxera (2008) and the decomposition of TFP growth estimates from EU KLEMS into frontier-shift and catch-up components seems tenuous.

3.32 The concept of catch-up that is relevant when making comparisons of productivity between countries seems different to the concept of catch-up that is relevant when a particular company improves its performance through imitation or adoption of working practices and technologies used by other companies. For instance, in the study cited by Oxera (2008), the technical efficiency frontier will be given by the country (or countries) with the highest productivity score in a particular year. A country is found to make improvements in efficiency (catch-up) from one year to the next if it reduces the distance between its productivity score and that of the country found to be at the technical efficiency frontier. 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 — the productivity improvements made by companies through catch up to best practice of the more efficient companies.

3.33 We have not carried out a literature review to look for further information about the 75 per cent decomposition. We expect there to exist a number of studies which seek to decompose changes over time in the productivity of companies in a sector or industry into catch-up and frontier-shift effects.

3.34 However, it seems ambitious to try to 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.

3.35 The difficulties of making such decomposition are exacerbated by ambiguity over what the term "frontier-shift" actually means. Any decomposition between frontier-shift and catch-up elements that is to be applied to productivity estimates from EU KLEMS should be sensitive to the way in which frontier-shift is defined.

3.36 At the last periodic review, ORR defined frontier-shift by reference to the continual improvement in efficiency "that would be expected from even the best (or better) performing companies". It matters whether it is defined by reference to the company judged (by some measure) as the single most efficient company or as some wider group of relatively efficient companies. We would expect the productivity growth available to a group of relatively efficient companies to be more than that available to the single most efficient companies, simply because some of the companies in the former group may be able to make improvements by adopting the working practices of the most efficient company. This implies that the rate of frontier-shift depends on whether it frontier-shift is defined by reference to the best performing company or to some group of relatively efficient companies — if the latter, it matters exactly how this group is defined.

3.37 At this stage, we are not sure how much more can reasonably be said than this: if the historical rate of productivity growth in a sector is estimated to 1 per cent per year, the rate of productivity growth that can be called frontier-shift is likely to lie somewhere between 0 per cent and 1 per cent per year.

Alternative method to combine EU KLEMS estimates with benchmarking analysis

3.38 The attempt to decompose the productivity estimates from EU KLEMS into frontier-shift and catch-up seems to arise from the desire to combine estimates of historical growth rates in measures of productivity and unit costs with the results from exercises comparing Network Rail's expenditure with that of other rail network operators (e.g. process-level benchmarking or comparative efficiency analysis based on econometric models). We do not believe that a decomposition of sector-level productivity estimates between catch-up and frontier-shift effects is necessary. We sketch one potential method below which does not draw on such a decomposition.

3.39 ORR could use comparisons with other rail network operators to estimate the cost reduction that Network Rail would need to achieve in order to realise a similar level of "efficiency" or unit costs as an average or normal rail network operator. This is probably best expressed in £m rather than as a percentage.

3.40 ORR could then decide, for the purposes of setting the price control, the time period over which this cost reduction will be achieved. It is helpful to distinguish between two methods:

(a) **Immediate catch-up**. ORR would decide that the price control will be set on the basis that the cost reduction estimated above will be implemented by the first year of the price control. Under this approach, there is no annual efficiency factor associated with catch-up. Instead, the full value of the cost reduction is taken into account when determining Network Rail's revenue for the first year of the price control.

(b) **Gradual catch-up**. ORR would decide that the price control will be set on the basis that a given proportion of the cost reduction estimated above can be achieved by the end of the price control period or that the full value of the cost reduction will be achieved gradually over a certain number of years. This method can be used to determine an annual catch-up factor which represents the cost saving that Network Rail would need to achieve in each year of the price control if it is to achieve the specified profile of catch-up.

3.41 Under either method, there remains a need to consider:

(a) The potential for Network Rail to make productivity improvements, over the period of the price control, in addition to those necessary to achieve the cost reduction identified from comparisons with other rail network operators.

(b) The potential for Network Rail's input prices (e.g. wages and materials prices) to grow at a faster or slower rate than the inflation index to be applied to the price control (currently the RPI).

3.42 We have suggested above that it is unnecessary to use separate estimates of productivity growth. Instead, it may be better to focus on estimates which capture the combined effects of historical productivity growth and changes, relative to the RPI, in input prices. On this basis, Table 7 indicates (with a tick) which types of estimates provided in this report would be relevant to different combinations of the expenditure categories applied to Network Rail.

Table 7 Mapping of estimates in this report to Network Rail expenditure categories

Expenditure categories	LEMS cost measure relative to RPI	RUOE estimates (over more recent time periods)	Output price indices relative to RPI, with emphasis on the construction sector
Operating expenditure	✓	✓	
Maintenance			✓
Renewals			✓
Enhancements			✓

3.43 Because this method is based on an estimate of catch-up to the average company, rather than catch-up to some frontier company, it is possible to use the industry-level or sector-level estimates shown in table 7 directly, without any decomposition of the estimates between catch-up and frontier-shift effects.

Compatibility of efficiency elements across expenditure categories

3.44 The capital substitution adjustment used to calculate the TFP composite benchmark for operating expenditure in Oxera (2008) reflects the idea that there are interactions between different categories of a company's expenditure. In particular, Oxera (2008) refers to the idea that a company's operating expenditure might reduce if there are improvements to its capital assets that allow it to use less labour.

3.45 These interactions are important in the context of making efficiency assumptions for Network Rail's price control. We start our discussion of these interactions by raising questions about the purpose of the capital substitution adjustment in Oxera (2008). We then highlight the risks of inconsistency across different parts of the price control that relate to concepts of capital substitution. Finally, we sketch a possible method to mitigate these risks.

Questions about the purpose of the capital substitution adjustment in Oxera (2008)

3.46 The TFP composite benchmark for operating expenditure in Oxera (2008) includes an adjustment for "capital substitution effects" which increases the implied "TFP growth" by 0.5 per cent per year. No similar or offsetting adjustment was made for maintenance or renewals.

3.47 As we explain in section 5, Oxera (2008) provides inadequate explanations of how its figures for capital substitution were calculated. We have looked back over previous studies and found that the main capital substitution adjustment used by Oxera is close to adjustment factors that we have calculated using the methods in Europe Economics (2001) and (2003) and a capital share of value added for the UK economy as a whole.

3.48 The methods used in Europe Economics (2001) and (2003) derive a figure for labour productivity growth from estimates of the growth in TFP and an assumed rate of capital substitution. In these methods, the term capital substitution refers to the growth rate in a measure of the volume of capital inputs less the growth rate in the volume of labour inputs. Productivity growth is on a value added basis.

3.49 If the capital substitution adjustment in Oxera (2008) refers to the same concepts, then Oxera's TFP composite benchmark for operating expenditure boils down to an estimate of what the weighted average labour productivity growth (on a value added basis) for the comparator sectors would have been if (i) these comparator sectors experienced the same rate of capital substitution as Oxera's estimate for the UK economy as a whole and (ii) these comparator sectors had the same share of capital in value added as the UK economy as a whole.

3.50 This raises some questions:

(a) If it makes sense to base the benchmark on estimates of historical TFP growth for comparator sectors, why not also base the benchmark on the historical rates of capital substitution and the share of capital in value added in these sectors?

(b) Why not simply base the benchmark on historical growth in labour productivity for the comparator sectors?

(c) What is achieved by combining estimates of TFP growth for comparator sectors with estimates of capital substitution effects for the UK economy as a whole?

(d) Is Oxera's TFP composite benchmark for operating expenditure just an over-complicated estimate of a labour productivity growth rate based on an unjustified mix of data from comparator sectors and the UK economy as a whole?

3.51 The premise for Oxera's capital substitution adjustment is that Network Rail's operating expenditure will reduce relative to the RPI due to: (i) improvements in total factor productivity and (ii) substitution away from labour inputs (which feature in operating expenditure) and towards capital inputs (the costs of which fall outside the scope of operating expenditure). This raises further questions:

(a) If the operating expenditure element of Network Rail's price control is set on the basis that reductions in operating expenditure will be achieved through a greater use of capital inputs, then do other elements of the price control provide the funding for those increases in capital inputs?

(b) If not, is there not a risk that the cost savings expected across the price control package, taken together, may be unachievable?

(c) Even if the price control is set on the basis that there will be increases in the volume or quality of capital employed by Network Rail, is it safe to rely on an adjustment to operating expenditure based on average rates of capital substitution for the UK economy as a whole?

The risks of inconsistency across different parts of the price control

3.52 The method in Oxera (2008) seems to focus on the impacts of capital substitution on Network Rail's operating expenditure without accounting for the potential interactions with other parts of the price control.

3.53 It is important to think about possible interactions across expenditure categories when setting price controls. For instance, Network Rail's operating expenditure requirements will depend on how much it spends on maintenance and both operating expenditure and maintenance expenditure will depend on how much it spends on asset replacement (and vice versa). There are risks that the projections used for one expenditure category within the price control package are not compatible with those used for other categories.

3.54 For example, in setting price controls for Network Rail:

(a) There are risks of inconsistency if the operating expenditure element is based on cost reductions which would only be achievable through the purchase of additional or better capital assets for which no provision has been made in the capital expenditure elements of the price control calculation. This risk might arise, for instance, if the rate of reduction for operating expenditure was chosen by ORR in light of estimates of reductions in unit costs, or improvements in labour productivity, for other companies or sectors which have experienced a shift in their input mix away from labour and towards a greater amount or quality of capital assets.

(b) There are risks of inconsistency if the price control is calculated on the basis that Network Rail will carry out investment that improves the quality of its capital assets but the potential impacts of this investment on operating and maintenance expenditure requirements is not taken into account (e.g. investment to introduce high-quality assets that have lower failure rates may lower future operating expenditure requirements).

3.55 We do not expect there to be a perfect solution to these interactions and risks. But we suggest that ORR takes measures to manage the interactions and mitigate the risks.

The use of a constant output and constant capital "base service" concept

3.56 A possible method to mitigate the risk of inconsistency highlighted above can be sketched as follows:

(a) **Base service**. Define a "base service" which applies to Network Rail's activities at the start of the price control period (or in some earlier reference year). The expenditure requirements to provide the base service are those to maintain a constant volume and quality of track access services (etc) over the price control period (e.g. no demand growth), and using a constant quantity and quality of capital assets. The expenditure on the base service should include expenditure necessary for Network Rail to maintain and replace — on a like-for-like basis — its existing capital assets. If frontier-shift and related estimates are used to take base service expenditure requirements in the first year, and to roll these forwards over the remaining years of the price control, then these estimates should themselves be compatible with the base service condition of no increase (or decrease) over the price control period in the volume or quality of the capital assets employed by Network Rail.

(b) **Outputs adjustment**. Produce separate estimates for any increase (or decrease) in Network Rail's expenditure requirements as a result of expected changes in the volume and quality of track access services (etc) it will provide. Adjustment may be needed not only for the capital expenditure to accommodate output growth, but potentially also for any additional operating expenditure requirements during the price control period. This output adjustment would have a greater scope than the current "enhancements" concept which, we understand, does not include operating expenditure.

(c) **Quality of capital adjustments**. The price control set for Network Rail might, in addition to the maintenance and replacement of existing assets and expenditure to cover output growth, allow for improvements to the quality of Network Rail's existing assets or for expansion of its capital assets at a faster rate than output growth. Adjustments may then be needed to the operating expenditure, maintenance and potentially renewals categories calculated for the base service above, using estimates of the impact of the improvements to capital assets on these areas of expenditure. For instance, an increase in the quality of capital assets might be achieved by replacing existing assets with new assets of a higher quality that have lower risks of faults and which are expected to reduce operating and maintenance expenditure in the future. To the extent that the investment is expected to lead to expenditure reductions in subsequent price control periods, it would also be important to ensure that these are taken into account as part of future price control reviews.

3.57 The LEMS cost measure that we describe in section 6 might be relevant to (a) because it is designed to be compatible with the constant capital concept: it provides an estimate of the growth rate in the costs of labour and intermediate inputs, per unit of output, had the sector in question experienced no growth in the volume of capital services per unit of output.

3.58 The approach sketched might not be the only way of addressing the risks of inconsistency. It would represent a departure from the approach that ORR took at the last periodic review. It would need further work and refinement before it could be applied safely.

4 RUOE estimates for regulated network industries

4.1 In this section we set out our analysis of changes over time in measures of real unit operating expenditure (RUOE) for a sample of regulated network companies in the UK that have some similarities with Network Rail, and for Network Rail itself.

4.2 Oxera (2008) presents an analysis of the change in RUOE in a number of regulated network industries in Great Britain. These are:

(a) Water and sewerage companies in England, Wales and Scotland;

(b) Electricity distribution companies in Great Britain;

(c) National Grid's electricity transmission business.

(d) Gas distribution companies in Great Britain.

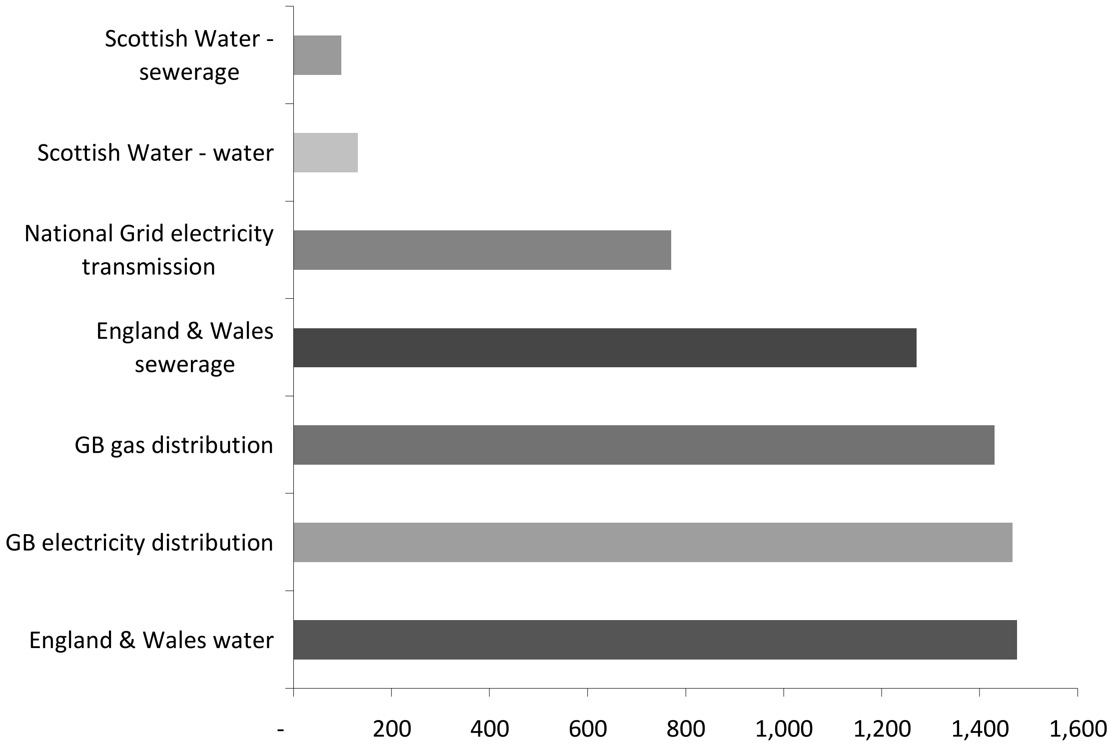
(e) BT's telecommunications business.

4.3 We have updated that work using more recently available data and provide some further analysis.

4.4 We agreed with ORR not to include BT within the scope of the RUOE analysis. In Oxera (2008), estimates of RUOE for BT are provided using two different output measures: total call minutes and the number of exchange lines. It is no longer reasonable to take call minutes as a primary output measure for BT. The communication services that BT provides its customers extend well beyond telephone calls, in particular including broadband services. The use of exchange lines is also problematic. With digital and fibre optic, lines the number of channels is not the same as the number of exchange lines. And whilst some lines owned by BT are operated by BT, other lines owned by BT are operated by other operators under local loop unbundling. More generally, there have been changes over time in the nature of BT's business which reflect the emergence of greater competition in different parts of the value chain.

4.5 Figure 8 indicates the relative scale of the operating expenditure accounted for by each industry, based on the expenditure data we use for the RUOE analysis.

Figure 8 Comparison of operating expenditure by industry covered (£m) 2009/2010



4.6 In addition to the update of Oxera (2008), we have also calculated some changes in RUOE for Network Rail, using data on controllable operating expenditure and output measures provided by ORR.

Method used for the update

4.7 We explain below some general aspects of the method that we have used.

Operating expenditure relative to the RPI

4.8 We have sought to use the same definition of operating expenditure as Oxera (2008) as far as possible. In some cases, as explained in the industry sub-sections that follow, there is some difference due to a lack of data.

4.9 We provide estimates of changes in operating expenditure relative to the RPI. We maintain the Oxera terminology of using the term "real" to describe the adjustment made for changes in the retail price index (RPI).

4.10 All of the operating expenditure data used in the analysis are for financial years (ending on 31 March) rather than for calendar years. We have calculated the price index for each financial year as the average of the monthly retail price index published by the ONS (series CHAW) over the relevant 12-month period.

Output measures

4.11 Changes in operating expenditure over time may be caused by changes in the scale of outputs or operations of a company. We examine changes in measures of unit operating expenditure. We calculate unit operating expenditure by dividing operating expenditure by an output measure.

4.12 We discuss the output measures used for each industry in the corresponding sub-sections below. We have followed the output measures used in Oxera (2008). In addition, we have carried out some further analysis on more recent data using some alterative output measures.

Economies of scale adjustment

4.13 If there are economies of scale with respect to a particular output measure, a calculation of unit costs will be affected by the extent to which the volume of outputs decrease or increase over time.

4.14 In its 2008 analysis, Oxera adjusted unit operating expenditure in order to control for the impact of economies of scale. We have sought to reproduce this adjustment for our updated to the Oxera (2008) analysis (we do not use it for the analysis of alternative output measures).

4.15 The adjustment is done when calculating the growth in the real unit operating expenditure between two years. The steps involved are as follows.

4.16 Say we want to compute the growth in the real unit operating expenditure between year *t* and year *t+1*. To adjust for the effect of economies of scale, we calculate a "corrected RUOE" for the first of these years, for year *t*. This is given by,

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

4.17 where ROE_t is operating expenditure that has been adjusted for changes in RPI, $\Delta O_{t,t+1}$ is the percentage change in the relevant output measure between the two periods, ε is the elasticity of costs with respect to output and O_{t+1} is the level of the output measure in the later year. The elasticity of costs with respect to output is interpreted as the percentage change in costs for a 1 per cent increase in the level of output. For example, an elasticity of 0.9 indicates that for a 1 per cent increase in output, costs will increase by 0.9 per cent. An elasticity below 1 (and above 0) represents economies of scale between that output and operating expenditure, whilst an elasticity above 1 would indicate diseconomies of scale. If the elasticity is 1, this implies that operating expenditure would grow exactly in proportion to the growth in the output measure.

4.18 We use the same values for ε as Oxera (2008).

4.19 The growth in the RUOE between the two successive years is then calculated as,

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

4.20 In other words, it is the percentage change from the "corrected" RUOE in year t to the real unit operating expenditure in year *t+1*.

Calculate of growth rates in RUOE

4.21 One difference in our presentation compared to that in Oxera (2008) is that we report our estimates as the change in real unit expenditure rather than as the rate of reduction. A positive number indicates an increase in unit expenditure relative to RPI and a negative number indicates a reduction relative to RPI. This is to ensure consistency in the meaning of positive and negative numbers with the estimates reported in other sections of this report.

4.22 We now present the estimates for each industry as well as providing some details of the issues encountered in our update. For each sector or company, we present:

(a) The estimates reported in Oxera (2008).

(b) Estimates using recent expenditure data that are now available and which were not used in Oxera (2008).

(c) The weighted average of annual changes for the whole period of data, i.e. a weighted average of (a) and (b).

4.23 For some sectors we also present some additional analysis that examines the impact of using alternative output measures.

Water and sewerage in England and Wales

Update to Oxera (2008)

4.24 In line with the approach used by Oxera, we have calculated changes in the real unit operating expenditure separately for England and Wales and for Scotland. This is due to the differences in structure between the two industries and the availability of data. We consider England and Wales first.

4.25 Data are available for ten water and sewerage companies and for 12 water-only companies in England and Wales. We calculate the increases in real unit operating expenditure for the industry as a whole between 2006/07 and 2009/10. We then combine these with the estimates taken from Oxera (2008) in order to compute the average increase in real unit operating expenditure over the period 1992/93 to 2009/10. Oxera (2008, page 41) states that the year 2005/06 is excluded from its analysis as it "cannot be considered a normal year" and we take this into account in determining the weights used for the weighted average.

4.26 All the data used in our update are taken from the companies' annual June Return, which is an annual submission from each company to the regulator Ofwat.

4.27 In line with Oxera (2008), the analysis combines two separate headings of operating expenditure:

(a) "Operating costs less indirect costs", defined as operating expenditure including expenditure on maintenance that is not capitalised, sometimes referred to as cash maintenance, but excludes depreciation, environmental charges, exceptional items, local authority rates and doubtful debts.[3]

(b) "Indirect operating costs", defined as business activities expenditure, general expenditure and support expenditure.[4]

4.28 Exceptional items account for less than three per cent of total operating expenditure across the period of our update.

4.29 We use the same output measures as reported in Oxera (2008). A different measure of output is used for each of the two headings of operating expenditure described above:

(a) For "operating costs less indirect costs", we use water delivered as the output measure for the water service, and population connected for the sewerage service.[5]

(b) For "indirect operating costs", we use the number of properties billed for water as well as for sewerage.[6]

4.30 Following Oxera (2008), the analysis is conducted at the industry level, with total industry operating expenditure equalling the operating expenditure of all companies.

4.31 As explained above, we apply an adjustment for economies of scale. For water and for sewerage, the elasticity of costs with respect to output is taken to be 0.96. This is the number used in Oxera (2008) and LEK/Oxera (2005).

4.32 Our final estimate is a weighted average of the percentage change in real unit operating expenditure minus indirect costs with the percentage change in real unit indirect costs. The weights are calculated using the average share of total operating

[3] This is taken from the June Return table 21 for water and table 22 for sewerage. It is the sum of lines 1–6 and 7–9.
[4] Again this is taken from tables 21 and 22 for water and sewerage respectively. It is the sum of lines 11 and 16.
[5] Water delivered is taken from line 21 of table D of the June Return. Population connected is taken from line 10 of table 13.
[6] Properties billed for water is taken from table 7 line 6 of the June Return. Properties billed for sewerage is from table 13 line 5.

expenditure that each of the two headings of expenditure represents across the period.[7]

4.33 The updated estimates of the increase in real unit operating expenditure for the water and for the sewerage sector in England and Wales are presented in table 8.

Table 8 Average annual percentage change in real unit operating expenditure for England and Wales water and sewerage companies

	Period	Water	Sewerage
Oxera (2008)	1992/93 – 2006/07	–1.8	–1.7
Update	2006/07 – 2009/10	0.3	–1.2
Weighted average	1992/93 – 2009/10	–1.4	–1.6

4.34 We set out in the tables below the data used to derive the estimates for the period from 2006/2007 used for the update. The expenditure data shown is in nominal terms, before adjustment for changes in the RPI.

Table 9 Data for England and Wales water companies

	2006/07	2007/08	2008/09	2009/10
Operating expenditure excluding general and support costs (£m)	749.7	686.5	791.1	827.6
General and support expenditure (£m)	614.6	632.9	638.6	629.3
Water delivered (Ml/d)	12,780.1	12,612.0	12,432.3	12,364.4
Total number of properties billed	21,757,060	21,853,467	22,033,806	22,180,841

[7] For example, to compute the weighted change in real operating expenditure between 2006/2007 — 2007/2008, the change in the real unit indirect costs between those two years would be weighted by the average of the share that indirect costs represents of total operating expenditure in 2006/2007 and in 2007/2008.

Table 10 Data used for England and Wales sewerage companies

	2006/07	2007/08	2008/09	2009/10
Operating expenditure excluding general and support costs (£m)	703.5	689.9	742.4	784.8
General and support expenditure (£m)	504.6	524.7	533.5	485.7
Population connected	53,839,767	54,147,609	54,347,050	54,679,550
Total number of properties billed	21,165,692	21,260,868	21,424,222	21,570,118

Further analysis: analysing base service operating expenditure

4.35 The estimates above concern changes in unit operating expenditure (relative to the RPI) in the England and Wales water and sewerage industry. By focusing on *unit* expenditure, and adjusting for the effects of economies of scale, that analysis seeks to identify changes in expenditure that are not attributable to changes in the scale of operations. However, the RUOE figures are sensitive to the output measures used and the elasticity value taken for the economies of scale adjustment.

4.36 An alternative approach is to calculate the change in expenditure (relative to the RPI) associated with a given, constant, level of output. Our analysis using data reported on the "base service" level of operating expenditure aims to do this. This provides an update of the analysis of base service operating expenditure in Reckon (2008) which was carried out for Ofwat as part oPR09.

4.37 Base service operating expenditure can be thought of as the level of expenditure incurred to provide the same volume and quality of outputs (including environmental outputs) as in the "base year". The "base year" is reset every five years, at the start of each price control period, so that the base service level too is rebased every five years.

4.38 Water and sewerage companies provide information to Ofwat on the operating expenditure associated with the base service. They do so by allocating their total operating expenditure between base service and "enhancements expenditure".

4.39 The expenditure allocated to enhancements includes operating expenditure needed to serve additional customers, meet changes in the consumption of existing customers and comply with new statutory quality standards. Base service operating expenditure includes operating expenditure, infrastructure renewals and non-infrastructure maintenance expenditure. Water companies provide information on the level of expenditure attributable to the base service in their June Return.

4.40 The data on base service operating expenditure include local authority rates. The RUOE estimates for base service operating expenditure have a different coverage to the water and sewerage company operating expenditure provided in Oxera (2008) and used in our update to that analysis above.

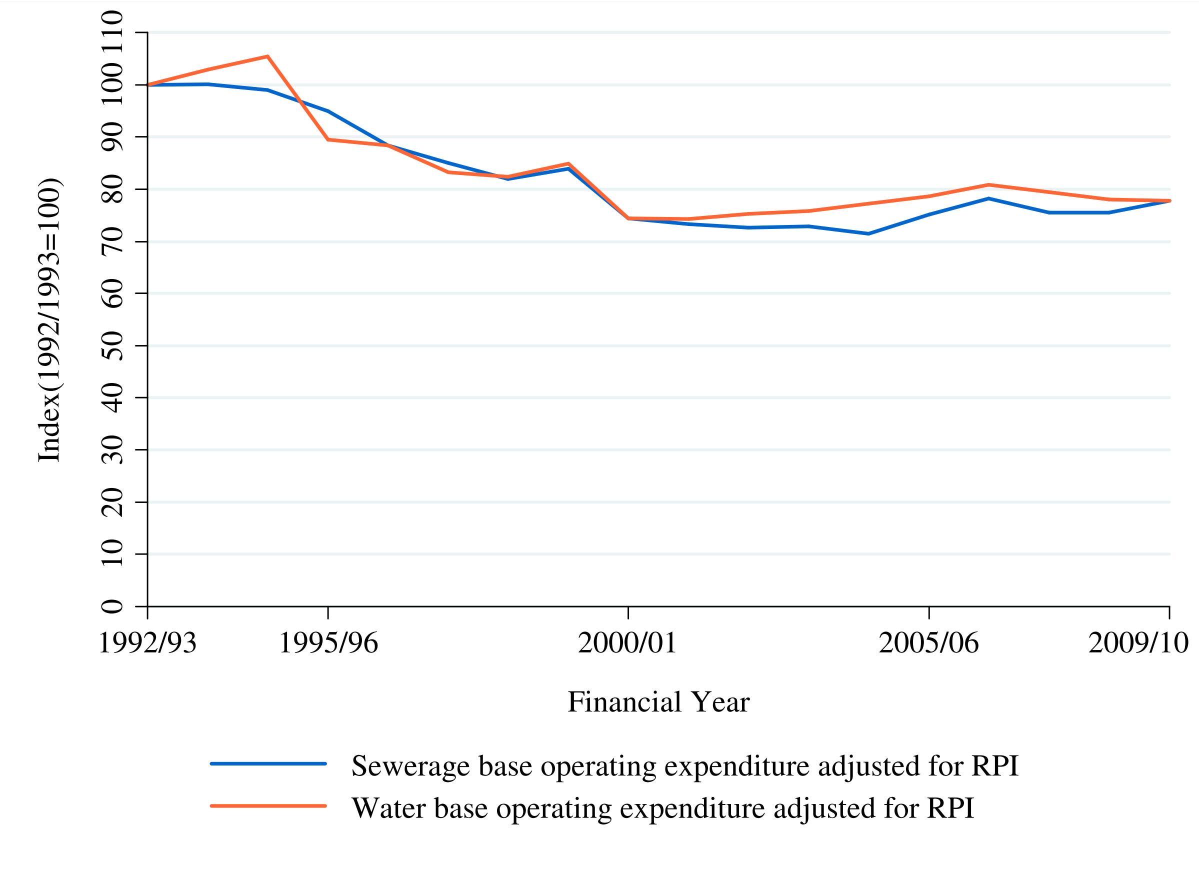
4.41 We calculate the average annual logarithmic growth rates for base service operating expenditure for water and sewerage between 1992/1993 and 2009/2010. We do this by (a) calculating the average annual growth rate across each period linked to a given level of base service, and (b) averaging these growth rates across each of the sets periods. Our results estimates are shown in table 11. We also provide the growth rate over the period 2000/2001 to 2009/2010.

Table 11 Average logarithmic growth in base service operating expenditure relative to RPI

Measure	Time period	Logarithmic annual growth rate (%)
Water base service operating expenditure	1992/1993 – 2009/2010	–1.5
	2000/2001–2009/2010	0.5
Sewerage base service operating expenditure	1992/1993 – 2009/2010	–1.5
	2000/2001–2009/2010	0.5

4.42 The average growth rates in table 11 show how operating expenditure has decreased relative to the RPI over the period. Figure 9 provides an index of base service operating expenditure, relative to RPI, for water and sewerage.

Figure 9 Water and sewerage base service operating expenditure relative to RPI



Water and sewerage in Scotland

Update to Oxera (2008)

4.43 Scottish Water provides water and sewerage services to the vast majority of customers in Scotland. We update Oxera's analysis on Scottish Water using an approach which is similar to the analysis conducted for England and Wales. We calculate the annual average percentage change in real unit operating expenditure for 2005/2006 to 2009/2010 and combine this with Oxera's estimates to give overall estimates for the period 2002/2003 to 2009/2010. At the end of section 4 we also show changes in RUOE and expenditure for Scottish Water between 2006/2007 and 2009/2010, which is the period of our updated analysis for other companies.

4.44 Scottish Water provides water and sewerage services to the vast majority of customers in Scotland. We update Oxera's analysis on Scottish Water using an approach which is similar to the analysis conducted for England and Wales. We calculate the annual average percentage change in real unit operating expenditure for 2005/06 to 2009/10 and combine this with Oxera's estimates to give overall estimates for the period 2002/03 to 2009/10.

4.45 The data are taken from Scottish Water's Annual Return, which is similar in design and structure to Ofwat's June Return.

4.46 One major difference between the analysis for Scotland and the above analysis for England and Wales is that, in line with Oxera (2008), a different definition of expenditure is used in the case of Scotland. In particular, the split between indirect costs and other operating expenditure is not made: instead, data on total operating expenditure are used. Correspondingly, a single measure of output is used for each of the services. We follow Oxera (2008) and use the amount of water delivered as an output measure for the water services, and the population connected for sewerage services.[8] The same adjustment is made for economies of scale in Scotland water and sewerage as for England and Wales.

4.47 The measure of operating expenditure includes non-capitalised maintenance expenditure, sometimes referred to as cash maintenance. In line with Oxera (2008), operating expenditure excludes depreciation, environmental charges, exceptional items, local authority rates and doubtful debts.[9]

4.48 The average annual percentage changes in real unit operating expenditure are reported in table 12, along with the values taken from Oxera (2008) and the weighted average of the two sets of estimates.

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[8] Output data are taken from Scottish Water's Annual return. Water delivered is given by the sum of lines 2.16 and 2.20 from table A. Sewerage population connected is given by line 2.8 from table A.

[9] These data are taken from Scottish Water's Annual return. Operating expenditure for water is calculated from table E as line 1.18 minus the sum of lines 1.5, 1.15, 1.16 and 1.17. For sewerage figures are taken from table E, and calculated as line 2.17 minus the sum of lines 2.5, 2.14, 2.15 and 2.16.

Table 12 Average annual percentage change in RUOE for Scottish Water

	Period	Water	Sewerage
Oxera (2008)	2002/03 – 2005/06	–8.8	–14.3
Update	2005/06 – 2009/10	3.3	1.3
Weighted average	2002/03 – 2009/10	–1.9	–5.4

4.49 Tables 13 and table 14 shows the expenditure and output data used.

Table 13 Data used for Scottish Water — water service

	2005/06	2006/07	2007/08	2008/09	2009/10
Operating expenditure (£m)	106.3	110.0	111.9	129.8	130.5
Water delivered (Ml/d)	1,334.4	1,409.9	1,405.6	1,362.3	1,300.2

Table 14 Data used for Scottish Water — sewerage service

	2005/06	2006/07	2007/08	2008/09	2009/10
Operating expenditure (£m)	80.9	86.8	91.5	89.5	96.3
Population connected	4,678,449	4,707,803	4,708,678	4,726,750	4,753,510

Electricity distribution in Great Britain

Update to Oxera (2008)

4.50 Oxera (2008) provides estimates of the average annual percentage reduction in real unit operating expenditure for the electricity distribution industry in Great Britain between 1990/91 and 2006/2007. We update these numbers using data that runs to 2009/10.

4.51 As part of their licence conditions, electricity distribution network operators submit to Ofgem annual regulatory accounts. We use these to extract data on operating expenditure for the period of our update: 2006/2007 to 2009/2010. Our measure of operating expenditure excludes depreciation and exceptional items but includes maintenance expenditure that is not capitalised. When more recent regulatory accounts provide a revised value for previous years, we have used the more recent figure.

4.52 Oxera (2008) reports that uncontrollable costs are excluded from the measure of operating expenditure, but does not specify exactly what these uncontrollable costs cover. The estimates in this report do not exclude uncontrollable costs due to the lack of available data for this adjustment.

4.53 Oxera excluded the change between 1999/2000 and 2000/2001 from the analysis of changes in RUOE. This was due to an abnormally large reduction in the RUOE estimate that was attributed to changes in accounting policies and industry re-structuring (Oxera, 2008, page 42).

4.54 The output measure used is the number of units distributed, expressed in GWh, taken from Ofgem (2010d). We adjust the operating expenditure for electricity distribution to take account of the impact of scale, using the figure of 0.721 for the elasticity of cost with respect to unit distributed.

4.55 The annual average percentage changes in the real unit operating expenditure for the years in our update are reported in table 15, along with the values taken from Oxera (2008), and the weighted average of the two estimates.

Table 15 Average annual percentage change in RUOE for electricity distribution companies in Great Britain

	Period	Average annual change (%)
Oxera (2008)	1990/01 – 2006/07	–4.0
Update	2006/07 – 2009/10	4.0
Weighted average	1990/01 – 2009/10	–2.7

4.56 Table 16 provides the data used to estimate the changes in RUOE over the past four years, as well as the customer numbers data used for additional analysis (see below).

Table 16 Data used for electricity distribution companies

	2006/07	2007/08	2008/09	2009/10
Operating expenditure (£m)	1,250.2	1,301.9	1,406.9	1,466.5
Electricity distributed (GWh)	321,368	321,098	315,932	306,995
Customer numbers	28,562,844	28,671,904	28,867,001	28,972,762

4.57 The analysis in Oxera (2008) was based on data to 2006/2007. The data suggest that in the period since then there has been an increase in real unit operating expenditure, as a result of both an increase in the level of operating expenditure and a decrease in the quantity of electricity distributed.

Further analysis: using an alternative measure of output

4.58 The estimates above use units distributed as the output measure. It can be argued that the number of connections provides a better output measure for operating expenditure for electricity distribution. The number of connections might be thought to be more closely related to the costs of operating a distribution network than the number of units distributed.

4.59 We have conducted some additional analysis for electricity distribution using the number of customers as an output measure. The data we have used cover the period from 2006/07 to 2009/10. The data on customer numbers are taken from Ofgem's electricity distribution quality of service reports, although data for 2009/2010 has been provided to us directly by Ofgem.

4.60 We do not make any adjustment for economies of scale in this analysis.

4.61 The average annual change in the RUOE for electricity distribution with customer numbers as the output measure over the period 2006/07 to 2009/10 was 2.4 per cent. This is lower than the changes in RUOE using units distributed as a measure of output; the difference can be explained by the fact that whilst there was a steady rise in customer numbers over the period, the quantity of units distributed has fallen over the last four years.

National Grid Electricity Transmission

4.62 National Grid Electricity Transmission is the system operator for electricity transmission in Great Britain. It is also the owner of the transmission network in England and Wales.

4.63 Oxera (2008) provides an analysis of reductions in RUOE for National Grid over the period from 1990/1991 to 2006/2007. We have updated this analysis using data that runs to 2009/2010.

4.64 Oxera (2008) does not provide an analysis of the operating expenditure of the two companies that own and maintain electricity transmission networks in Scotland. We have not included these companies in our update.

4.65 Some years are excluded from Oxera's analysis. Oxera (2008, page 44) says:

> "The 1991/1992 period is excluded due to it being an anomalous result because it is the first year after privatisation. 2002/03 is also excluded due to a change in reporting standard – NGC started to report volumes transmitted for the whole GB market (i.e. E&W and Scotland)."

4.66 We interpret this to mean that the first annual change that is recognised is that between 1991/1992 and 1992/1993. We use this interpretation in making a weighted average of the estimates from Oxera (2008) and our updated analysis.

4.67 For our update, operating expenditure is taken from National Grid's regulatory accounts and excludes depreciation and expenditure on the balancing services incentive scheme (BSIS), in line with the method used in Oxera (2008). We took data on BSIS costs for 2006/2007 to 2008/2009 from Ofgem (2010c, page 8) and for 2009/2010 from Frontier Economics (2010, page 14).

4.68 Oxera (2008) does not explain the exclusion of BSIS costs. We looked back at previous studies in this field and found a similar exclusion was used in Europe

Economics (2001).[10] That report (page 569) justified the exclusion of transmission system incentive scheme costs, a predecessor of BSIS costs, as follows:

> "Figures for 1998 and 1999 exclude the costs of the Transmission Services Incentive Scheme, which was introduced in April 1997 to transfer some extra costs associated with the transmission system to NGC, rather than being recovered via pool uplift. Since this accounted for over £250 million in nominal terms during 1998 and 1999, it has been removed from the series to ensure previous numbers are on a comparable basis."

4.69 On this basis, the exclusion of BSIS costs, to support the comparability of National Grid's operating expenditure over time, seems reasonable.

4.70 The output measure used is electricity transmitted and this is taken as annual demand from National Grid's Seven Year Statement (page 15). We took the weather adjusted figure. We adjust our RUOE estimates for the impact of economies of scale using the method described towards the start of section 4. We use the cost elasticity figure of 0.721 from Oxera (2008) for this adjustment.

4.71 Table 17 provides the data used for the updated RUOE estimate over the last four years.

Table 17 Data used for analysis of electricity transmission

	2006/07	2007/08	2008/09	2009/10
Operating expenditure including BSIS costs (£m)	1,188	1,217	1,627	1,409
BSIS costs (£m)	495	451	827	640
Annual demand adjusted for weather (TWh)	345.3	346.0	331.6	325.4

4.72 The results of our update are shown in table 18. We present Oxera's RUOE estimates alongside those from our update and show the weighted average of the two.

[10] The Europe Economics report is contained as Appendix D to Mazars Neville Russell (2001).

Table 18 Average annual percentage change in real unit operating expenditure for National Grid's electricity transmission business

	Period	Average annual change (%)
Oxera (2008)	1990/91 – 2006/07	–4.9
Update	2006/07 – 2009/10	2.5
Weighted average	1990/91 – 2009/10	–3.6

Gas distribution in Great Britain

4.73 Oxera's 2008 analysis of gas distribution operating expenditure was limited to forecasts made by Ofgem for the 2008–2013 price control review. Oxera (2008, page 43) reports that historical data was unavailable.

4.74 Expenditure data for gas distribution companies are now available from companies' regulatory accounts. We have collected data on the level of operating expenditure in the industry from 2006/07 to 2009/10.[11] Our measure of operating expenditure is taken for the distribution business only, excluding expenses incurred due to metering or de minimis business activities. Operating expenditure excludes depreciation and exceptional items but includes direct maintenance expenditure.

4.75 Regulatory accounts are also available for the 11 month period ending in March 2006. We have not used these data in our analysis as they do not cover a time period that can be compared directly with subsequent financial years. Whilst it might be possible to use the figures for the 11-month period in an RUOE analysis, at least on an approximate basis, the potential benefits of doing so seem limited. For instance, the data for the period to March 2006 may be less reliable than for subsequent years because it covers the first year following major structural change in the gas distribution industry.

[11] Despite regulatory accounts being available for the year ending March 2006, these only cover the previous 11 months and are therefore incompatible with our method without an arbitrary adjustment. We therefore chose to exclude this year from our analysis.

4.76 The output measure used for gas distribution is annual gas demand for the distribution network, taken from National Grid Gas' "Ten Year Statement". The output data are monthly for the more recent years; data for earlier years are provided on a calendar year and gas supply year (October through to September) basis. We adjust the data in order to ensure the output variable fits with the time period used for expenditure. The adjustment uses weights from 2009 for annual distribution network demand, and uses them to estimate financial year demands using those reported by National Grid for the calendar year.

4.77 In line Oxera (2008), we use a figure of 0.9 per cent for the elasticity of operating expenditure with respect to the output measure, for the economies of scale adjustment.

4.78 On this basis, our estimate for the annual percentage change in real unit operating expenditure for gas distribution over the period 2006/07 to 2009/10 is 2.6 per cent using annual demand as an output measure, and –1.0 per cent using the number of customers as an output measure.

4.79 As with electricity distribution, we are concerned about the reliance on one particular measure of output for gas distribution. We have therefore also conducted an analysis using the number of customers on the gas distribution system as an output measure. Data on customer numbers for 2008/09 and for 2009/10 were provided by Ofgem and, for earlier years, were taken from Ofgem's gas distribution quality of service reports. In running the analysis using customer numbers as the measure of output, we do not make an adjustment for economies of scale.

4.80 We find that between 2006/07 and 2009/10, the average annual change in real unit operating expenditure for gas distribution companies, using customer numbers as the output measure, was –1.0 per cent.

4.81 Table 19 reports the data used for gas distribution, including expenditure data and the two different output measures.

Table 19 Data used for gas distribution

	2006/07	2007/08	2008/09	2009/10
Operating expenditure (£m)	1,351.8	1,378.5	1,404.2	1,429.5
Annual demand (TWh)	650,723	635,234	611,336	584,520
Customer numbers	21,430,504	21,496,985	21,649,506	21,691,236

Network Rail

4.82 Oxera (2008) does not provide an analysis of RUOE for Network Rail. ORR provided us with data for Network Rail and its predecessor Railtrack for the period from 2001/2002 to 2009/2010. These data allow us to calculate measures of annual changes in Network Rail's unit operating expenditure.

4.83 As in the RUOE analysis of other sectors, a necessary step is to select a relevant measure of output. Of the data provided to us, there are a number of candidate measures that could be used including:

(a) length of lines;

(b) passenger train kilometres; and

(c) freight gross tonnes kilometres.

4.84 In its 2003 report for Ofwat, Europe Economics' analysis of Network Rail's RUOE reported two different unit cost figures: one based on passenger train kilometres and another based on length of open track. Europe Economics had taken the same approach in their 2001 report for Ofgem's Transco price control review.

4.85 We have followed the choice of Europe Economics and calculated two different measures of unit costs: one based on length of lines and another based on passenger train kilometres. We have not made any adjustment for potential economies of scale. Table 20 presents the estimates of changes in RUOE using these two output measures.

Table 20 Growth in RUOE for Railtrack / Network Rail relative to RPI

Measure of output	Period	Logarithmic annual growth rate (%)
Passenger train km	2001/2002–2009/2010	–3.6
Length of lines, km	2001/2002–2009/2010	–1.2

4.86 The choice of output measure has a clear impact on the calculated annual growth rate in RUOE. When passenger train kilometres is used as the relevant measure of output, then operating unit expenditure has fallen relative to the RPI at a rate equivalent to 1.2 per cent per year between 2001/2002 and 2009/2010. In contrast, if the length of lines is taken as the relevant measure of output, then operating unit expenditure has fallen relative to the RPI at a rate equivalent to 3.7 per cent per year over the same period. This difference reflects the following changes over the period from 2001/2002 to 2009/2010:

(a) Over the nine-year period, Network Rail's controllable operating expenditure has increased by 8 per cent in nominal terms; it has fallen by 17 per cent relative to the RPI.

(b) Passenger train kilometres has increased by 16 per cent over the period.

(c) The length of lines has fallen by around 5 per cent over the period.

4.87 Table 21 sets out the data on operating expenditure and output measures that we have used in this RUOE analysis for Network Rail. The data were provided to us by ORR, with the operating expenditure data from regulatory accounts and the output measures from the UIC/LICB dataset. For 2009/2010, £65m was subtracted from Network Rail’s controllable opex as to make that figure consistent with previous years following a change in definition between maintenance and operating expenditure.

Table 21 Data used for Railtrack / Network Rail

Financial year	Total controllable opex (£m)	Length of lines (km)	Passenger train km (million passenger kilometres)
2001/2002	860	16,500	438
2002/2003	1,036	16,522	441
2003/2004	1,060	16,493	445
2004/2005	934	16,116	459
2005/2006	865	15,810	468
2006/2007	878	15,789	470
2007/2008	878	15,815	474
2008/2009	908	15,766	480
2009/2010	926	15,753	508

Summary and synthesis across sectors

4.88 In this final section, we present a summary and synthesis of the analysis across the sample of regulated network industries that we have covered. We first present a summary to our update of the RUOE estimates in Oxera (2008). We then provide estimates from our more detailed analysis of operating expenditure data over the last four years, which uses alternative output measures and data sources.

Table 22 Summary of growth rates in RUOE (average annual percentage change)

	Period	Estimate from Oxera (2008)	Update for last four or five years	Weighted average over whole period
GB electricity distribution	1990/1991–2009/2010	–4.0	4.0	–2.7
England and Wales water	1992/1993–2009/2010	–1.8	0.3	–1.4
England and Wales sewerage	1992/1993–2009/2010	–1.7	–1.2	–1.6
Scottish water	2002/2003–2009/2010	–8.8	3.3	–1.9
Scottish sewerage	2002/2003–2009/2010	–14.3	1.3	–5.4
Electricity transmission	1990/1991–2009/2010	–4.9	2.5	–3.6

4.89 Table 23 provides estimates of changes in RUOE for each industry between 2006/2007 and 2009/2010 using a number of different output measures, and with and without the adjustments for economies of scale described above. It also shows the growth in operating expenditure relative to RPI — i.e. a growth rate in operating expenditure before any adjustment for changes in outputs. Due to data availability, there are some differences across the estimates in terms of the expenditure coverage (e.g. the estimates for the England and Wales water industry that use base service operating expenditure include local authority rates whereas the other water industry estimates exclude these rates). More information on the methods used in each case has been provided in the sub-sections on each industry above. In the case of Scottish Water, our update to Oxera (2008) presented above covers the period from 2005/2006, but the estimates in table 23 are from 2006/2007 for consistency with the other industries.

4.90 The figures in table 23 are averages of the logarithmic annual growth rates over the period 2006/2007 to 2009/10. In contrast, for the update of Oxera (2008) summarised above followed Oxera in presenting the arithmetic average of the percentage change in the RUOE across successive years. We think it is preferable to calculate logarithmic annual growth rates (see the appendix to this report for further details on this calculation). A logarithmic growth rate makes more sense in circumstances in which there may be a time lag of more than a year between a change in the volume of output and the associated change in operating expenditure requirements.

Table 23 Average logarithmic annual growth rates between 2006/2007 and 2009/2010

Industry	Growth in operating expenditure relative to RPI (%)	Output measure(s)	Adjusted for economies of scale?	Growth in RUOE (%)
Electricity distribution in Great Britain	2.8	Units distributed	Yes	3.9
		Units distributed	No	4.4
		Customer numbers	No	2.4
England and Wales water	–0.3	Water delivered and households billed	Yes	–0.1
			No	0.0
		Base service	No	–0.1
England and Wales sewerage	–0.8	Population connected and population billed	Yes	–1.5
			No	–1.4
		Base service	No	–1.3
Gas distribution in Great Britain	–0.6	Annual demand	Yes	2.6
		Annual demand	No	2.9
		Customer numbers	No	–1.0
National Grid Electricity Transmission	1.0	Annual demand	Yes	2.4
		Annual demand	No	3.0
Scottish Water water service	3.2	Water delivered	Yes	5.8
		Water delivered	No	5.9
Scottish Water sewerage service	1.0	Population connected	Yes	0.7
			No	0.7
Network Rail	–0.7	Length of lines	No	–0.6
		Passenger train kilometres	No	–3.3

5 Update of TFP composite benchmarks

5.1 This section provides an update of the work on TFP composite benchmarks provided in Oxera (2008), using more recently available data. It is structured as follows:

(a) We explain what the TFP composite benchmarks are and describe the method we have used for our update.

(b) We provide estimates for the TFP composite benchmarks based on updated data.

(c) We provide further information on the capital substitution adjustment which increases the TFP composite benchmark for operating expenditure in Oxera (2008).

Method used for the update

5.2 Taken together, Oxera (2008) and (2008b) calculate TFP composite benchmarks for separate categories of Network Rail expenditure: operating expenditure, maintenance, renewals and enhancements. The TFP composite benchmark for each expenditure category was constructed using the following method:

(a) Decompose the expenditure category into a series of activities (e.g. the activity of track maintenance within the overall maintenance expenditure category).

(b) Map each activity to one of more comparator sectors of the UK economy for which data on total factor productivity (TFP) growth is available from the EU KLEMS dataset (e.g. map track maintenance to the transport and storage sector).

(c) For each of the selected comparator sectors, calculate the average annual growth in total factor productivity (on a value added basis) over the period 1981 to 2004.

(d) Calculate the TFP composite benchmarks as a weighted average of the average annual TFP growth in the selected comparator sectors, with weights given by each activity's share of expenditure.

5.3 In the case of operating expenditure, an additional adjustment was made for the effects of capital substitution.

5.4 The difference between the composite benchmark for each expenditure category and TFP for the whole economy was then used to provide the outperformance in productivity that might be expected for Network Rail.

5.5 Since Oxera (2008) and (2008b) there has been a new release of the EU KLEMS dataset which provides data for the UK between 1970 and 2007. We have been asked by ORR to provide an update for Oxera's TFP composite benchmarks using the more recent data.

5.6 In constructing the composite benchmark, we have sought to follow the method and approach used by Oxera. We have taken the breakdown of activities used by Oxera and applied the same comparator sectors to these activities.

5.7 We have updated the weights for renewals expenditure using Network Rail's delivery plan for CP4 (Network Rail, 2011). The weight for each expenditure category is given by its average proportion of total spending over the five year period.

5.8 We agreed with ORR to retain the weights used by Oxera for the other expenditure categories due to a lack of data for a full update. We do not expect this to have a large impact on the results. First, several expenditure activities are mapped to the same sector of the UK economy. The effect of this is that even quite large changes in weights would have a limited impacted on the value of the composite benchmark. Second, we would not expect large changes in the proportion of activities that make up expenditure categories.

5.9 The tables below display the weight used for each expenditure category and the chosen comparators, providing the weights used by Oxera (2008) and Oxera (2008b) as well as our updated weight for renewals. The weights may not add to exactly 100 due to rounding error.

Table 24 Weight and comparators used for opex composite benchmark

Activity	Oxera weights (%)	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

Table 25 Weight and comparators used for maintenance composite benchmark

Activity	Oxera weight (%)	Comparators
Track	36	Transport and storage Electricity, gas and water supply
Signals	11	Transport and storage Electricity, gas and water supply
E&P	5	Transport and storage Electricity, gas and water supply
Telecoms	6	Post and telecommunications
Maintenance-other	5	Transport and storage Electricity, gas and water supply
Overheads	23	Transport and storage Electricity, gas and water supply
Engineering	6	Rental of machinery and equipment and other business activities
NDS	5	Transport and storage
Other	4	Transport and storage Electricity, gas and water supply Rental of machinery and equipment and other business activities

Table 26 Weight and comparators used for renewals composite benchmark

Activity	Oxera weight (%)	Updated weight (%)	Comparators
Track	29.9	28.9	Transport and storage Electricity, gas and water supply
Signalling	20.8	17.2	Transport and storage Electricity, gas and water supply
Civils	17	14.0	Construction
Operational property	12.6	10.3	Construction
Telecoms	7.4	8.6	Post and telecommunications
Electrification	4	4.7	Transport and storage Electricity, gas and water supply
Plant and machinery	3.1	3.1	Electricity, gas and water supply
IT and other	5.1	10.9	Rental of machinery and equipment and other business activities

Table 27 Weight and comparators used for enhancement composite benchmark

Activity	Oxera weight (%)	Comparators
Track	22	Transport and storage Electricity, gas and water supply
Signalling	28	Transport and storage Electricity, gas and water supply
Structures	7	Construction
Operational property	19	Construction
Electrification and Plant	16	Transport and storage Electricity, gas and water supply
Telecoms	2	Post and Telecommunications
Other	6	Renting of machinery and equipment and other business activities

5.10 In line with Oxera (2008), we have included an adjustment for capital substitution for operating expenditure. This adjustment is, we understand, made so that the productivity benchmark for operating expenditure takes account of both: (i) opportunities to reduce operating expenditure due to improvements in total factor productivity and (ii) opportunities to reduce operating expenditure from a move away from relatively labour-intensive towards more capital intensive production techniques and working practices. Oxera report that the second element is based on applying an estimate of the rate of capital substitution for the UK economy as a whole to the composite benchmarks. We have used the same adjustment for capital substitution (0.5 per cent per year) as in Oxera (2008). We discuss this issue further after the presentation of results.

Estimates based on updated data

5.11 The steps above identified a series of comparator sectors for different areas of Network Rail expenditure. In order to construct the composite benchmark, we calculate the average value added total factor productivity growth for each of these sectors. We use the index of value added TFP growth provided in the EU KLEMS dataset.

5.12 In contrast to Oxera (2008) we have not attempted to map our chosen data period to include a specific number of business cycles. We do not believe that we have a sufficient understanding of the nature of business cycles to do this. We consider two time periods:

(a) The whole period of available data, 1970 to 2007.

(b) An update of the time period identified by Oxera, taking data from 1981 to 2007 rather than 1981 to 2004.

5.13 Table 28 shows the estimated value added productivity growth for each of the comparator sectors used in the composite benchmarks for the two periods 1970 to 2007 and 1981 to 2007.

Table 28 Average annual value added TFP growth (%)

Industry	1970 – 2007	1981 – 2007
Electricity, gas and water supply	2.1	1.3
Construction	0.7	1.6
Transport and storage	2.1	2.1
Post and telecommunications	2.7	3.5
Financial intermediation	–0.5	0.5
Renting of machinery and equipment and other business activities	–0.2	0.2

5.14 These value added TFP numbers are then combined with the weights for each expenditure category to form the composite benchmarks.

5.15 Table 29 shows the updated composites benchmark, as well as the benchmarks from Oxera (2008) for operating, maintenance and renewals expenditure. The estimate for operating expenditure includes a capital substitution adjustment of 0.5.

Table 29 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

5.16 We also provide an update for the analysis conducted in Oxera (2008b) on enhancement expenditure, which uses two different sets of comparators. The main comparators used for enhancements are set out in the section above describing the method used for the updated analysis. The alternative comparator selection gives a weight of 94 per cent to the construction sector and the remaining weight to the "Renting of machinery and equipment and other business activities". Table 30 shows updated estimates for enhancement expenditure for these two benchmarks.

Table 30 TFP composite benchmarks for enhancement expenditure

	Main benchmark	Alternative benchmark
Oxera (2008) benchmark 1981–2004	2.0	1.8
Updated benchmark 1981–2007	1.6	1.5
Updated benchmark 1970–2007	1.6	0.6

The capital substitution adjustment

5.17 The "estimated TFP growth" for "opex" in Oxera (2008) includes an adjustment for "capital substitution effects" which increases TFP growth by 0.5 per cent per year. No similar adjustment was made for maintenance or renewals.

5.18 Oxera (2008, page 24) explains the role of the capital substitution adjustment:

> "This study assumes that the effects of factor substitution in maintenance and renewals activities are similar to the industries that comprise the composite benchmark. Given that these activities use a balanced mix of capital and labour inputs, it could be argued that further adjusting the productivity growth estimates for substitution could be excessive. Operation costs, however, predominantly comprise of labour costs. Therefore, the scope for productivity gains could be greater than those derived from the performance of the composite benchmark. As such, an adjustment for capital substitution could be appropriate for this cost category …"

5.19 The method used for the adjustment is explained as follows (Oxera, 2008, page 30):

> "With regard to the effects of capital substitution, the analysis made an adjustment for OPEX only, as discussed above. The calculation of the adjustment is based on the assumption that the rate of capital substitution for the composite benchmark is the same as that observed in the UK economy (0.35) and follows the same principles used in the 2005 study."

5.20 In Oxera (2008), the reference to the "2005 study" can only relate to LEK and Oxera (2005). But we found no principles or method set out in LEK and Oxera (2005) that explain the figure of 0.5 for the adjustment.

5.21 We have looked back at previous studies in this field. Europe Economics (2001) provides a discussion of capital substitution in the context of using estimates for TFP growth to inform on an operating expenditure trend for the gas transportation company Transco (now part of National Grid).[12]

5.22 Europe Economics (2001) identifies that a measure of capital substitution is the rate of change in the "capital-labour ratio", which is the ratio of volume of capital employed divided by the volume of labour (page 575). The rate of change is labelled gKLR. Europe Economics (2001) assumes that gKLR is the same across all industries and draws on reported estimates in the literature for the UK business sector to produce a figure for gKLR of 1.7 per cent. Europe Economics (2001) reports that the 1.7 per cent was calculated as the difference between the growth in labour productivity (2.1 per cent) and the growth in capital productivity (0.4 per cent) for the UK business sector, over the period 1980-1990.[13]

5.23 From this, Europe Economics (2001) states (page 576):

> "If this value of gKLR is taken as a benchmark across all comparators, and if operating costs are identified with the labour input of the two-factor model, the adjustments necessary to [convert] RUOE figures (corrected for input prices) into TFP growth figures would be given by
>
> $$gLP - gTFP = 1.7\% \times [\text{capital share of value}]$$
>
> For example, if the capital share of value is of the order of 50 per cent, 0.85 per cent would need to be deducted from TFP growth to obtain a figure relevant to operating expenditure (adjustments for input prices and output changes are still required)."

5.24 We have looked at the data in the EU KLEMS dataset over the period 1981 to 2004, which Oxera (2008) uses for its main TFP benchmarks. We find that the average capital share of value added over this period is 0.3 (to one decimal place). Using the equation above, and the figure from EU KLEMS of 0.3 for the capital share of value, we obtain an adjustment factor of 1.7*0.3 = 0.5.

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[12] The Europe Economics report is contained as Appendix D to Mazars Neville Russell (2001).

[13] These figures are reported to be taken from Englander A and Gurney S (1994) "Medium term determinants of OECD productivity", OECD Economic Studies, 22, pages 49 to 109.

5.25 The Europe Economics equation was cast as an adjustment to convert RUOE figures corrected for input prices into TFP growth figures. This could be taken in reverse as an adjustment to convert a TFP growth rate into a figure for RUOE corrected for input prices. In this case, the adjustment factor would be added to TFP growth. This would provide a method for coming up with a figure of around 0.5 to add to a TFP growth rate in order to obtain a figure relating to the rate of reduction in unit operating expenditure corrected for input prices.

5.26 Oxera (2008) is silent on the method used to obtain its capital substitution adjustment of 0.5 for "opex". We have not found a basis for the figure quoted by Oxera of 0.35 for rate of capital substitution in the UK economy. But we can see how using relevant data from EU KLEMS and the Europe Economics (2001) capital substitution adjustment equation could give an adjustment of 0.5 per cent a year, the same value as used by Oxera.

5.27 Oxera (2008, page 31) also reports a sensitivity analysis which involves an alternative capital substitution adjustment which is described as being based on the method used in Europe Economics (2003). Oxera (2008) reports a figure for the TFP composite benchmark for opex of 1.5 based on this alternative capital substitution method. Oxera (2008) does not explain how the figure of 1.5 is calculated.

5.28 We have looked at Europe Economics (2003), which is a study for Ofwat on the potential scope for efficiency improvements in the regulated water and sewerage industries. This study uses the same equation for a capital substitution adjustment that allows estimates of TFP growth to be converted into estimates of labour productivity growth (which was identified with RUOE corrected for input prices in Europe Economics, 2001). But rather than a figure of 1.7 per cent, a figure of 2 per cent is used in Europe Economics (2003): "we assume that the gap between TFP and labour productivity growth is two per cent times the relevant industry's capital share of value" (Europe Economics, 2003, appendix, A2.24). This figure of 2 per cent is chosen in light of the estimates from Englander and Gurney that were used in Europe Economics (2001), other estimates for the UK economy and differences between TFP growth and labour productivity growth in comparator sectors.

5.29 We have not been able to derive the figure of 1.5 per cent shown in Oxera's sensitivity analysis from the method set out in Europe Economics (2003).

5.30 If we apply the Europe Economics (2003) figure of 2 per cent, and multiply it with the capital share of value added for the UK economy as a whole of 0.3 taken from EU KLEMS (see above), we obtain 0.6, which is close to the capital substitution adjustment in the "base case" in Oxera (2008), and nowhere near the adjustment in the sensitivity analysis in Oxera (2008).

5.31 Network Rail asked LECG to provide a review of the approach in Oxera (2008). Oxera (2008c) provides a response to issues raised by LECG, including arguments that the results are sensitive to the assumption on capital substitution and that this assumption is not well-supported. But Oxera (2008c) provides no further information on the method or calculations and at page 23 simply points the reader back to the discussion in Oxera (2008). As highlighted above, that discussion is not sufficient to understand what was done. Oxera (2008c) also reproduces the sensitivity analysis for capital substitution provided in Oxera (2008), but the calculations are not explained.

5.32 In short, Oxera (2008) provides inadequate explanations of how its figures for capital substitution were calculated. We have looked back over previous studies and found that the main capital substitution adjustment used by Oxera is close to adjustment factors calculated using the methods in Europe Economics (2001) and (2003) and a capital share of value added for the UK economy as a whole. We can find no plausible source for the capital substitution sensitivity analysis in Oxera (2008).

5.33 We have not sought to update or refine the capital substitution adjustment used in Oxera (2008). Even if this capital substitution element of the TFP composite benchmark was put on a sounder footing, there remain other problems — in particular the use of value added measures of productivity growth and the wide scope for disagreement about the particular comparators selected. Furthermore, we question in section 3 the purpose of this capital substitution adjustment. We suggest an alternative approach altogether.

6 Further analysis of EU KLEMS data

6.1 This section presents analysis of the EU KLEMS dataset that is intended to address some of the vulnerabilities and limitations of the TFP composite benchmarks. We provide estimates of several different measures which relate to changes over time in productivity and the costs of production for different sectors of the UK economy.

6.2 The section is structured as follows:

(a) We introduce the various measures that are used in this section and discuss some measurement issues.

(b) We present estimates for these measures for the 30 most disaggregated sectors for which relevant data are available from EU KLEMS. The main set of estimates that we provide are based on the full period of available data, 1970 to 2007. We also use a simple regression analysis to estimate time trends for each measure.

(c) We examine the sensitivity of these estimates to the period over which they are calculated, by comparing them to estimates for the last ten and last twenty years of data.

(d) We provide some analysis of the average growth rates over consecutive five-year periods. There is more variation in these five-year averages than in the longer-term averages. A five-year period may be relevant if Network Rail's price controls continue to be set for five years.

6.3 We provide an appendix at the end of the document which sets outs the calculations used for the analysis and a full set of results.

Introduction to the measures

6.4 We use the EU KLEMS data to examine several different measures that relate to changes over time in productivity and the costs of production. These are:

(a) LEMS cost measure (with and without an adjustment for constant capital).

(b) LEMS productivity measure (with and without an adjustment for constant capital).

(c) Output price indices.

(d) Gross output total factor productivity measure.

6.5 We have set out in section 3 how these measures might be relevant as part of the work to set Network Rail price controls in the future, particularly if changes were made to the approach used at the last periodic review.

6.6 We discuss each of these measures below and then provide a brief discussion of some measurement issues.

LEMS cost measures and LEMS productivity measures

6.7 In our 2008 report for Ofwat, *PR09 Scope for efficiency studies*, we identified a cost measure which we called "LEMST unit costs". This was designed to capture, albeit imperfectly, the growth in operating expenditure per unit of output, for the different sectors of the UK economy covered in the EU KLEMS dataset. This measure was calculated in a way that we considered most compatible with the "base service operating expenditure" concept that Ofwat uses to set price limits for water and sewerage companies.

6.8 For this study, we have produced estimates of the growth rates for a similar measure, which we call the LEMS cost measure. We use the term "LEMS" because the cost measure covers four of the five input categories from which the term "KLEMS" is derived: labour (L), energy (E), materials (M) and services (S). The cost measure does not cover capital inputs (K). The data provided in EU KLEMS report energy, materials and services as a single category, which is called intermediate inputs.

6.9 The LEMS cost measure captures labour costs and expenditure on intermediate inputs and excludes the purchases of capital by a sector. The growth in the LEMS cost measure provides an estimate of the changes over time in the labour costs and expenditure on intermediate inputs per unit of output produced — but with an adjustment intended to exclude the impact on these costs of any changes in the volume of capital employed per unit of output. This rationale for this adjustment is set out in the discussion at the end of section 3. The appendix provides the calculation used for the LEMS cost measure.

6.10 The LEMS cost measure we used in this report differs from the measure that we used in our study for Ofwat because the latest available version of the EU KLEMS dataset does not include the variable TXSP which provides data on taxes on production net of subsidies. We do not expect the differences between the rates of change in these measures to be substantial, especially when we look at averages over long periods or time.

6.11 The LEMS cost measure is a unit cost measure. It can be seen to reflect the combined effect of productivity improvements and changes over time in wages and the prices of intermediate inputs.

6.12 We have also calculated a LEMS productivity measure which is related to the LEMS cost measure. The growth in LEMS productivity (at constant capital) provides an estimate of the decrease in the volume of labour and intermediate inputs that might be expected from past productivity trends, if there was to be a constant volume of output and a constant volume of services from capital. This is calculated by first taking an estimate of gross output total factor productivity growth achieved and then making an estimate of what would have happened if that total factor productivity growth had only been manifest through reductions in the volume of labour and intermediate inputs.

6.13 Table 31 provides a summary of these two measures.

Table 31 Summary of LEMS productivity measure and LEMS cost measure

	LEMS productivity measure (at constant capital)	**LEMS cost measure**
Type of measure	Productivity measure	Unit cost measure
Input coverage	Volume index for labour inputs and intermediate inputs	Labour compensation (including wages, the self-employed and taxes on labour) Expenditure on intermediate

		inputs
Output measure	Volume index of gross output	Volume index of gross output
Treatment of changes in capital	Adjustment to exclude the impact on volume of labour and intermediate inputs that is attributed to changes in the volume of capital employed	Adjustment to exclude the impact on costs that is attributed to changes in the volume of capital employed
Interpretation	The rate of reduction in the volume of labour inputs and intermediate inputs if there had been: • A constant volume of outputs • A constant volume of capital	The growth (relative to CPI) in labour costs and expenditure on intermediate inputs if there had been: • A constant volume of outputs • A constant volume of capital
Link to productivity and input prices	Calculation takes account of: • Total factor productivity growth • An estimate of what would have happened if that total factor productivity growth had only been manifest through reductions in the volume of labour and intermediate inputs	Calculation takes account of: • Total factor productivity growth • An estimate of what would have happened if that total factor productivity growth had only been manifest through reductions in the volume of labour and intermediate inputs • Wage growth and changes in the prices of intermediate inputs

6.14 We have also produced results for versions of the LEMS cost measure and the LEMS productivity measure that are not adjusted for constant capital inputs. The growth in the unadjusted LEMS cost measure is calculated as the growth rate in the sum of labour costs and intermediate inputs expenditure minus the growth in the volume of output produced. We provide algebra for all these measures in the appendix.

Output price indices

6.15 We also provide estimates of the growth rate (relative to RPI) in the variable "GO_P" from the EU KLEMS dataset, which is described as "Gross output, price indices, 1995 = 100”. For a particular sector of the economy, this represents an index of the prices of the goods and services supplied in that sector.

6.16 The outputs to which these indices apply cover both goods and services for final consumption by households or Government, and outputs used by other businesses (i.e. outputs that are then taken as intermediate inputs).

6.17 The growth rate in the gross output price index for a particular sector of the economy will reflect changes over time in their costs of production and in the rate of profits. These will, in turn, reflect the productivity growth achieved by these companies and changes in the prices of the inputs that these companies use (relative to the RPI).

6.18 These price indices play an important role in the calculation of productivity measures and the LEMS measure described above. For example, to calculate total factor productivity on a gross output basis, a necessary ingredient is a measure of the volume of gross output produced by a sector. An index of the volume of gross output can be obtained by dividing the nominal value of the gross output of that sector by the output price index for that sector. In this way, the rate of change (as a natural logarithm) in the volume of gross output can be seen as the rate of change in the value of gross output minus the rate of change in the output price index.

Gross output total factor productivity measure

6.19 We have calculated estimates of the growth in gross output total factor productivity. These relate to the growth rate in the volume of gross output relative to the growth rate in the volume of inputs.

6.20 The growth in gross output total factor productivity can be seen as an estimate of the increase in the annual volume of gross output that might be obtained from a constant volume of labour, services from capital and intermediate inputs. It can also be seen as the growth rate in the volume of gross output that is not attributed to growth in the volume of inputs used.

6.21 This is a different concept from estimates of total factor productivity growth based on an alternative measure of output — gross value added — which are often cited in macroeconomic studies. Similar to other consultancy studies for UK economic regulators, the Oxera report for ORR in 2008 focuses on measures of productivity growth on a value added basis.

6.22 However, for the purposes of this study, if data are available to calculate both gross output total factor productivity measures and value added factor productivity measures, we do not see the basis for using the latter. The concept of "value added" relates to the difference between the value of output produced in a sector and the expenditure of that sector on intermediate inputs (e.g. materials and services but not labour). Whilst this concept is useful in growth accounting and macroeconomics, it is not well suited to be reconciled with accounting or business concepts such as operating expenditure or with the changes over time in the efficiency and costs of particular companies. We see no reason to use a measure of output that is based on the value added concept.

6.23 Gross output total factor productivity estimates are more common in microeconomic studies, especially ones that concern the productivity growth achieved by specific companies.

6.24 The measures of total factor productivity that we calculate in this report are sometimes referred to as multi-factor productivity (MFP). MFP may be a technically more accurate term than TFP, but we use the terminology of TFP and total factor productivity for consistency with previous studies and regulatory precedent.

Measurement issues with gross output productivity and unit cost measures

6.25 Whilst gross output productivity seems the more relevant productivity concept, it suffers from some measurement issues.

6.26 Gross output is a reasonably straightforward concept when it applies to a single company, but complications arise for the large aggregations of organisations captured by the industries and sectors for which the EU KLEMS data are available.

6.27 A productivity or unit cost measure based on gross output is most meaningful when it relates to data for a single company. Total factor productivity on a gross output basis for a company can be calculated as the growth in a measure of the volume of outputs produced by the company minus a weighted-average of the growth in the volume of inputs used by the company (e.g. labour inputs, materials inputs and services from capital).

6.28 The data available from EU KLEMS are not provided for individual companies. They are provided for various sectors or industries, and for further aggregations of these sectors. If we calculate total factor productivity on a gross output basis for one of the sectors in the EU KLEMS database, we obtain an estimate of the weighted average total factor productivity growth achieved by companies in the sector. The weights used for the weighted average relate to each company's share of gross output. In a simple case, a company's gross output is its turnover.

6.29 If total factor productivity growth is calculated on a gross output basis, the following features apply:

(a) Total factor productivity growth will be sensitive to the organisation of enterprises within a sector — in particular, the extent of vertical integration. This feature may limit the reliability of comparisons of total factor productivity growth over time, between sectors and between countries. For instance, the measure of total factor productivity will be affected if the extent of vertical integration changes over time through a greater use of sub-contractors rather than in-house production.

(b) The contribution of each company's total factor productivity growth to the productivity growth for the sector will depend on each company's share of gross output. The gross output of a company within a sector gives no reliable indication of the relative importance of the company to the sector, in terms of using labour and capital inputs to take things produced by other sectors (and imports) and transform them into the sector's output.

6.30 These measurement issues may be relevant not only to estimates of gross output total factor productivity growth but also to estimates of changes in the LEMS cost measures and LEMS productivity measures, because gross output is used as the output measure in each case.

6.31 The extent to which measures of gross output total factor productivity growth can be affected by vertical integration may depend on the level of aggregation of the sector. The researchers involved in the EU KLEMS project say the following:[14]

> "MFP measures [also known as TFP measures] can be derived at various levels of aggregation. Gross output decompositions are most meaningful at the lowest level of aggregation, viz., establishments. As soon as aggregates of gross output are decomposed, one runs into problems of comparability over time and across countries, depending on differences in the vertical integration of firms. Ideally, decomposing gross output should be done on a sector output measure which excludes intra-sectoral deliveries of intermediates (Gollop, 1979). […] Therefore, we present gross output decompositions only at the lowest possible industry level, depending on the level of detail of outputs and inputs, and do not show any industry aggregates. In the current database we also present the decompositions of value added growth, which is insensitive to the intra-industry delivery problem."

6.32 In this light, we only report estimates based on gross output concepts for the most disaggregated sectors available from the EU KLEMS dataset. This means, for example, that we report estimates for various different categories of manufacturing industries rather than for manufacturing overall.

High-level comparison of vulnerability to measurement error

6.33 All of the data that we take from the EU KLEMS dataset are potentially subject to measurement error. Table 32 takes each measure in turn and highlights its vulnerability to potential measurement error in different data series reported in EU KLEMS. For instance, each of the measures that we calculate rely on the data reported in EU KLEMS on output price indices or output price volumes, but only the productivity measures rely on data on the volume of labour inputs used by a sector.

6.34 Table 32 is not intended to provide a comprehensive identification of potential data problems. For instance, it leaves aside potential measurement error in the value of labour compensation and the value of intermediate input consumption which could affect all of the measures shown apart from the output price indices. The table is

[14] O'Mahony, M and M P Timmer (2009) page F395

intended to highlight the most important differences between the measures in terms of their reliance on specific data series.

Table 32 Comparison of potential vulnerability to different sources of measurement error

	Data on output volume or output prices	Data on volume of capital inputs	Data on volume of labour inputs	Data on volume of intermediates inputs
Gross output total factor productivity	Potentially vulnerable	Potentially vulnerable	Potentially vulnerable	Potentially vulnerable
LEMS productivity measure (at constant capital)	Potentially vulnerable	Potentially vulnerable	Potentially vulnerable	Potentially vulnerable
LEMS productivity measure not adjusted for capital	Potentially vulnerable	–	Potentially vulnerable	Potentially vulnerable
LEMS cost measure	Potentially vulnerable	Potentially vulnerable	–	–
LEMS cost measure not adjusted for capital	Potentially vulnerable	–	–	–
Output price index	Potentially vulnerable	–	–	–

6.35 The comparison shown in table 32 lies behind the statement we make in section 3, that there are some grounds to believe that the estimates of the growth rates for measures of LEMS costs and for output price indices are less vulnerable to measurement error than estimates of productivity growth.

6.36 For the purposes of regulatory decisions, different measures may serve different purposes. For instance, the methodological discussion in section 3 suggests that the LEMS cost measure adjusted for constant capital may be more relevant for setting price controls for Network Rail than the unadjusted LEMS cost measure. This may lead to a focus on the LEMS cost measure adjusted for constant capital, despite possible concerns about measurement error. But where there is a choice of methodology — or where alternative methods seem to give conflicting results — the comparison in table 32 may be helpful.

Growth rates in unit cost and productivity measures (1970 to 2007)

6.37 We present estimates for the 30 most disaggregated sectors for which relevant data are available from EU KLEMS.

6.38 In the charts that follow we use short names for each of these sectors, rather than the names from the EU KLEMS dataset. This is partly for presentational purposes, but also because in some cases the names from EU KLEMS can give a misleading picture of what the sector comprises. The letter or number in brackets is the NACE code for the sectors (or NACE codes where it applies to an aggregation of sectors). We have chosen our sector names based on a review of what sub-sectors each sector comprises. Table 33 shows the mapping of short names to EU KLEMS sectors.

Table 33 Short names that we use for EU KLEMS sectors

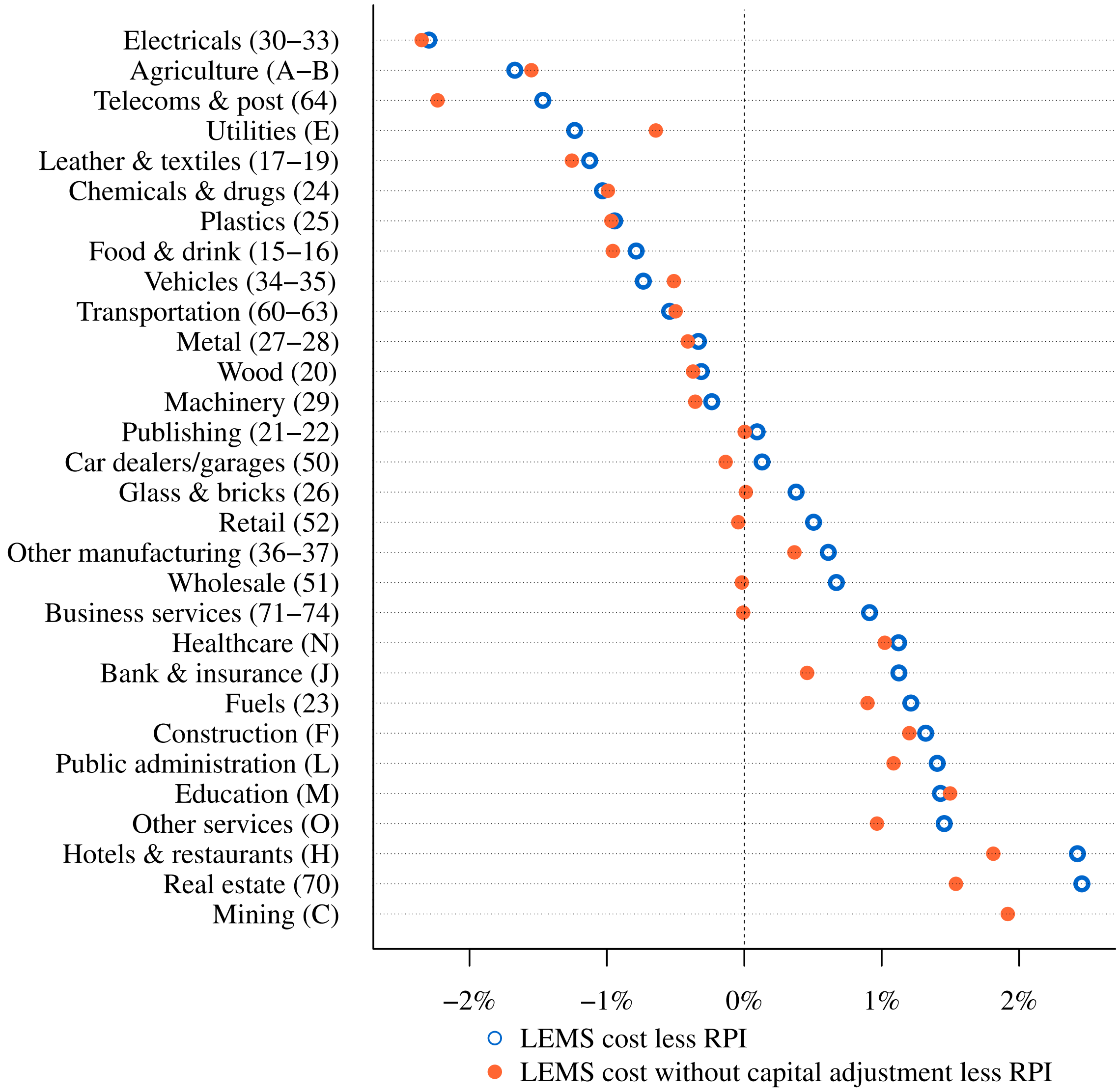
EU KLEMS description	Short name
Agriculture, Hunting, Forestry And Fishing	Agriculture (A-B)
Mining And Quarrying	Mining (C)
Food , Beverages And Tobacco	Food & drink (15-16)
Textiles, Textile , Leather And Footwear	Leather & textiles (17-19)
Wood And Of Wood And Cork	Wood (20)
Pulp, Paper, Paper , Printing And Publishing	Publishing (21-22)
Coke, Refined Petroleum And Nuclear Fuel	Fuels (23)
Chemicals And Chemical	Chemicals & drugs (24)
Rubber And Plastics	Plastics (25)
Other Non-Metallic Mineral	Glass & bricks (26)
Basic Metals And Fabricated Metal	Metal (27-28)
Machinery, Nec	Machinery (29)
Electrical And Optical Equipment	Electricals (30-33)
Transport Equipment	Vehicles (34-35)
Manufacturing Nec; Recycling	Other manufacturing (36-37)
Electricity, Gas And Water Supply	Utilities (E)
Construction	Construction (F)
Sale, Maintenance And Repair Of Motor Vehicles And Motorcycles; Retail Sale Of Fuel	Car dealers/garages (50)
Wholesale Trade And Commission Trade, Except Of Motor Vehicles And Motorcycles	Wholesale (51)
Retail Trade, Except Of Motor Vehicles And Motorcycles; Repair Of Household Goods	Retail (52)

EU KLEMS description	Short name
Hotels And Restaurants	Hotels & restaurants (H)
Transport And Storage	Transportation (60-63)
Post And Telecommunications	Telecoms & post (64)
Financial Intermediation	Bank & insurance (J)
Real Estate Activities	Real estate (70)
Renting Of Machinery and Equipment And Other Business Activities	Business services (71-74)
Public Admin And Defence; Compulsory Social Security	Public administration (L)
Education	Education (M)
Health And Social Work	Healthcare (N)
Other Community, Social And Personal Services	Other services (O)
Total	Whole economy

Estimates for LEMS cost and productivity measures

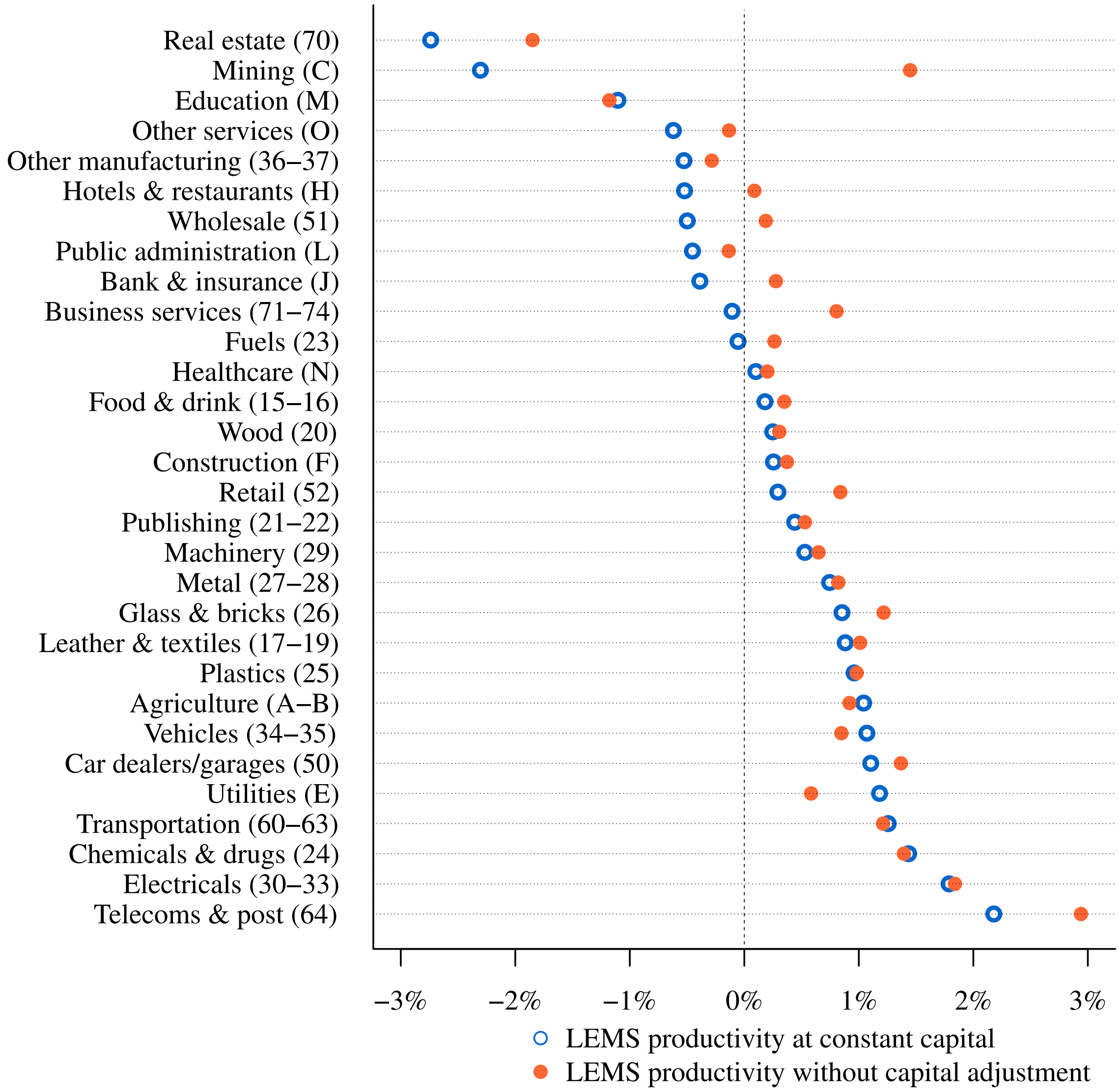
6.39 Figure 10 shows estimates for the logarithmic annual growth rate (relative to RPI) in the LEMS cost measure. In Figure 10, a positive number indicates costs rising relative to the RPI. It also shows estimates the LEMS cost measure that does not involve the constant capital adjustment.

Figure 10 Growth rate in LEMS cost measure (relative to RPI) 1970 – 2007



6.40 Figure 11 shows estimates for the logarithmic annual growth rate, over the whole data period, for the measures of LEMS productivity (at constant capital) and for the measure of LEMS productivity that does not involve the constant capital adjustment.

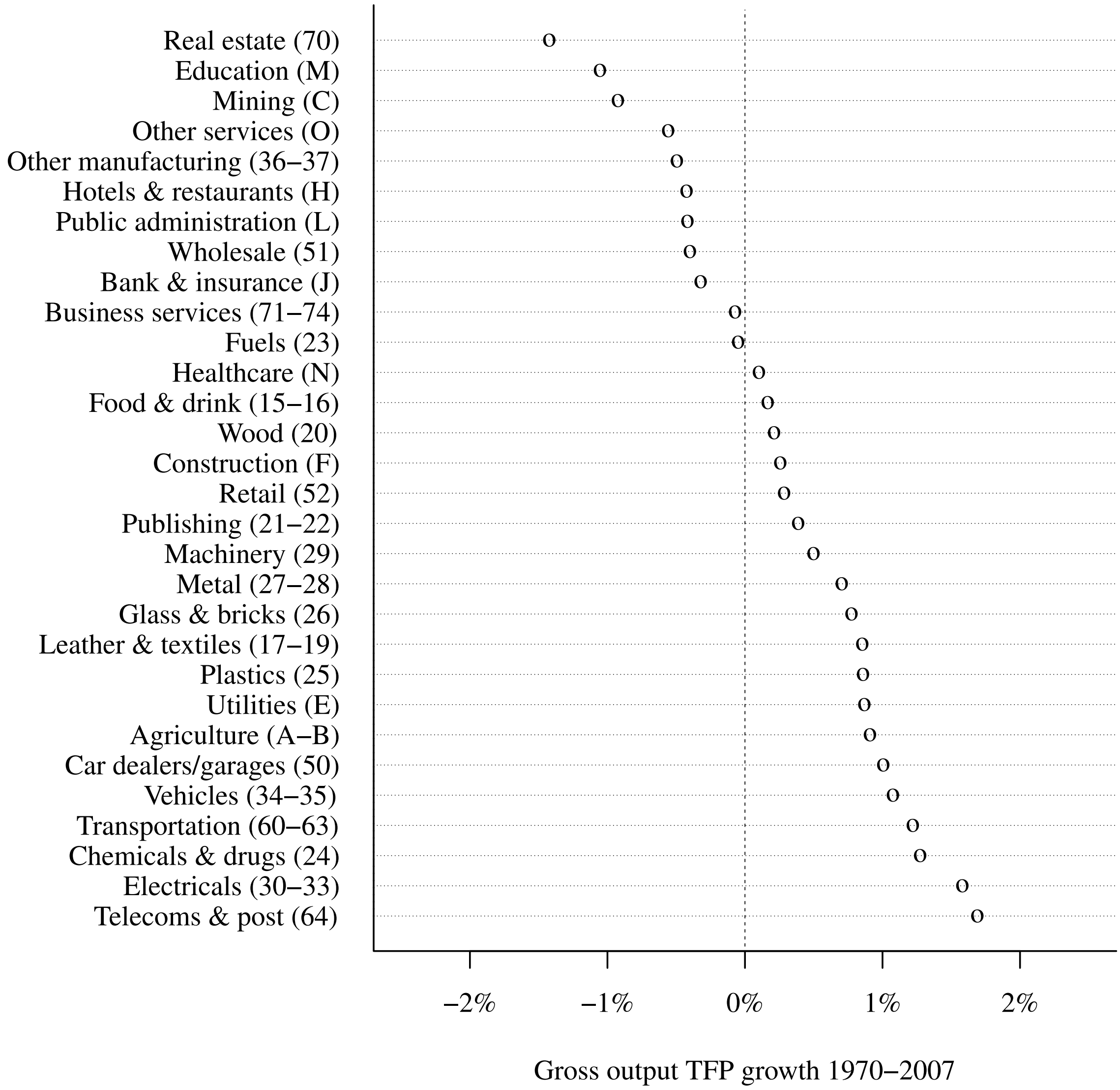
Figure 11 Growth rate in LEMS productivity measures 1970 – 2007



Gross output total factor productivity

6.41 Figure 12 shows estimates for the logarithmic annual growth rate, over the whole data period, for the gross output productivity measure.

Figure 12 Growth rate in gross output productivity measure 1970 – 2007



6.42 We would not normally expect negative total factor productivity growth over long periods of time. The estimates of negative growth rates in figure 12may reflect measurement issues with the EU KLEMS data rather than a decrease in productivity over the period.

6.43 For instance, there are particular problems with the estimation of productivity growth for activities that do not lead to outputs that are sold to customers and which therefore lack a market price. Market prices provide information that is used by national statistical agencies as part of methods to estimate the volume of output produced by a sector in circumstances in which there may be changes in the quality of outputs and the introduction of new products. These problems are likely to affect sectors such as public administration (L) education (M) and other services (O). It is possible that estimates of negative productivity growth reflect a situation in which the quality of outputs has improved over time but this has not been captured well in the data available on the volume of output produced. There are further potential measurement issues beyond those related to public sector activities.[15]

6.44 However, it is possible that some sectors have experienced negative productivity growth for reasons unconnected with measurement error. For instance, some Government regulations or legislation may reduce productivity. As an example, if safety regulation means that more labour is needed to produce the same output, this could offset the productivity growth otherwise experienced in a sector.

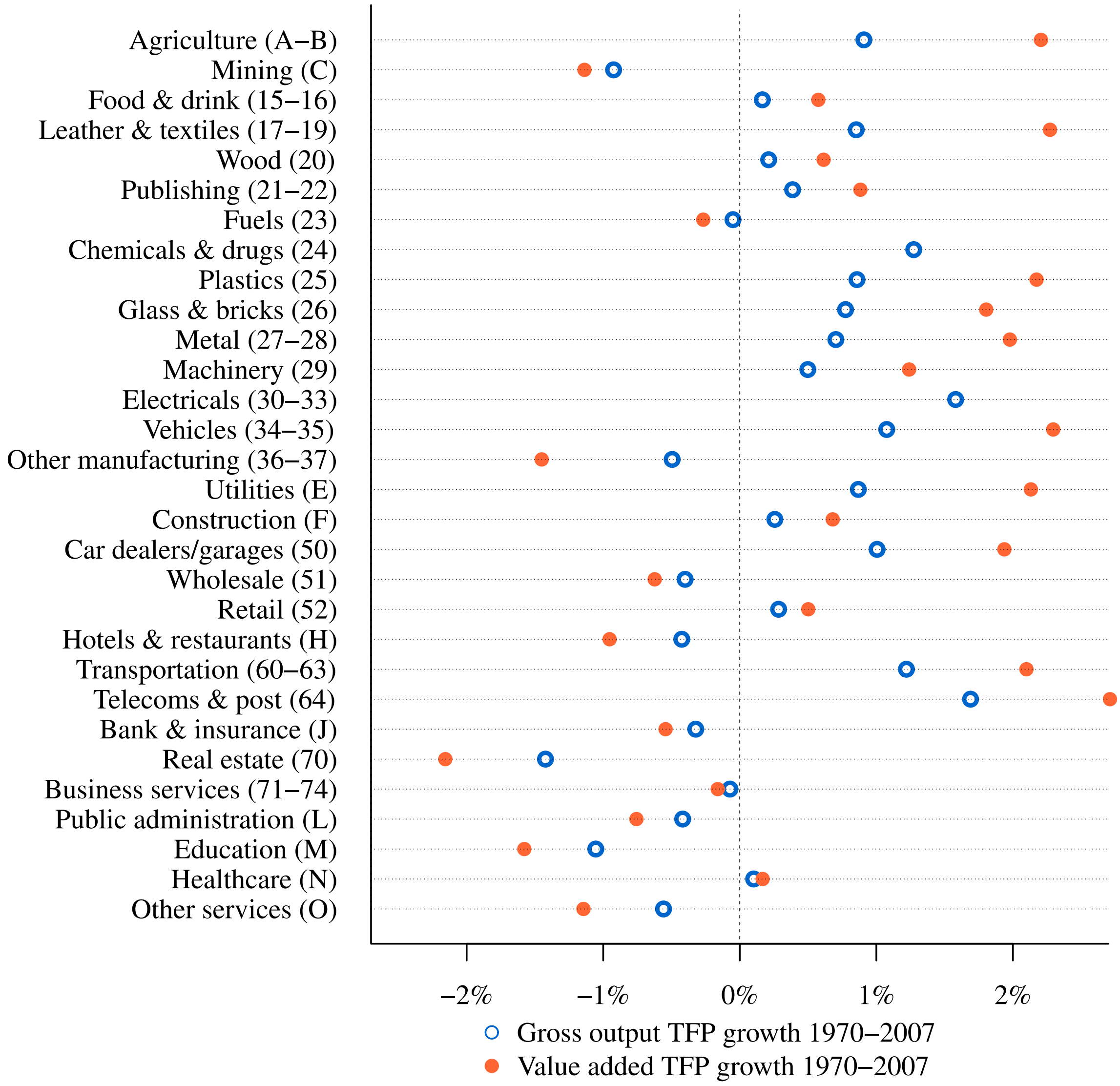
Comparison of gross output and value added productivity growth

6.45 Figure 13 shows a comparison of gross output total factor productivity growth and value added total factor productivity growth for each sector.

6.46 For each sector, the growth rate in value added total factor productivity growth is shown to be of a greater magnitude (i.e. greater in absolute terms) than the gross output total factor productivity growth. This is expected from the mathematical relationship between the two. The growth in value added TFP is equal to the growth in gross output TFP multiplied by gross output of the sector and divided by the gross value added in the sector. The gross value added in a sector is defined as gross output minus the consumption of intermediate inputs and so gross output is always greater than gross value added. This means that value added TFP growth will be greater in magnitude than gross output TFP growth. For example, if the gross value added of a sector is equal to half of the gross output in that sector, value added TFP growth will be double gross output TFP growth.

[15] O'Mahony, M and M P Timmer (2009) discuss negative TFP growth in the context of EU KLEMS data.

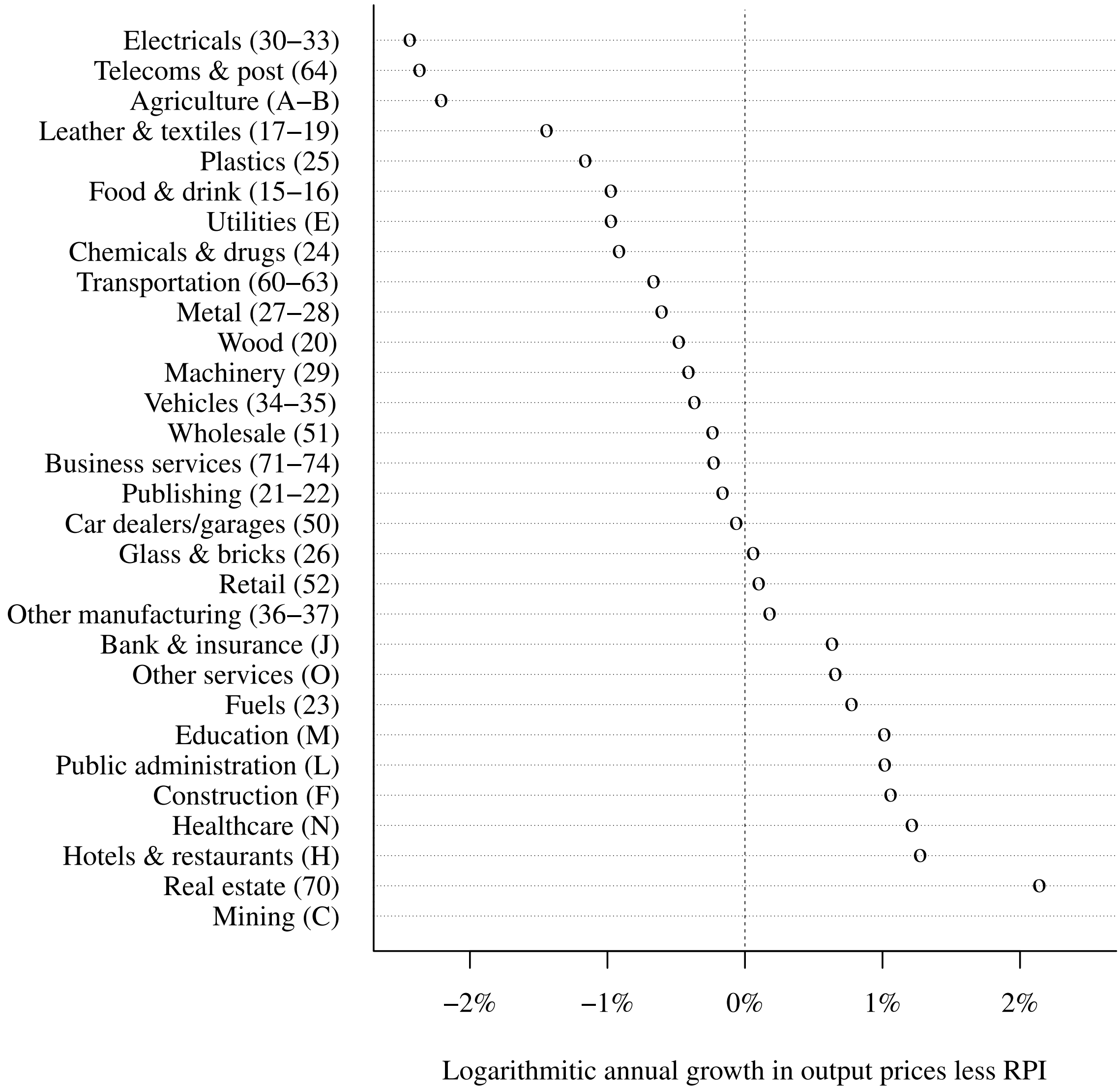
Figure 13 Comparison or value added and gross output TFP growth 1970 – 2007



Output price indices

6.47 Figure 14 shows estimates for the logarithmic annual growth rate (relative to RPI) in output price indices. In Figure 14, a positive number indicates output prices rising relative to the RPI.

Figure 14 Growth rate in output price indices (relative to RPI) 1970 – 2007



Simple OLS time trend regression analysis

6.48 The logarithmic annual growth rates presented above will reflect the overall growth in each measure over the time period. These growth rates may be particularly sensitive to the first and last year's data. To get a better idea of this sensitivity we have carried out a simple regression analysis to estimate time trends for each of the measures presented above. This form of sensitivity analysis was suggested to us by ORR.

6.49 For each measure and for each sector, we constructed an index based on the annual growth rates in that measure relative to RPI. We then used the ordinary least squares

(OLS) technique to estimate values for the constant and coefficient in the following equation:

Natural logarithm of index in year t = constant + [coefficient * t] + random error term

6.50 The coefficient from the regression can be seen as an estimated time trend in the measure relative to RPI.

6.51 We provide the estimated coefficients in the results tables in the appendix, along with the root mean square error (RMSE) for each regression. The latter provides an indication of the dispersion of the logarithm of the index around the fitted time trend. We have not attempted to provide any confidence intervals for the estimated coefficients. This would require assumptions about the distribution of the error term in the equation above. It would not make sense to specify a model in which the random error term in one year is independent of the error term in the previous year.

6.52 We present the estimated coefficients for each sector in graphical form in a series of charts below. We show these coefficients alongside the logarithmic average growth rates reported above in order to illustrate the degree of difference between them. In most cases, there is little difference.

6.53 Figure 15 compares the logarithmic annual growth rate in the LEMS cost measure to the estimated time trend for the LEMS cost measure.

Figure 15 Time trend regression analysis for LEMS cost measure 1970 – 2007

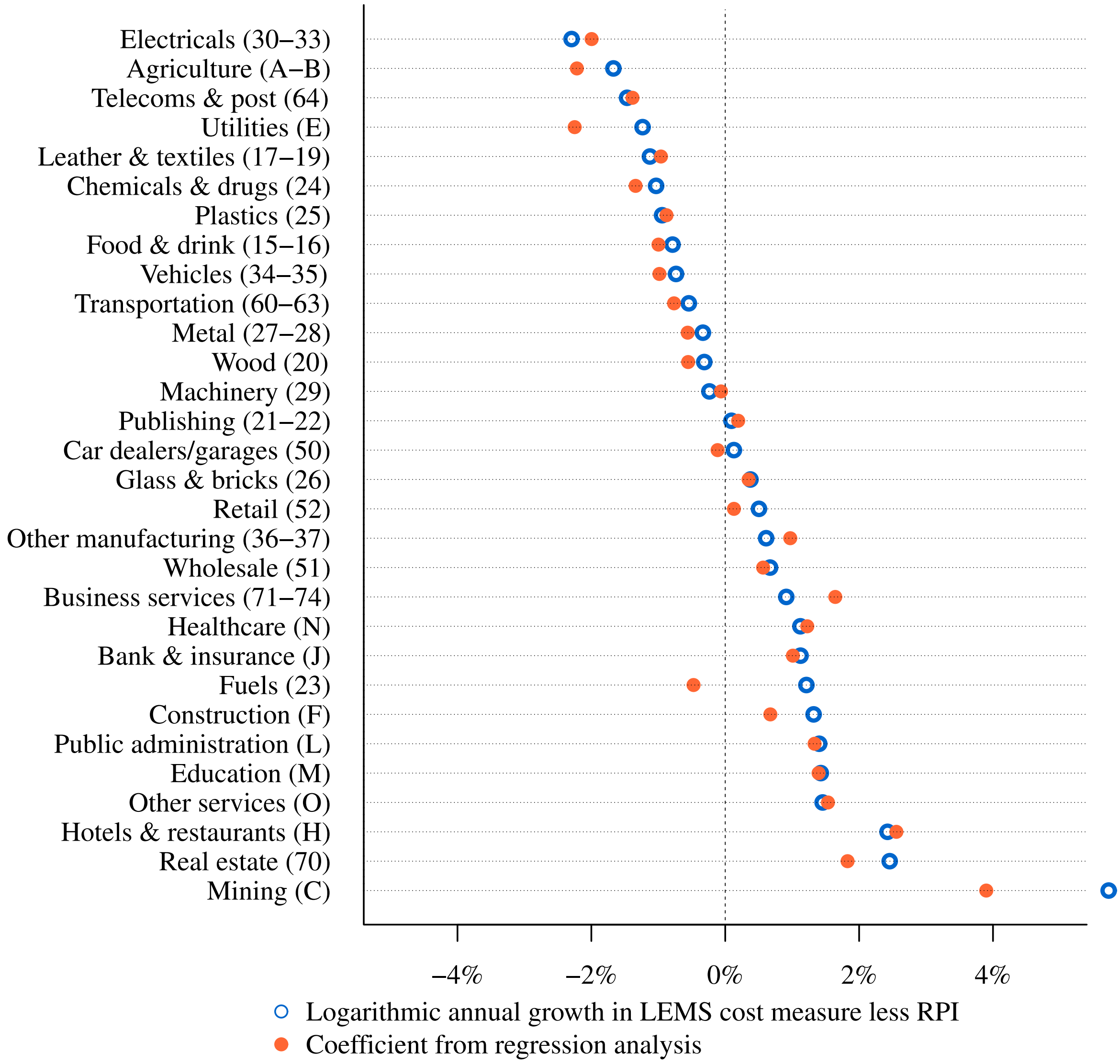
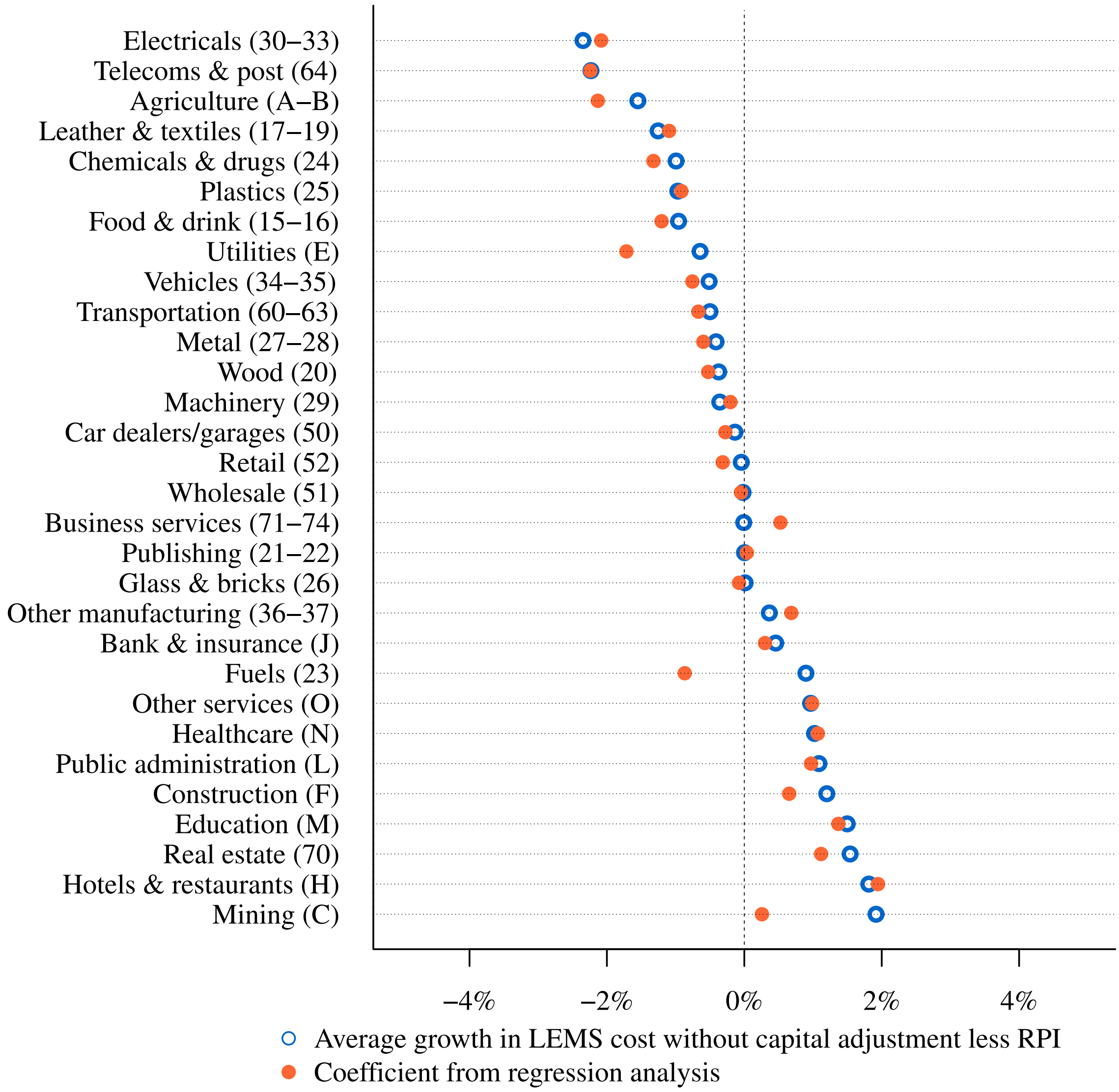


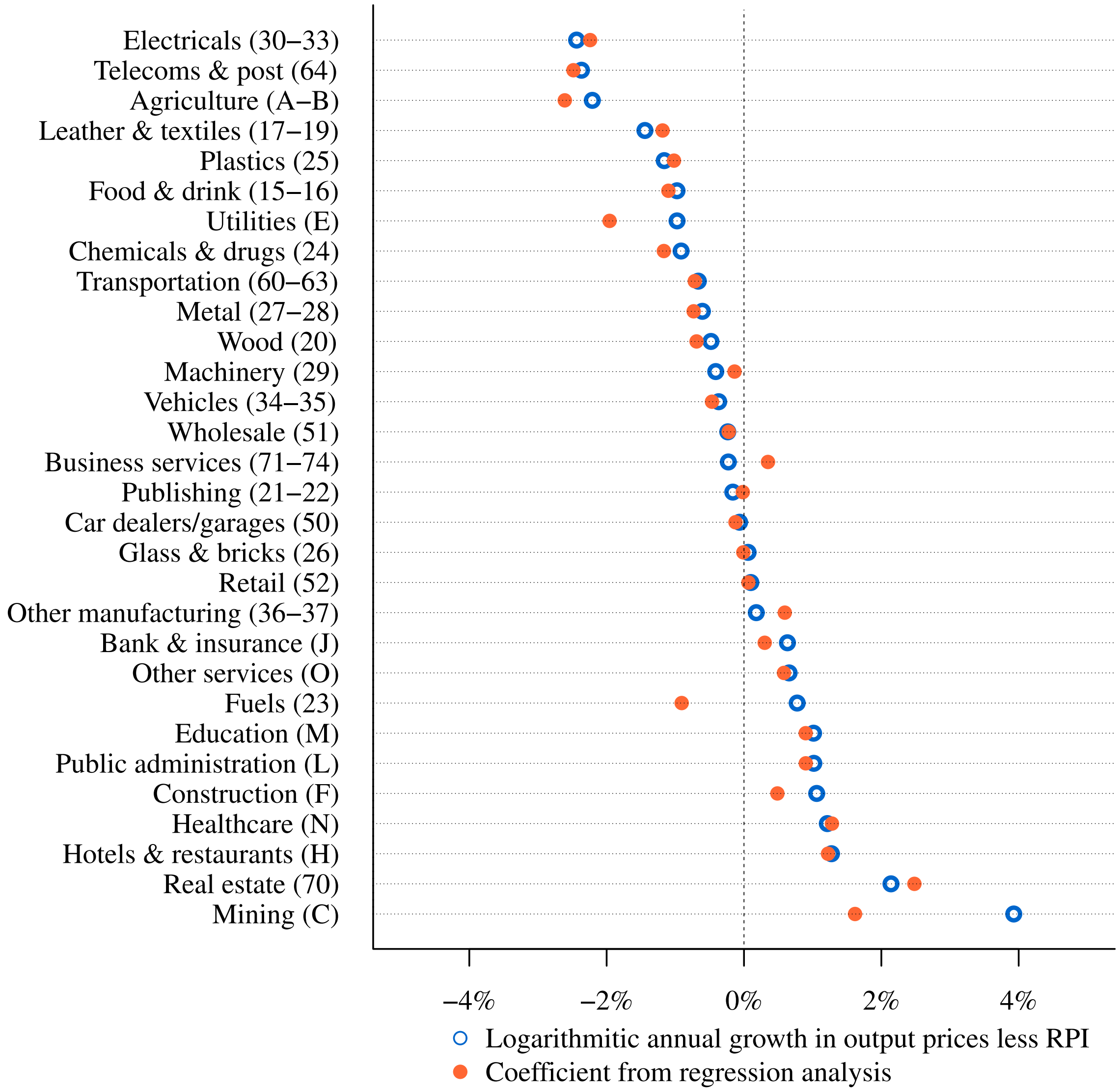
Figure 16 Time trend regression analysis for LEMS cost measure without capital adjustment 1970 – 2007



6.54 As with the LEMS cost measure adjusted for constant capital, the unadjusted LEMS cost measure's logarithmic annual growth rates and times trends are similar across the sectors. There are some sectors in which there is a large difference, such as the mining and fuels sectors.

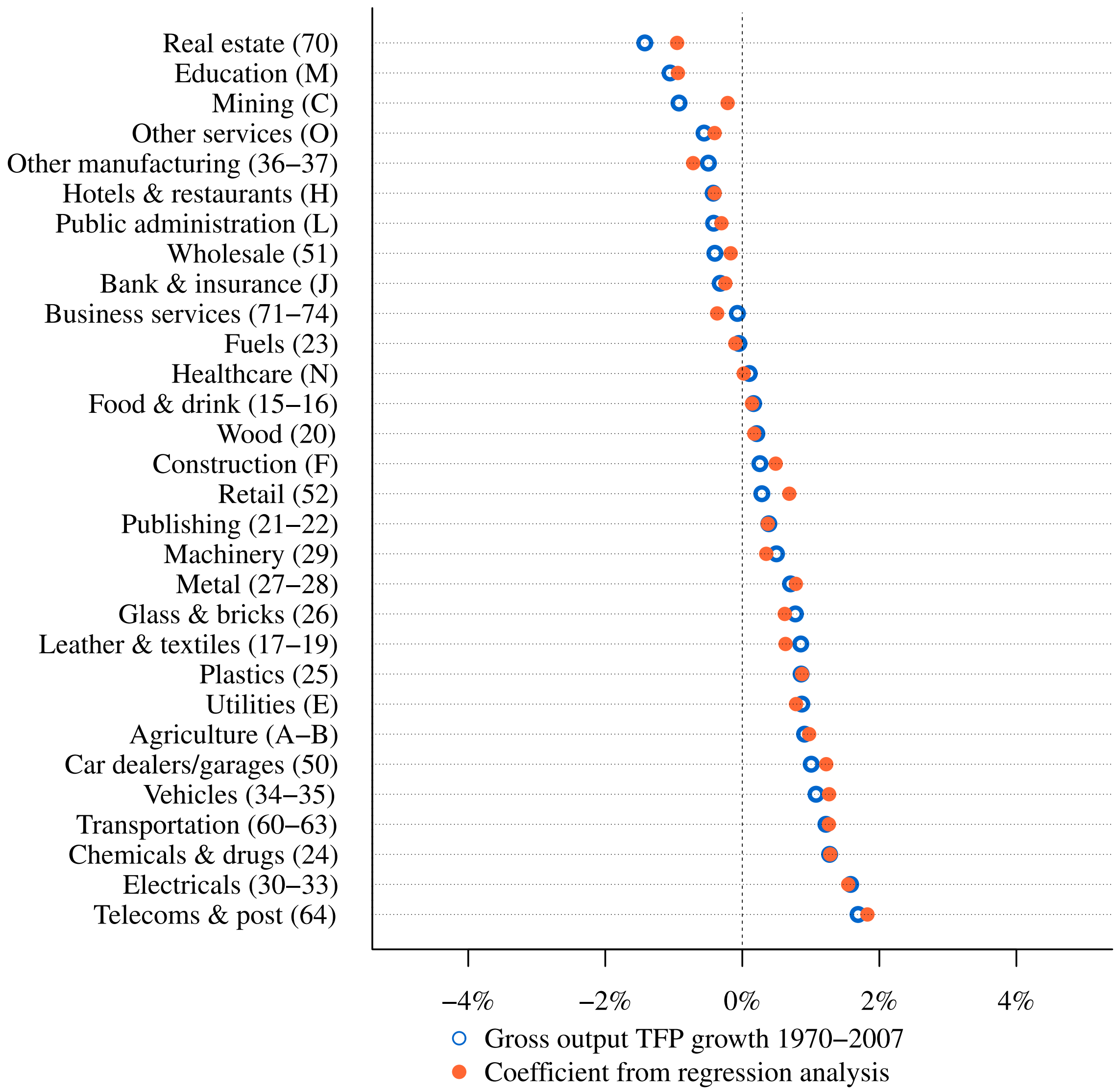
6.55 Figure 17 provides the comparison for output price indices. The majority of sectors show little difference between the time trend from the OLS regression analysis and the annualised average growth estimates. Once again the mining and fuels sectors show a degree of separation, as well as the utilities sector.

Figure 17 Time trend regression analysis for output price growth (relative to RPI) 1970 – 2007



6.56 Figure 18 provides the comparison for gross output TFP. The estimated time trends are in most cases very similar to the logarithmic annual growth rates.

Figure 18 Time trend regression analysis for gross output TFP 1970 – 2007



Sensitivity of estimates to time period

6.57 We have set out earlier in this section the logarithmic annual growth rates in the various measures between 1970 and 2007. This period encompasses the full range of data provided in the version of the EU KLEMS database that we have used.

6.58 Using the full period is good because the large sample size should make the estimates less vulnerable to measurement or data error. We are not aware of any compelling argument that data from the 1970s, for example, would not be relevant whilst data from the 1990s would be relevant. Nonetheless, there will undoubtedly have been changes over time in the nature and composition of the sectors covered and in the composition of the RPI.

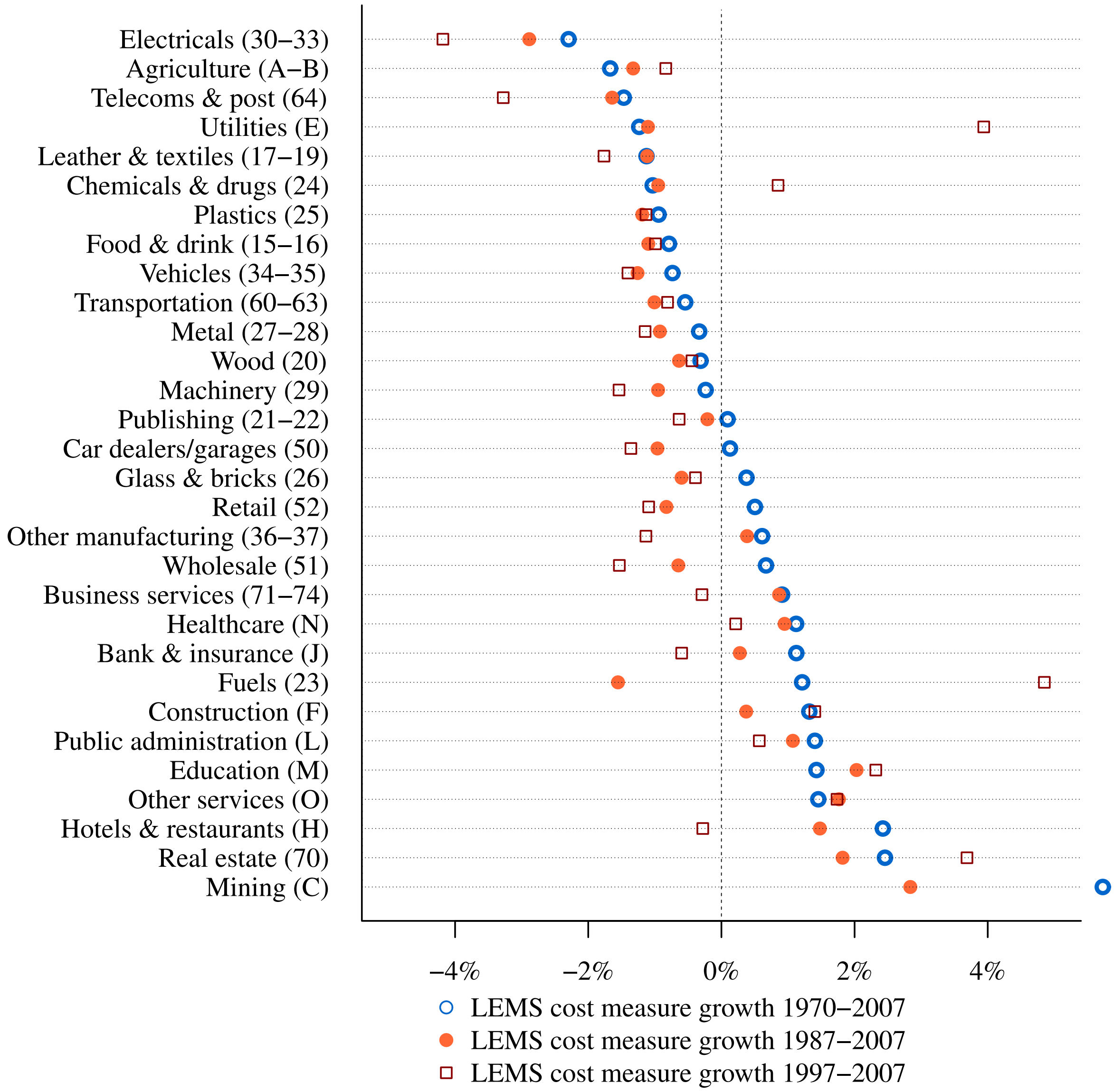
6.59 To get a better understanding of how the choice of time period affects the estimates, we have produced estimates for two additional time periods:

(a) The last twenty years of available data: 1987–2007.

(b) The last ten years of available data: 1997–2007.

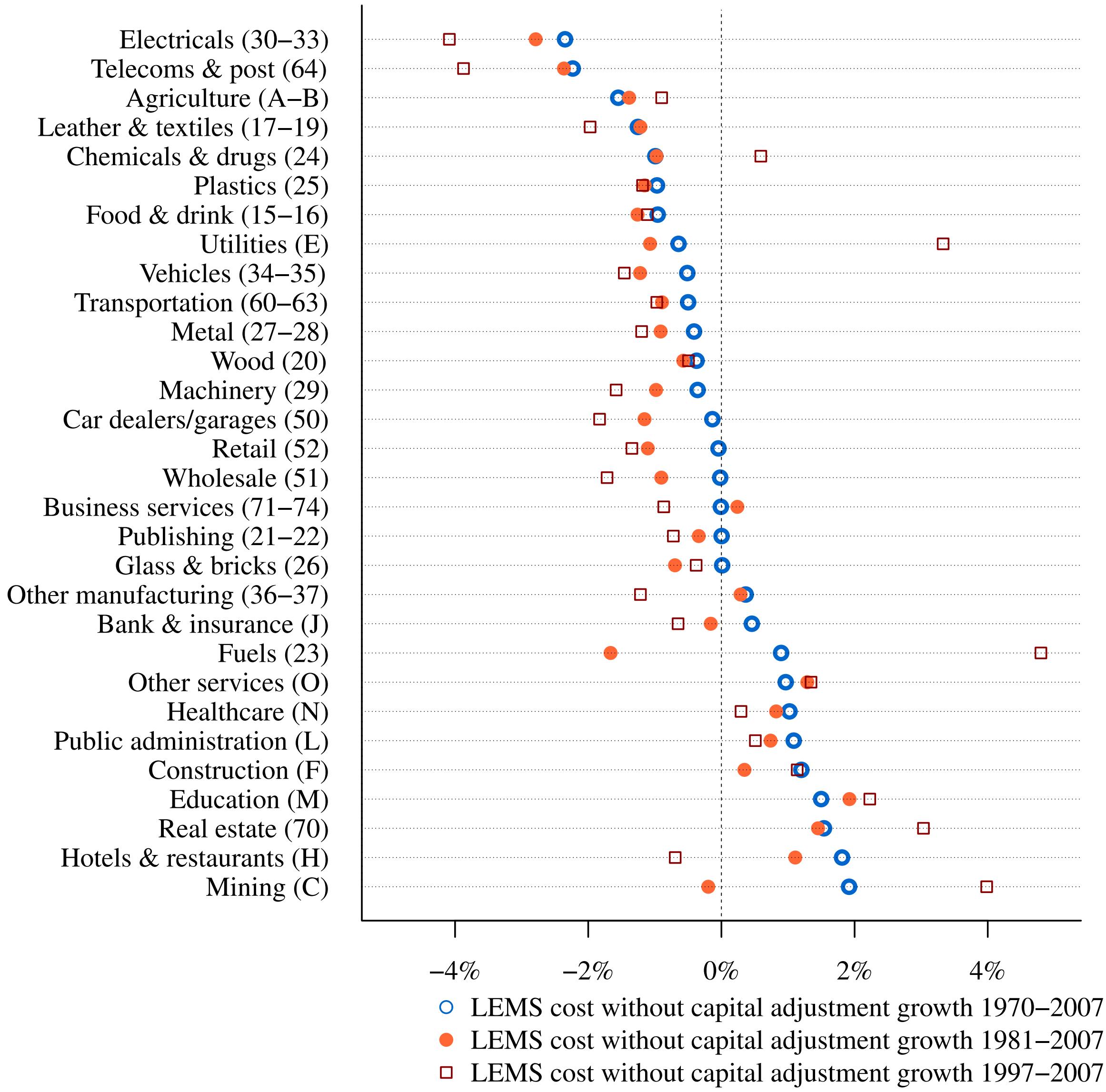
6.60 We present estimates for these time periods in a series of charts below, together with estimates calculated over the period 1970 to 2007 to show the scale of difference. A full set of estimates is provided in the appendix.

Figure 19 Average annual growth in LEMS cost measure (relative to RPI) over alternative time periods



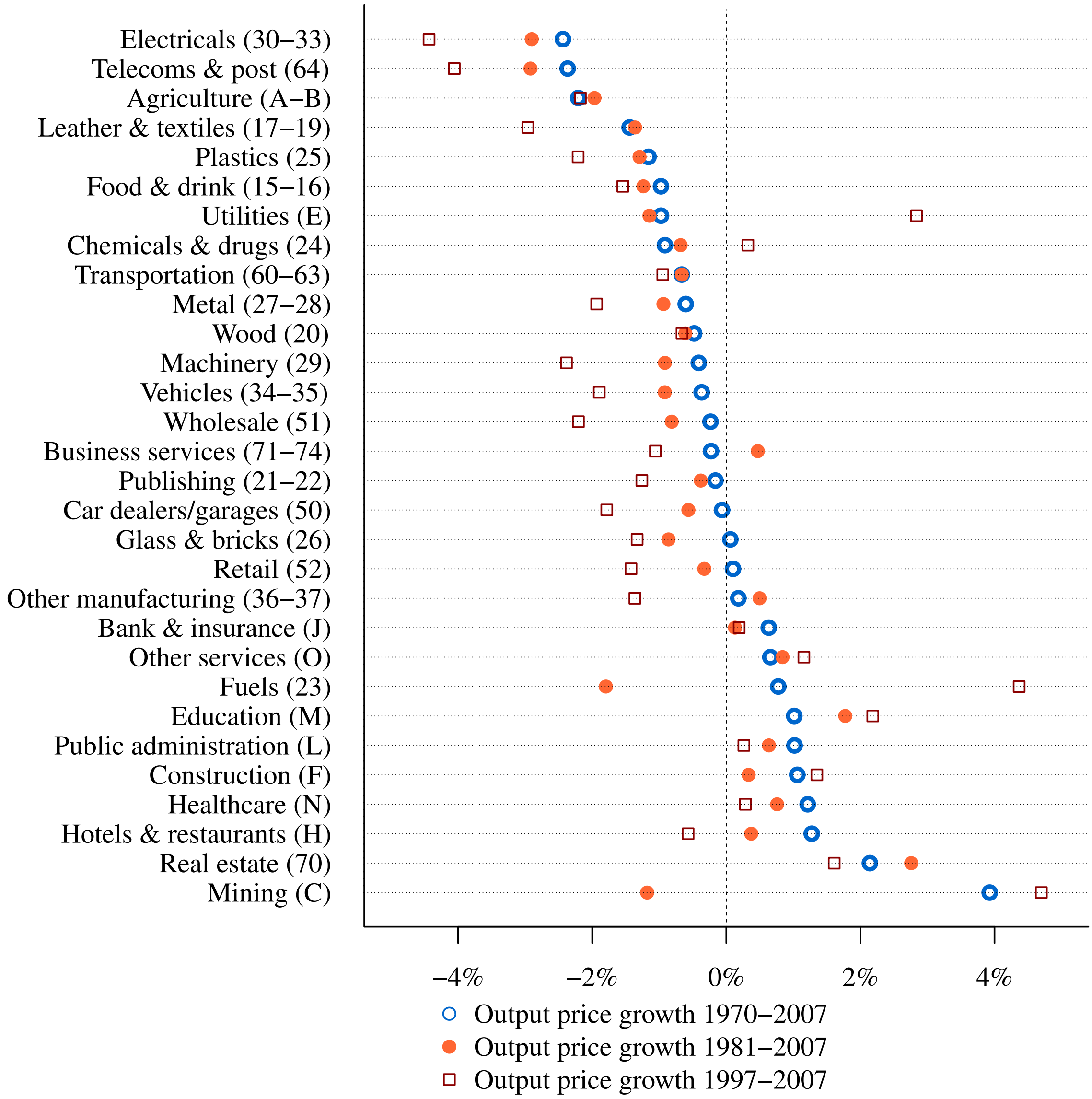
6.61 The average annual growth in the LEMS cost measure over the last ten years appears lower for the majority of sectors, in some cases by as much as one percentage point. Across the 30 sectors of the UK economy that we cover, the median value for the average annual growth rate for the LEMS cost measure is –0.6 over the period 1997 to 2007 compared to 0.3 over the period 1970 to 2007.

Figure 20 Average annual growth in the LEMS cost measure without capital adjustment (relative to RPI) over alternative time periods



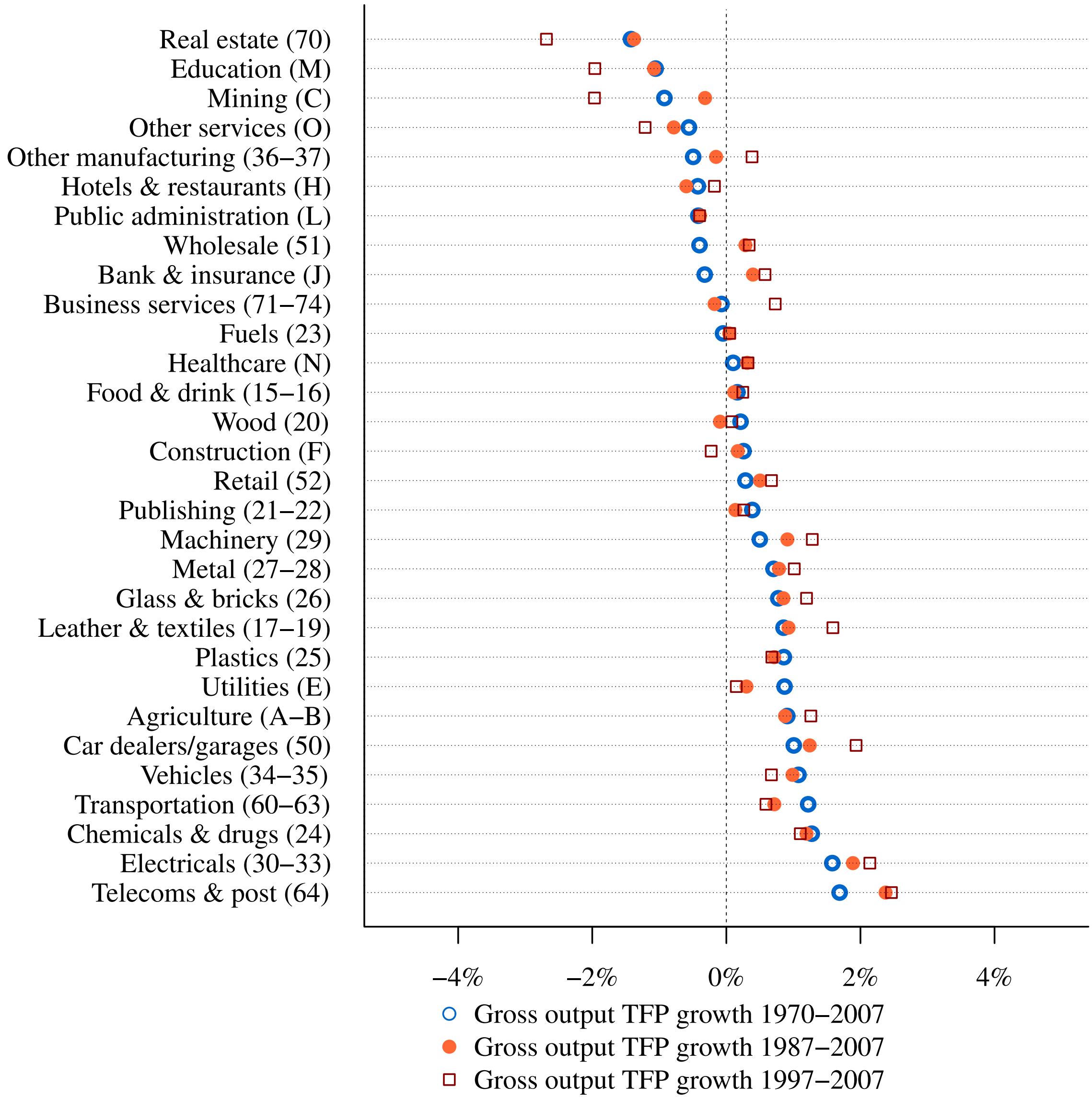
6.62 As with the adjusted LEMS cost measure, the logarithmic average annual growth rate for the unadjusted LEMS cost measure appears lower for the more recent period.

Figure 21 Average annual output price growth (relative to RPI) over alternative time periods



6.63 As shown in figure 22, the choice of time period seems to have less effect in the case of gross output TFP, than for output prices and LEMS cost measures.

Figure 22 Average annual growth in gross output TFP over alternative time periods



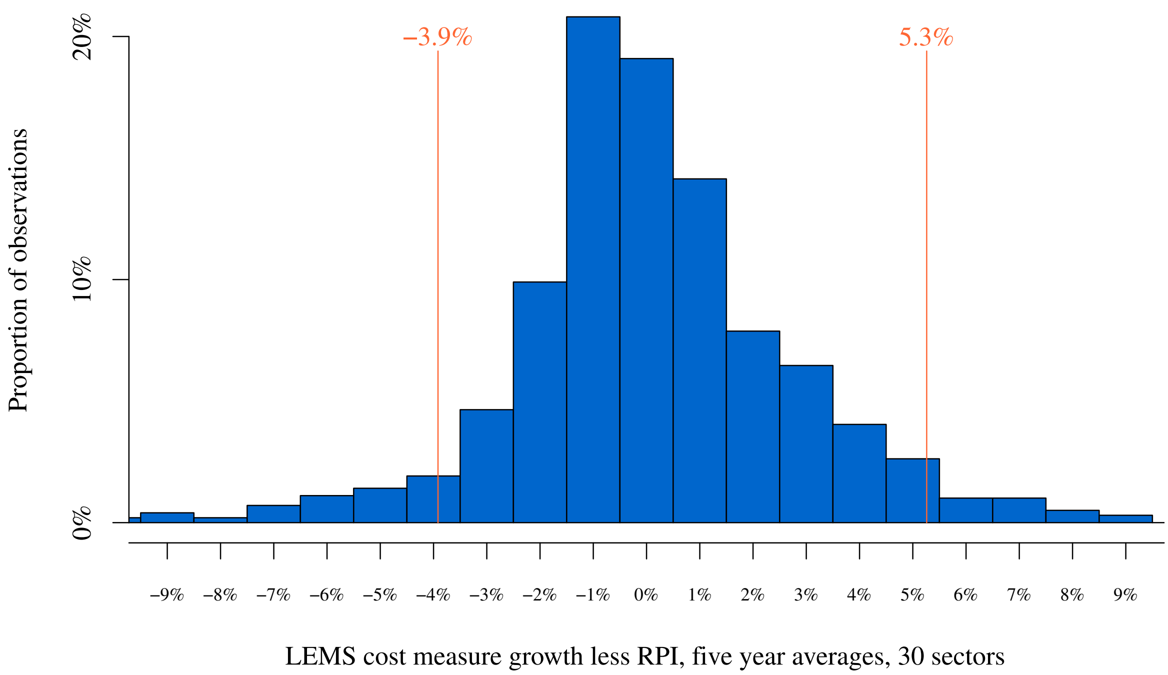
Analysis of average growth rates over consecutive five-year periods

6.64 For the analysis above we have reported estimates separately for 30 different sectors of the UK economy. This enabled us to plot the estimates for each sector next to each other and also to see how the choice of time period impacts on the result for each sector. We have also examined the average growth rates over shorter periods of time, looking across all sectors taken together.

6.65 We have calculated rolling five-year averages for each sector, starting with the first five years, then the second to the sixth year, right up until the last five years of the data period. We can use a histogram to show the incidence and variation of the growth rates over the five-year periods.

6.66 The histogram in figure 23 shows the frequency distribution of the 1,020 observations corresponding to each combination of a sector (there are 30 sectors) and a period of five consecutive years (there are 34 such periods between 1970 and 2007). For each observation, the annual average growth in the LEMS cost measure less RPI is calculated, and is placed in the "band" corresponding to the nearest integer percentage value. The height of each bar on the histogram is proportional to the proportion of the observations in the relevant band.

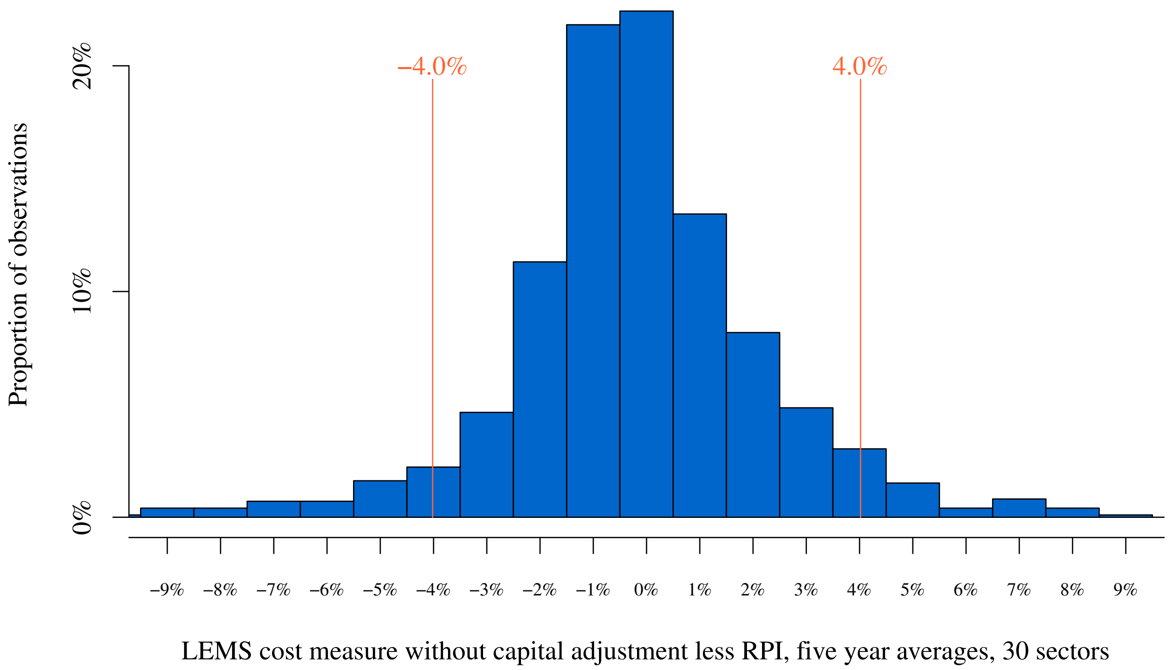
Figure 23 Distribution of annual growth rates for LEMS cost measure relative to RPI (five-year averages, all sectors)



6.67 The mean of the five-year averages is 0.3 per cent and the median is –0.1 per cent. The vertical lines in the histogram enclose 90 per cent of the observations. This means that, in 90 per cent of cases for which we have data, the average growth rate of the LEMS cost measure relative to the RPI, over a consecutive five-year period, was between –3.9 per cent and 5.3 per cent.

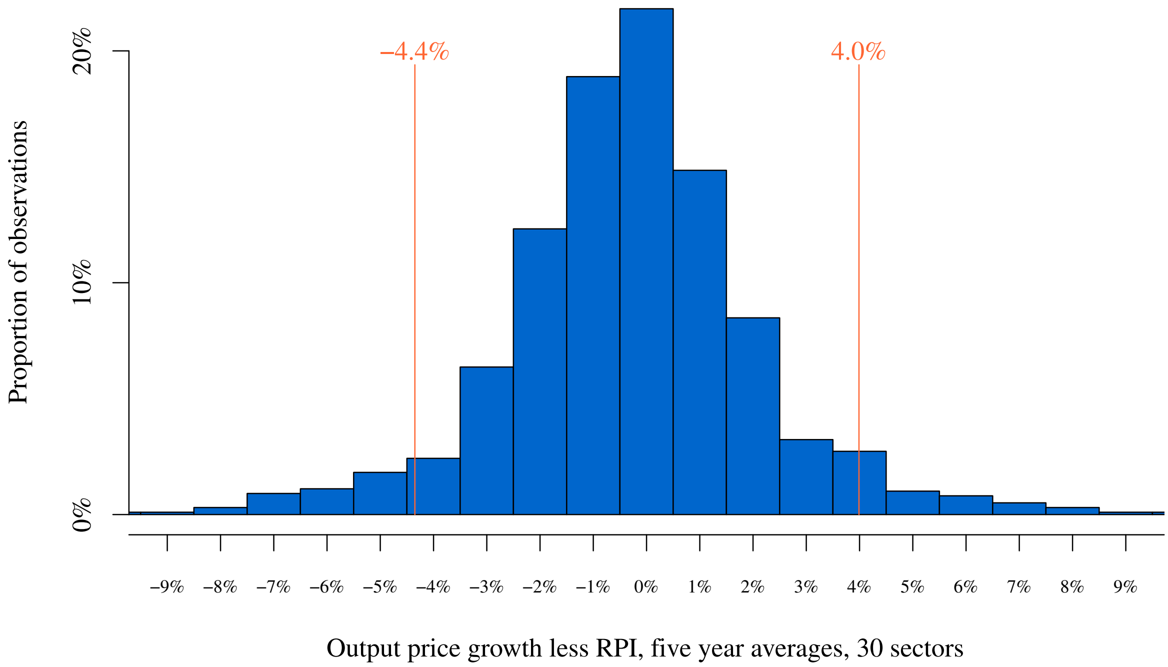
6.68 We provide below similar histograms for the unadjusted LEMS cost measure, for output price indices and for gross output TFP.

Figure 24 Distribution of annual growth rates for LEMS cost measure unadjusted for constant capital relative to RPI (five-year averages, all sectors)



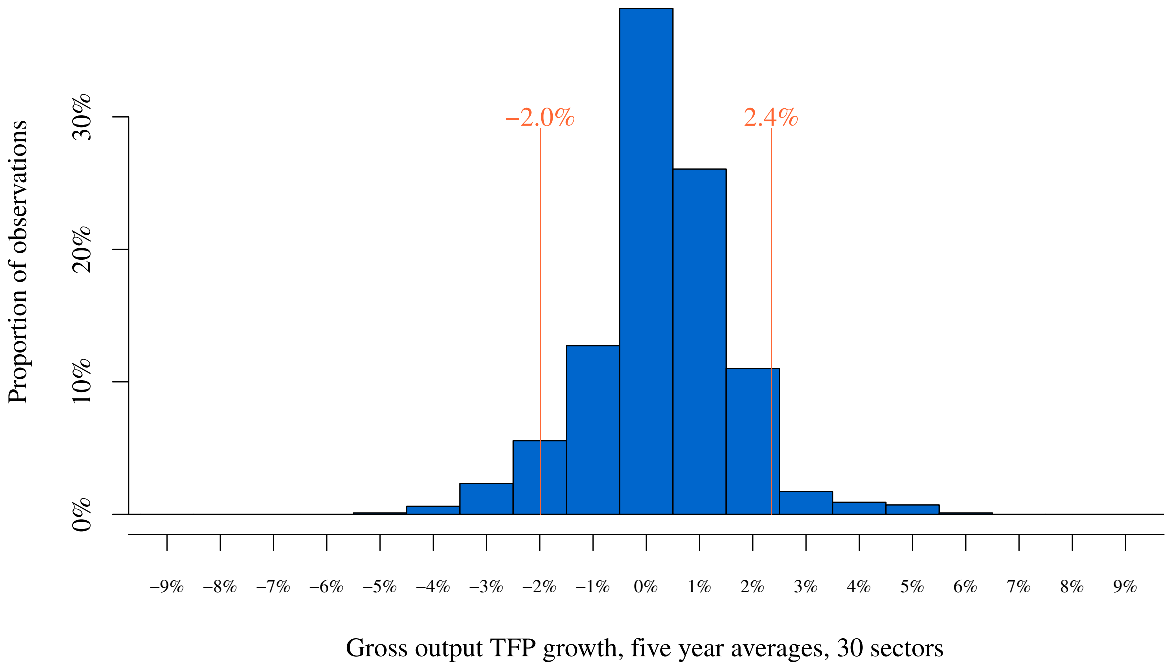
6.69 The mean of the five-year averages is –0.1 per cent and the median is –0.3 per cent. In 90 per cent of cases for which we have data, the average growth rate of the unadjusted LEMS cost measure over a five-year period was between –4.0 per cent and 4.0 per cent.

Figure 25 Distribution of annual growth rates for output prices relative to RPI (five-year averages, all sectors)



6.70 The mean of the five-year averages is –0.1 per cent and the median is –0.3 per cent. In 90 per cent of cases for which we have data, the average growth rate of the output price index over a five-year period was between –4.4 per cent and 4.0 per cent.

Figure 26 Distribution of annual growth rates for gross output TFP (five-year averages, all sectors)



6.71 The mean of the five-year averages is 0.3 per cent and the median is 0.3 per cent. In 90 per cent of cases for which we have data, the average growth rate of gross output TFP over a five-year period was between –2.0 per cent and 2.4 per cent.

7 Construction price indices

7.1 Changes over time in a price index should reflect the combined effects of the productivity growth achieved by companies who produce goods and services that feature in that index and changes in wages and other input prices experienced by those companies.

7.2 The previous section included estimates of changes over time in output price indices for different sectors of the UK economy, including the construction sector, based on the EU KLEMS dataset.

7.3 The construction sector seems particularly relevant to Network Rail's activities, especially to renewals and enhancements and potentially also maintenance. In addition to the data on the construction sector from the EU KLEMS dataset, we have examined data on construction prices from the Department for Business, Innovation and Skills (BIS) Construction Price and Cost Indices published by the Building Cost Information Service (BCIS).

7.4 The BIS construction price data are available for a number of different categories of construction. Output price indices are available for the aggregated category "all new construction works" as well for six categories within this: public housing, private housing, public works, private commercial, private industrial and infrastructure.

7.5 In addition to the data on new construction works, BIS indices are available for:

(a) Deflators for repairs and maintenance. These are based on the costs of materials and labour.

(b) Price indices for public works, which measure the movement in prices for public sector building contracts. In addition to the aggregated category of "all public works", indices are available for the categories of roads, non-roads, buildings and civil engineering.

7.6 Table 34 shows the average annual growth (in logarithms) of some of the more relevant indices available. Some of the series were redefined in 2010 and we provide growth rates for both the new and old series. The new series are indicated by "2010" in their description. We use the full period of available data, which differs between the new and old series. The data available from BCIS for the second and third quarters of 2010 was provisional data.

Table 34 Average logarithmic annual growth in selected construction price indices

Index	Period	Average logarithmic annual growth (%)
BIS Output Price Index for Repair and Maintenance (2010): All Repair and Maintenance	1995Q1 to 2010Q3	1.0
IS Output Deflators for Contractors: Repairs and Maintenance	1990Q1 to 2009Q4	0.3
BIS Output Price Index for New Construction (2010): All New Construction	1995Q1 to 2010Q3	0.1
BIS Output Price Index for New Construction: All New Construction	1990Q1 to 2009Q4	–0.3
BIS Output Price Index for New Construction (2010): Infrastructure	1995Q1 to 2010Q3	0.0
BIS Output Price Index for New Construction: Infrastructure	1990Q1 to 2009Q4	–0.4
BIS Output Price Index for Public Works: Civil Engineering	1990Q1 to 2009Q4	–0.4

7.7 The construction price indices tend to fluctuate substantially over time. Figures 27 and 28 show the evolution of the price indices for "all new construction" and "infrastructure" respectively. Both figures present both the new and old indices rebased to 1995.

Figure 27 BIS Output Price Index for New Construction: All New Construction

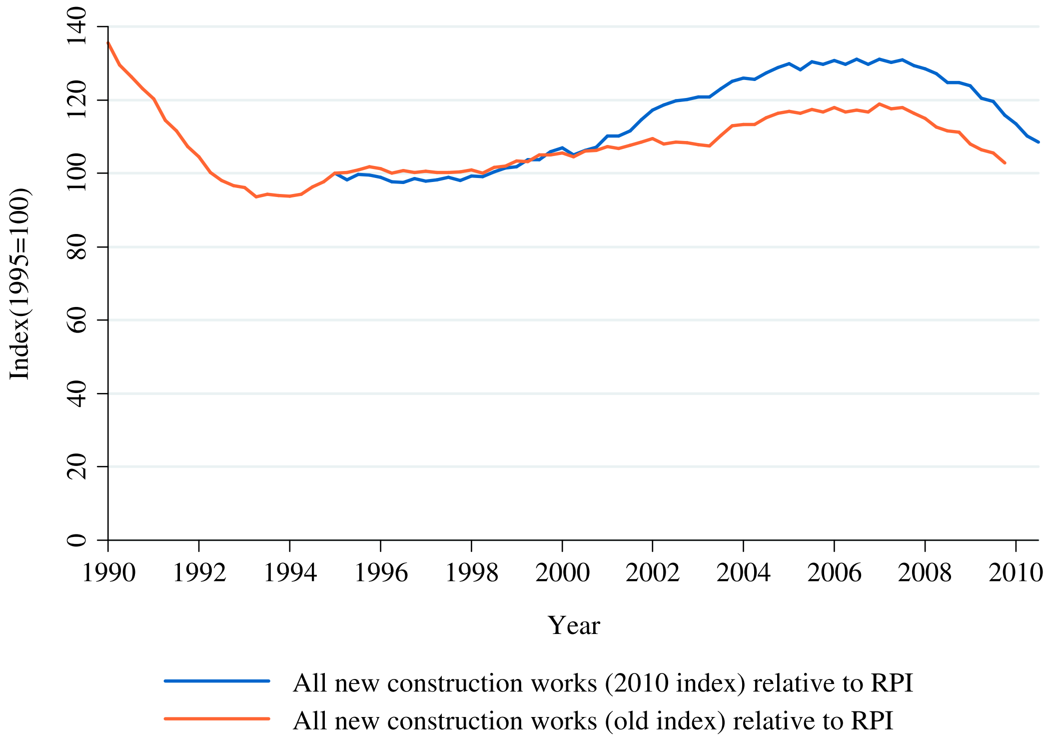
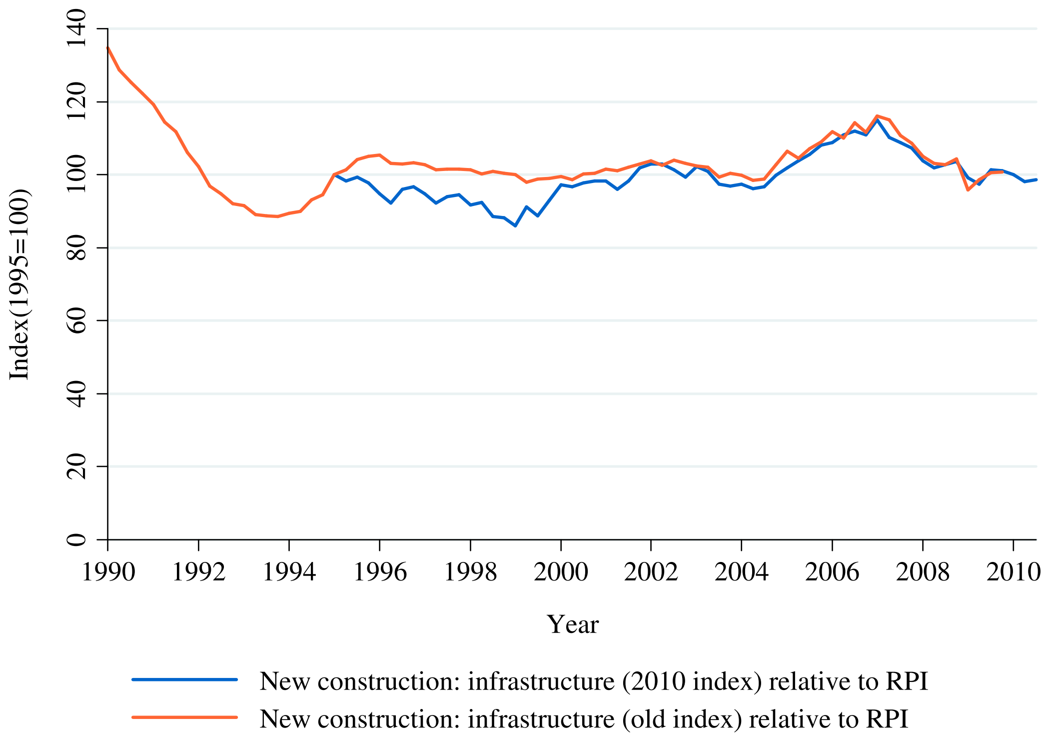


Figure 28 BIS Output Price Index for New Construction: Infrastructure



8 Regulatory precedent and other literature

8.1 Table 35 provides a summary of the some recent UK regulatory decisions insofar as these concern assumptions or forecasts about future productivity growth or efficiency improvements by regulated companies. A negative number in the table indicates an assumption of costs falling relative to relevant inflation index (e.g. RPI). The assumptions made by different regulators are not perfectly comparable and the table below should not be read in isolation from the more detailed information that follows.

Table 35 Summary of recent regulatory precedent

Regulator	Review	Efficiency or productivity assumption (%)	Comment
PPP Arbiter	Tube lines Periodic Review (1 July 2010 to 30 December 2017)	Frontier-shift: –1 per cent per annum	Operating expenditure trend allowed relative to RPI. Additional adjustment made for input price inflation over RPI and risk.
Ofwat	Price Review 2009 - England and Wales: water and sewerage (2010-2015)	Ongoing efficiency: Base opex: –0.25 Enhancement opex: –0.375 Capex: –0.4 Catch-up range (opex): 0 to –2.9 (water) 0 to –2.2 (sewerage)	Allowed expenditure trends relative to the RPI. Ongoing efficiency includes productivity improvements and input price inflation. Capex trend taken for allowed expenditure added to the RAV.
The Utility Regulator	Northern Ireland water (2010–2013)	Base opex: –0.25 PPP: –0.125 Capex: –0.4	Allowed trend relative to RPI. Capex trend taken for allowed expenditure added to the RAV. Additional catch-up trend also applied to opex and capex.
	Northern Ireland: electricity transmission and distribution (2007–2012)	N/A	A rolling mechanism is used for operating costs, with allowable operating costs set at the level of actual spend five years ago, indexed to the RPI. Whilst this requires no efficiency projection, two reductions in expenditure are made for the first two years to cover efficiency improvements.

Regulator	Review	Efficiency or productivity assumption (%)	Comment
Ofgem	Distribution Price Control Review 5: Electricity distribution (2010 – 2015)	Opex and network investment: –1 Real price effects: Opex: 1.4 Network investment: 1.1	Ongoing efficiency and real price effects combine to give allowed expenditure trend relative to the RPI
Postcomm	Royal Mail's price control (2006–2010, extended to 2011)	Operating expenditure: –3	Operating expenditure relative to RPI.
CAA	NATS (En Route) plc CP3 Price Control Review (2011-2014)	–1.25	Allowed operating expenditure relative to RPI.

8.2 We now provide further information on some of the decisions identified in the table above. The discussion is intended to highlight the general approach adopted in specific regulatory decisions and does not attempt to cover all details of efficiency assessment at each review.

PPP Arbiter (2009) Tube lines Periodic review for infrastructure service charge (2010 – 2017)

8.3 The Public-Private Partnership (PPP) Agreement governed the relationship between London Underground, who run the underground rail network, and private firms which maintained the infrastructure of the underground rail network and charged an infrastructure service charge to London Underground for this service. When an agreement could not be reached between the parties for the next contract period, a reference was made to the PPP Arbiter who then decided on the level of the charge.

8.4 Such a reference was made in 2009 when negotiations between London Underground and Tube Lines led to one party referring the matter to the Arbiter.

8.5 In determining the relevant level of costs for the company's cash-flow, the arbiter focused on a notional infrastructure company. This notional infrastructure company would run the same services, have the same contractual obligations and third-party contracts as the actual infrastructure company, but would be run in an overall efficient and economic manner.

8.6 The notional infrastructure company's base cost level was determined for the next contract period. This covered operating and capital costs. An adjustment for efficiency gains, differential inflation and allowances for risk was made to the base cost level.

8.7 The notional infrastructure company was assumed to have achieved all catch-up efficiency in the previous period and therefore no allowance was made for any catch-up efficiency gains. Therefore, the efficiency factor concerned the rate of frontier-shift possible.

8.8 The Arbiter set the frontier-shift at 1 per cent per year. This was based upon judgements by economic advisers, composite total factor productivity estimates from industries performing similar activities and a survey of recent regulatory precedent.

8.9 Frontier-shift was not applied to all base costs. This 'blanket' approach was avoided due to the nature of contracting that existed for the infrastructure company, preventing frontier-shift efficiency improvements in certain elements of cost. Instead, frontier-shift was only applied to certain parts of the base costs, with the appropriate proportion of costs to within each cost category being estimated and then applied as such.

8.10 In addition to the allowance for frontier-shift efficiency improvement, an allowance was made for the impact of input price inflation. The infrastructure service charge was indexed to RPIX inflation, which is the RPI index excluding mortgage payments. The input price allowance was made with respect to the degree that the price of the notional infrastructure company's inputs grew at a different rate to RPIX. Differential inflation considered the projected evolution of indices which reflected the price movements of inputs for the infrastructure company compared to projected RPIX.

8.11 Table 36 provides the allowances given in the PPP Arbiter's directions on costs and related matters (PPP Arbiter, 2010, page 55).

Table 36 Differential inflation assumptions from the PPP Arbiter

Cost element	Differential to RPIX (per cent per year)
Labour-general	1.3
Labour-specialist	1.9
Materials-iron and steel	–0.3
Materials-general	0.9
Equipment-signalling	–0.6
Equipment-general	–0.2
Rent and rates	3.0

8.12 This approach to setting an allowance for input price inflation is similar to that used by Ofgem when setting real price effects for DPCR5.

8.13 In addition to this adjustment, an allowance of £128 million was made for the risk that differential inflation differed from forecast.

8.14 These directions were made under the context of a PPP agreement. Since then, the role of the arbiter has become defunct due to the takeover of Tube Lines by Transport for London, a government owned entity which also owns London Underground.

Ofgem (2009) Distribution price control review 5 (2010 – 2015)

8.15 In Distribution Price Control Review 5 (DPCR5), Ofgem's approach to efficiency was built upon establishing efficient baseline costs for each company based upon relative efficiency analysis and unit cost comparisons, combined with an ongoing productivity element for all companies and adjustments for real price effects that allow for increases in input prices above RPI. Capital costs and operating costs were treated separately.

8.16 For capital costs, the baseline expenditure analysis for each company considered the relative unit costs for different categories of capital expenditure as well as the impact of volume growth. For operating costs, networks were benchmarked against each other and this fed into the assessment for the efficiency baseline, although some categories of operating costs relied upon expert opinion rather than benchmarking to set the baseline.

8.17 These baselines, which were company-specific, were then combined with an ongoing efficiency projection and an adjustment for real price effects.

8.18 The ongoing efficiency projection reflected evidence on productivity growth in comparator sectors and related to the expectation that operators will be able to constrain the increase in expenditure required in the face of increased network investment. The evidence included calculations of LEMS productivity growth and cost measures similar to those provided in section 6 of this report. Evidence from the distribution network operators and their consultants were also taken into account when setting the productivity projection.

8.19 The ongoing efficiency projection set in DPCR5 was similar in nature to the frontier-shift assumption set by the PPP Arbiter for frontier-shift in that it reflected expected productivity gains. This can be contrasted with the approach taken by ORR at PR08. ORR's figures for frontier-shift concerned productivity outperformance compared with the UK economy rather than simply the expected productivity improvement.

8.20 Ofgem's approach for real price effects was similar to that used by other regulators in setting input price inflation adjustments. The information that Ofgem drew on was largely based on historical trends for different categories of expenditure with some adjustments for short term forecasts.

Ofwat (2009) Periodic review of water and sewerage charges (2010 – 2015)

8.21 Ofwat sets limits on the prices charged by water and sewerage companies in England and Wales. The most recent decision was at the 2009 Periodic Review (PR09), which set price limits for the period 2010 – 2015.

8.22 Under Ofwat's approach, each company's efficiency projection comprised a catch-up element for that company that reflected its relative efficiency and an element to capture "continuing efficiencies" that leading or frontier companies would be expected to achieve.

8.23 The catch-up element set the extent to which each company could be considered inefficient compared to its peers and therefore able to reduce expenditure through a process of catch-up. Each company was placed into a relative efficiency band reflecting the efficiency relative to the leading company. The bands were calculated using econometric analysis and unit cost comparisons.

8.24 For base operating expenditure, Ofwat assumed that inefficient companies would close 60 per cent of the efficiency gap with the leading (or frontier) company/ companies by the end of the regulatory period. This contrasts with the immediate catch-up to the benchmarks used in DPCR5 by Ofgem. Catch-up factors for enhancement operating expenditure were assumed to be one and a half times those of base operating expenditure. The catch-up factors were based on Ofwat's 2008/2009 assessment of each company's relative efficiency.

8.25 For PR09, the catch-up factors ranged between 0 to 2.9 per cent per year for water, and 0 to 2.2 per cent per year for sewerage.

8.26 The efficiency projections for capital expenditure were calculated in a similar way to those for operating expenditure, although the company specific relative efficiency element was calculated with reference to the middle ranking company rather than the frontier company.

8.27 For base operating expenditure, Ofwat set continued efficiency improvement for all companies at 0.25 per cent per year. Enhancement operating expenditure was given a higher reduction projection of 0.375 per cent. The initial estimates were adjusted downwards to prevent double counting and account for uncertainty.

8.28 The continuing efficiency projections used by Ofwat can be thought of as similar to the combination of productivity improvement and input price inflation assumptions used by other regulators, such as Ofgem in DPCR5. However, there are important differences in the approach, including in the way that catch-up assumptions are combined with other elements.

Competition Commission (2010) Determination of Bristol Water's charges (2010–2015)

8.29 At the 2009 periodic review, Bristol Water asked that its determination be referred to the Competition Commission. As part of its decision, the Competition Commission conducted its own analysis into the scope for continuing efficiency. The approach used was similar to that taken by Ofgem at DCPR5, but not identical.

8.30 The Competition Commission's approach differed slightly from that used by Ofwat, although the final results were the same. The Competition Commission looked at a number of different sources, such as total factor productivity growth estimates from EU KLEMS data and some adjustments for capital substitution. The Competition Commission's report does not disclose whether the total factor productivity estimates used were on a value added or gross output basis. The productivity challenge was set at 0.9 per cent per year.

8.31 The Competition Commission then separately estimated input price effects, or real price effects, using a notional bottom-up input price inflation analysis. The Competition Commission separately forecast RPI for each year of the price control and compared this to forecasts of nominal input price growth for different elements of Bristol Water's input prices: labour; equipment; chemicals; rates; bad debt; Environment-Agency charges; and "other".

8.32 The overall real price effect estimated was 0.4 per cent per year. Combining this with the productivity challenge gave a continuing efficiency projection of 0.5 per cent per year. This estimate was then lowered to 0.25 per cent per year to reflect uncertainties and the risk of double counting, providing the same number as Ofwat.

8.33 The Competition Commission agreed with Ofwat's projection of 0.4 per cent per year reductions for unit capital costs, in particular highlighting the view that the gap between private sector wages and the RPI will narrow over the PR09 period, allowing for a reduction in capital expenditure.

8.34 With respect to the indexing of forecast capital costs, the Competition Commission assumed an increase in COPI of RPI plus 0.75 for PR09.

The Utility Regulator (2010) Northern Ireland Water's water and sewerage price control (2010 – 2013)

8.35 The approach used to set prices for Northern Ireland Water (NIW) at its last price control was similar in nature to Ofwat's approach for the 2009 periodic review. As with Ofwat, the efficiency projection was estimated by combining two factors; a catch-up element and a continuing efficiency element.

8.36 The continuing efficiency element comprised of productivity gains and input price inflation, and the catch-up element identified the relative efficiency of NIW compared to water companies in England and Wales.

8.37 In line with Ofwat's approach, the continuing efficiency element for base operating expenditure was set at 0.25 per cent per year; for capital expenditure the continuing efficiency element was set at 0.4 per cent per year. In addition, a continuing efficiency challenge of 0.125 per cent per annum was applied to the operating expenditure element of the Public Private Partnership unitary charges accounted for within operating expenditure.

8.38 This was then combined with a catch-up element. For capital costs, the catch-up element was derived using the upper quartile of England and Wales companies' unit costs and an assumption that 75 per cent of the gap can be closed over one year.

8.39 In addition to the efficiency projections, specific allowances were also given for certain areas of input prices. For example, additional allowances are given for Voluntary Early Retirement and Voluntary Severance costs.

Water Industry Commission for Scotland (2009) Strategic review of Scottish Water's charges (2010 – 2015)

8.40 Scottish Water is the main water company operating in Scotland. The approach used to set its prices in the last price control period was not too dissimilar to the approaches used by the other water regulators within the UK. However, the Water Industry Commission for Scotland (WICS) differed on certain elements of efficiency, notably the approach to operating expenditure.

8.41 Operating expenditure efficiency projections were set by reference to concepts relating to relative efficiency and continuing efficiency.

8.42 An analysis of the relative efficiency of Scottish Water compared to the England and Wales companies set the challenge of achieving the upper quartile of 2007/2008 levels of operating efficiency and levels of service of England and Wales companies by 2013/2014. An increase in operating expenditure was allowed for the beginning of the regulatory period to fund this, with the allowance decreasing in the future.

8.43 WICS did not conduct a similar analysis to Ofwat or the Utility Regulator on continuing efficiency. Instead, the allowance for operating costs was based largely on the historical performance of companies in the water industry, with particular attention given to the performance of companies in England and Wales. From this evidence, it is suggested that water and sewerage companies were able to deliver broadly constant real operating expenditure in the past, i.e. in line with RPI. This would imply at future productivity gains and input price inflation will cancel each other out relative to the RPI.

8.44 Efficiency projections for capital maintenance and enhancement expenditure were set using a similar approach to that used by Ofwat, utilising a cost base at the programme level for expenditure. A series of standard costs for Scottish Water were benchmarked against the England and Wales companies and a projection of upper quartile efficiency was set.

8.45 The overall efficiency challenge in the final determination was a reduction in 14.5 per cent in allowed investment for the price control, which reflected expected efficiency improvements as well as general reductions in the projected cost levels. This was applied to the total level of enhancement expenditure which was built up from a consideration of the cost of a number of projects that together form the investment programme for Scottish Water.

The Utility Regulator (2006) Northern Ireland electricity transmission and distribution price control (2007 – 2012)

8.46 The approach used by the Utility Regulator to set the price control for Northern Ireland electricity transmission and distribution is different from the others discussed above.

8.47 Rather than using the building blocks approach used by other UK regulators, a rolling mechanism was used to set the level of allowed controllable operating expenditure (opex). Allowed controlled operating expenditure for each year was set to actual controllable operating expenditure in the corresponding year of the previous price control period (RP3) five years ago, updated in line with the RPI. This approach removes the requirement to make specific forecasts on the evolution of expenditure by the companies, and therefore avoids the need to estimate the efficiency projections set by other regulators. Two adjustments were made to the starting level of allowed operating expenditure in order to bring it in line with the Utility Regulator's view of efficient costs.

8.48 The rolling mechanism presents an automatic pass-through of the savings in controllable operating expenditure achieved by Northern Ireland Electricity Transmission and Distribution to customers, albeit after five years.

8.49 Capital expenditure allowances were set after cross-examining the projected costs of investment plans. The final projected costs included an expectation that the company could reduce its investment costs by 10 per cent over the period, relating to 6 per cent efficiency gains and a 4 per cent reduction in volume.

Civil Aviation Authority (2010) Price control for air traffic control (2011 – 2014)

8.50 NATS (En route) plc (NERL) is the operator of air traffic control services in the UK. The approach to setting the prices it charges to airlines has several elements in common with the approach of other regulators in the UK, although there are also some noticeable differences.

8.51 The approach to setting the allowance for operating expenditure at the last review looked at a number of different areas of efficiency such as relative efficiency and productivity improvement, as well as several other issues. The Civil Aviation Authority (CAA) conducted a number of benchmarking analyses for areas of NERL's costs as well as a study into labour productivity. These studies fed into determining the efficiency factor for NERL. The final allowance for operating expenditure allowance was set using the following approach:

(a) an efficiency factor is applied to 2009/2010 actual costs;

(b) an allowance for traffic growth is made;

(c) adjustments for redundancy, relocation and cost of services are made;

(d) an allowance for bad debt is made; and

(e) an adjustment for the level of contingency is made.

8.52 The CAA set the efficiency factor at 1.25 per cent per annum, based upon the studies conducted by the CAA and the points raised by NERL in relation to the ability to reduce operating costs. Pension costs were given a pass through status with the provision that they were reasonably incurred. This is to be assessed at the next price control (CP4).

8.53 The CAA adopted the projections of capital expenditure that were set out in NERL's formal proposals.

Postcomm price control decisions for Royal Mail (2006 – 2012)

8.54 The last full price control for Royal Mail ran from 1 April 2006 to 31 March 2010. Since then, two separate one year rollovers of this price control have been in place.

8.55 In the first price control, Postcomm set the maximum price rise of Royal Mail products for the four year period from April 2006. In setting the allowed operating expenditure an efficiency factor of 3 per cent per year in real and constant volume terms was applied. This was based upon the following:

(a) an assessment of Royal Mail's allowable costs in the base year, 2003/2004;

(b) a forecast of costs using volume forecasts and assuming no efficiency gains;

(c) a statistical internal benchmarking analysis; and

(d) a top down benchmarking analysis using Royal Mail's past efficiency trends, as well as those of other postal networks and other regulated industries.

8.56 The 3 per cent number was accompanied with a significant allowance for capital expenditure and a number of adjustments for different areas of expenditure, such as funding the pension deficit.

8.57 The first one year extension to the price control rolled the control over until March 2011. The efficiency projection for this extension remained at 3 per cent but an adjustment was made to the treatment of inflation, setting it to zero in the face of the negative change in RPI.

8.58 The second one year rollover of Royal Mail's price control will apply from 1 April 2011 to 31 March 2012. Royal Mail has been allowed additional revenues of £100m in order to fund modernisation and accelerate cost reductions in the medium term. These extra revenues will be allowed through an increase in the rate at which prices can increase relative to RPI.

Other literature

8.59 In addition to the review of regulatory precedent provided above, we have also conducted a brief review of some recent consultancy reports or studies that concern frontier-shift efficiency. We summarise below a couple of documents that highlight some of the more recent thinking in this field. The first is a paper by First Economics from 2010 which briefly traces some of the history of regulators' decisions and methods and then provides a recommended approach. The second is a Reckon report for Ofwat from 2008, which adopted a different approach to that recommended by First Economics.

First Economics (2010) Frontier-shift: An Update

8.60 In this paper, First Economics provides an update on their views on frontier-shift efficiency assumptions used by economic regulators to set price controls. It provides an overview of the frontier-shift estimates used by regulators within the UK and highlights how, on the whole, the estimates used have changed from expecting frontier-shift efficiency less than the RPI prior to 2007 to more in line and sometimes above RPI for decisions in 2008 and 2009.

8.61 According to First Economics (2010, page 4), the approach that most regulators are now using to set frontier-shift efficiency involves the following formula:

> Frontier-shift (relative to RPI) = input price inflation – productivity improvement – forecast RPI – measured inflation

8.62 According to First Economics (2010, page 15), this compares to a previous approach which used the following formula:

> Frontier-shift (relative to RPI) = relative input price inflation – productivity outperformance

8.63 The second formula was based upon the premise that the RPI reflects the combined effects of average input price inflation and average productivity improvement in the UK economy. Under this assumption the two formulae produce the same estimate of frontier-shift. However, First Economics points out that the RPI actually measures the change in the price of goods consumed by UK households, some of which are not produced within the UK economy. This means that the RPI benchmark and the UK economy are likely to have a different composition and therefore the two formulae above are unlikely to be equivalent.

8.64 The approach recommended by First Economics is to combine three different factors when estimating frontier-shift:

(a) Expected productivity growth.

(b) Expected input price inflation (in nominal terms)

(c) Expected RPI.

8.65 At PR08, ORR's approach to frontier-shift resembled that seen in the second equation above rather than the first. Value added TFP benchmarks were constructed for each expenditure category and then taken away from total economy TFP after removing catch-up effects and adjusting for capital substitution for operating expenditure.

Reckon (2008) PR09 Scope for efficiency studies

8.66 As part of its periodic review of price limits for regulated water and sewerage companies in England and Wales, to be effective for five years from April 2010, Ofwat commissioned Reckon to carry out a study in relation to what Ofwat calls the "scope for efficiency improvements" by regulated water and sewerage companies.

8.67 We provided separate analyses for operating expenditure and for unit capital expenditure. For operating expenditure, we focused on changes over time in operating expenditure for a notional industry that produces a constant output using constant capital inputs. We did not consider changes in the future operating expenditure requirements of water and sewerage companies that may arise from growth in the number of customers or from increases in quality standards.

8.68 The operating expenditure analysis involved the following elements:

(a) We examined historical changes in water and sewerage companies' operating expenditure, using data since 1992/1993. This included analysis at the level of aggregated operating expenditure and of individual components of operating expenditure. We placed emphasis on the data for base service operating expenditure for water and sewerage companies that we include in our RUOE analysis in section 4.

(b) We used the EU KLEMS dataset to examine data on expenditure in different categories of operating expenditure (e.g. labour and materials) for different industries within the UK. We calculated a measure which is similar to the LEMS cost measure described in section 6 (the difference relates to some data on taxes and subsidies that is not available in the latest version of the EU KLEMS dataset). We also calculated a labour cost measure which was based on a value added concept of output and which we do not consider in the present report.

8.69 We commented as follows on the historical expenditure data for water and sewerage companies (Reckon, 2008, page 4):

> "Between 1992/1993 and 2007/2008, base service operating expenditure in water and sewerage decreased relative to the RPI. The bulk of the cost reduction came in the years up to 2000/2001, as illustrated in the figure below. We have made our forecast of 0 per cent per year on the view that the cost reductions relative to the RPI in the 1990s were brought about by privatisation and the development of incentive regulation, and that there will not be corresponding opportunities in the period from 2010 to 2015."

8.70 For capital costs, we focused on changes over time in the expenditure required to carry out capital maintenance or capital enhancement projects. These cost changes represent the combined effects of productivity improvements and changes in input prices. We examined the "cost base" submissions that companies make to Ofwat; these submissions contain estimates, at different points in time, of the unit costs of specific capital projects. We also examined changes over time in published output price indices for the construction industry, using the same dataset for construction output prices as examined in section 7 above. We also employed an engineering firm to provide a bottom-up analysis of the sources of productivity improvements affecting water and sewerage capital expenditure.

8.71 We provided a reconciliation analysis of the results from the various methods and data sources. We analysed the potential vulnerabilities and limitations of each within the context of the study.

8.72 We were asked to provide forecasts for the period 2010 to 2015. For operating expenditure, we forecast a rate of growth of 0 per cent per year relative to the RPI, for both water and sewerage. This is under an assumption of no changes in the quantity and quality of outputs of the water and sewerage industries, and no changes in the amount and quality of capital.

8.73 We forecast a growth rate for both water and sewerage of –0.5 per cent per year relative to the RPI for changes in unit capital costs. These are the changes attributable to productivity growth and to changes in input prices relative to the RPI, excluding any changes attributable to changes in the nature, quantity or quality of the capital outputs delivered by the capital programme.

9 Appendix to analysis of EU KLEMS data

9.1 This appendix describes the calculations that we have used to derive the estimates and statistics presented in section 6, which are based on the EU KLEMS dataset. It then provides a full set of results for different measures, different sectors and different time periods as well as results from the OLS regressions described in section 6.

Use of logarithms in growth rates

9.2 Except where otherwise specified, we use natural logarithms for the measures of rates of change that we have calculated. For example, if a variable X changes from 105 to 110 then its logarithmic growth, gX, will be defined as ln(110/105) = 0.0465 — or 4.65 per cent.

9.3 This convention enables growth rates over a period to be calculated as a simple arithmetic average of the annual growth rates.

9.4 An advantage of using logarithmic growth rates is that if A = B * C, then the logarithmic growth rate in A can be calculated as the logarithmic growth rate in B plus the logarithmic growth rate in C. This feature may be useful if, for example, a growth rate in costs is to be calculated by combining a productivity growth assumption and an assumption on the growth in input prices, as discussed in section 3.

9.5 To convert a logarithmic growth rate into percentage increase from one period to the next, the conversion formula is:

[Percentage increase] = 100 * [exp(logarithmic growth) – 1]

9.6 For example, an logarithmic annual growth rate for a unit cost measure of 4.65 per cent implies an increase in unit costs of 4.76 per cent from one year to the next, which is calculated as:

4.76 = 100 * [exp(0.0465) – 1]

9.7 Further adjustments might be necessary to convert between logarithm measures of growth rates and any non-logarithmic measures relative to RPI used in price control calculations.

Data source

9.8 Our calculations were based on data for the United Kingdom from the November 2009 release of the EU KLEMS dataset, downloaded from http://www.euklems.net/ on 8 February 2011.

Output price growth

9.9 The EU KLEMS dataset includes a series (GO_P) of output price indices. Output price growth between year t–1 and year t is calculated as:

$$gGOP = \ln(GO\_P_t/GO\_P_{t-1})$$

Gross output measure of total factor productivity growth

9.10 The gross output measure of total factor productivity growth is defined as:

$$gTFPGO = gGOQ - K/GO*gKQ - L/GO*gLQ - II/GO*gIIQ$$

where

gTFPGO is the gross output measure of total factor productivity growth.

gKQ is the logarithmic growth in the quantity of services from capital used in the sector.

K/GO is the proportion of gross output value accounted for by services from capital.

gLQ is the logarithmic growth in the quantity of labour used in the sector.

L/GO is the proportion of gross output value accounted for by labour.

gIIQ is the logarithmic growth in the quantity of intermediate inputs used.

II/GO is the proportion of gross output value accounted for by intermediate inputs.

LEMS cost measure

9.11 The annual growth in the LEMS cost measure is defined as follows:

$$gLEMS = gGOP + ((gKQ + gGOP)*K/GO - dK/GO) / (1 - K/GO)$$

where

gLEMS is the logarithmic growth in LEMS costs in a sector gGOP is the logarithmic growth in a gross output price index for the sector.

gKQ is the logarithmic growth in the quantity of services from capital used in the sector.

K/GO is the proportion of gross output value accounted for by services from capital. (We used the midpoint of the ratios in the two years.)

dK/GO is the year-on-year change in value of services from capital, expressed as a proportion of the value of gross output. (We used the midpoint of the gross output value in the two years.)

9.12 Expressing the logarithmic growth in the value of gross output, gGO, as the sum of gGOP and the logarithmic growth in the volume of gross output, which we denote gGOQ, then the above formula can be rearranged into the following identity:

$$gGO = (gGOQ + gLEMS)*(1 - K/GO) + dK/GO - (gKQ - gGOQ)*K/GO$$

9.13 This can be interpreted as a decomposition of growth in the value of gross output price into:

(a) A LEMS cost effect, gGOQ + gLEMS, weighted by the proportion of LEMS cost in gross output, which is 1 – K/GO. The growth in the volume of gross output appears in this term because gLEMS is defined as the growth in LEMS costs at constant volume of gross output.

(b) An effect associated with the change in the value of services from capital relative to the value of gross output, dK/GO.

(c) An adjustment associated with the change in the volume of services from capital per unit of gross output, gKQ – gGOQ, weighted by the proportion of the value of services from capital in gross output, which is K/GO.

9.14 Adjustment (c) ensures that gLEMS is measured at constant volume of services from capital. gLEMS is the growth in the cost of non-capital inputs which would be consistent with the observed growth in the value of output assuming constant volume of services from capital per unit of gross output.

9.15 In cases where the value of services from capital is, and remains, positive, a price index for services from capital can be defined as the difference between the logarithmic growth in the value of services from capital and the logarithmic growth in the quantity of services from capital.

9.16 Let us denote by gKP the price index for services from capital. Then:

dK/K = gKP + gKQ

9.17 A relationship between the output price index and gLEMS can be obtained by deducted output volume growth from both sides of the above relationship between gGO and gLEMS. This gives:

gGOP = gLEMS*(1 – K/GO) + gKQ/GO – gKQ

9.18 In the EU KLEMS dataset for the United Kingdom, there are many instances where the value of services from capital is shown as a negative number, which means that gKP is not defined. We used the formula stated at the beginning of this section, which does not depend on a positive value of services from capital, in order to calculate the growth in the LEMS measure in all sectors and years.

LEMS cost measure without capital adjustment

9.19 The LEMS cost measure without capital adjustment is calculated as follows:

gLEMSunad = g(L+II) – gGOQ

LEMS productivity at constant capital and relationship to LEMS cost measure

9.20 The growth in LEMS productivity (at constant capital) is defined as:

gLEMSPcK = gTFPGO / (1 – K/GO)

where

gLEMSPcK is the growth in LEMS productivity (at constant capital).

gTFPGO is the gross output measure of total factor productivity growth.

K/GO is the proportion of gross output value accounted for by services from capital.

9.21 This provides a measure of the rate of reduction in a volume index for labour and intermediate inputs that would arise if all gross output total factor productivity growth took place through reductions to the volume of labour and intermediate inputs, with no change to the volume of output produced or to capital inputs.

9.22 There is a relationship between the LEMS cost measure and the LEMS productivity measure (at constant capital) which provides another way to derive the LEMS cost measure. The relationship between gLEMS and gLEMSPcK is:

$$gLEMS = L/(II+L)*gLP + II/(II+L)*gIIP - gLEMSPcK$$

where

L is the value of labour.

II is the value of intermediate inputs.

gLP is the growth in wages.

gIIP is the growth in intermediate input prices.

9.23 The first two terms above provide the weighted average growth in the price of labour inputs (e.g. wages) and the price of intermediate inputs. The LEMS cost measure can therefore be seen to be calculated as the rate of change in a measure of the price of labour and intermediate inputs minus the rate of change in a measure of the volume of labour and intermediate inputs that would arise if all the gross output total factor productivity growth took place through reductions to the volume of labour and intermediate inputs only. This provides an alternative method to calculate the LEMS cost measure at constant capital, and was used in Reckon (2008).

9.24 The relationship between gLEMS and gLEMSPcK is obtained by combining:

(a) The definitions of gTFPGO, gLEMSPcK and gLEMS set out above.

(b) The fact that gross output is the sum of the value of labour, intermediate inputs and services from capital.

(c) The idea that changes in the value of each of labour, intermediate inputs and services from capital can be decomposed between a price effect and a volume effect.

LEMS productivity without capital adjustment

9.25 LEMS productivity without capital adjustment is calculated as follows:

gLEMSPRODnocap = gGOQ – L/(II+L)*gLQ – II/(II+L)*gIIQ

where

gGOQ is the growth in the quantity of gross output.

gLQ is growth in the quantity of labour.

gIIQ is growth in the quantity of intermediate inputs.

Relationship to data available from EU KLEMS

9.26 Table 37 provides a mapping between the algebra used above and the variables from the EU KLEMS dataset that we have used as the input data for our analysis.

Table 37 Mapping to EU KLEMS data

Algebra used in this appendix	Source variable(s) in EU KLEMS dataset
GO	GO
K	CAP
L	LAB
II	II
KQ	CAP_QI
LQ	LAB_QI
IIQ	II_QI
GOP	GO_P
IIP	II_P
KP	Calculated as CAP/CAP_QI
LP	Calculated as LAB/LAB_QI

Results from EU KLEMS analysis between 1970 and 2007 (average annual logarithmic growth)					
Sector	LEMS cost at constant capital	LEMS cost unadjusted	Output price index	Gross output TFP growth	LEMS productivity growth at constant capital
Agriculture (A-B)	-1.7%	-1.5%	-2.2%	0.9%	1.0%
Mining (C)	5.7%	1.9%	3.9%	-0.9%	-2.3%
Food & drink (15-16)	-0.8%	-1.0%	-1.0%	0.2%	0.2%
Leather & textiles (17-19)	-1.1%	-1.3%	-1.4%	0.9%	0.9%
Wood (20)	-0.3%	-0.4%	-0.5%	0.2%	0.2%
Publishing (21-22)	0.1%	0.0%	-0.2%	0.4%	0.4%
Fuels (23)	1.2%	0.9%	0.8%	0.0%	-0.1%
Chemicals & drugs (24)	-1.0%	-1.0%	-0.9%	1.3%	1.4%
Plastics (25)	-0.9%	-1.0%	-1.2%	0.9%	1.0%
Glass & bricks (26)	0.4%	0.0%	0.1%	0.8%	0.9%
Metal (27-28)	-0.3%	-0.4%	-0.6%	0.7%	0.7%
Machinery (29)	-0.2%	-0.4%	-0.4%	0.5%	0.5%
Electricals (30-33)	-2.3%	-2.3%	-2.4%	1.6%	1.8%
Vehicles (34-35)	-0.7%	-0.5%	-0.4%	1.1%	1.1%
Other manufacturing (36-37)	0.6%	0.4%	0.2%	-0.5%	-0.5%
Utilities (E)	-1.2%	-0.6%	-1.0%	0.9%	1.2%
Construction (F)	1.3%	1.2%	1.1%	0.3%	0.3%
Car dealers/garages (50)	0.1%	-0.1%	-0.1%	1.0%	1.1%
Wholesale (51)	0.7%	0.0%	-0.2%	-0.4%	-0.5%
Retail (52)	0.5%	0.0%	0.1%	0.3%	0.3%
Hotels & restaurants (H)	2.4%	1.8%	1.3%	-0.4%	-0.5%
Transportation (60-63)	-0.5%	-0.5%	-0.7%	1.2%	1.3%
Telecoms & post (64)	-1.5%	-2.2%	-2.4%	1.7%	2.2%
Bank & insurance (J)	1.1%	0.5%	0.6%	-0.3%	-0.4%
Real estate (70)	2.5%	1.5%	2.1%	-1.4%	-2.7%
Business services (71-74)	0.9%	0.0%	-0.2%	-0.1%	-0.1%
Public administration (L)	1.4%	1.1%	1.0%	-0.4%	-0.5%
Education (M)	1.4%	1.5%	1.0%	-1.1%	-1.1%
Healthcare (N)	1.1%	1.0%	1.2%	0.1%	0.1%
Other services (O)	1.5%	1.0%	0.7%	-0.6%	-0.6%
Whole economy	0.4%	0.1%	0.1%	0.2%	0.2%

Results from EU KLEMS analysis between 1987 and 2007 (average annual logarithmic growth)

Sector	LEMS cost at constant capital	LEMS cost unadjusted	Output price index	Gross output TFP growth	LEMS productivity growth at constant capital
Agriculture (A-B)	-1.3%	-1.4%	-2.0%	0.9%	1.0%
Mining (C)	2.8%	-0.2%	-1.2%	-0.3%	-1.5%
Food & drink (15-16)	-1.1%	-1.3%	-1.2%	0.1%	0.1%
Leather & textiles (17-19)	-1.1%	-1.2%	-1.4%	0.9%	0.9%
Wood (20)	-0.6%	-0.6%	-0.6%	-0.1%	-0.1%
Publishing (21-22)	-0.2%	-0.3%	-0.4%	0.1%	0.1%
Fuels (23)	-1.6%	-1.7%	-1.8%	0.0%	0.0%
Chemicals & drugs (24)	-0.9%	-1.0%	-0.7%	1.2%	1.4%
Plastics (25)	-1.2%	-1.2%	-1.3%	0.7%	0.8%
Glass & bricks (26)	-0.6%	-0.7%	-0.9%	0.9%	0.9%
Metal (27-28)	-0.9%	-0.9%	-0.9%	0.8%	0.8%
Machinery (29)	-1.0%	-1.0%	-0.9%	0.9%	1.0%
Electricals (30-33)	-2.9%	-2.8%	-2.9%	1.9%	2.1%
Vehicles (34-35)	-1.3%	-1.2%	-0.9%	1.0%	1.0%
Other manufacturing (36-37)	0.4%	0.3%	0.5%	-0.2%	-0.2%
Utilities (E)	-1.1%	-1.1%	-1.1%	0.3%	0.4%
Construction (F)	0.4%	0.3%	0.3%	0.2%	0.2%
Car dealers/garages (50)	-1.0%	-1.2%	-0.6%	1.2%	1.4%
Wholesale (51)	-0.6%	-0.9%	-0.8%	0.3%	0.3%
Retail (52)	-0.8%	-1.1%	-0.3%	0.5%	0.6%
Hotels & restaurants (H)	1.5%	1.1%	0.4%	-0.6%	-0.7%
Transportation (60-63)	-1.0%	-0.9%	-0.7%	0.7%	0.8%
Telecoms & post (64)	-1.6%	-2.4%	-2.9%	2.4%	2.9%
Bank & insurance (J)	0.3%	-0.2%	0.1%	0.4%	0.5%
Real estate (70)	1.8%	1.5%	2.8%	-1.4%	-3.0%
Business services (71-74)	0.9%	0.2%	0.5%	-0.2%	-0.2%
Public administration (L)	1.1%	0.7%	0.6%	-0.4%	-0.4%
Education (M)	2.0%	1.9%	1.8%	-1.1%	-1.1%
Healthcare (N)	0.9%	0.8%	0.8%	0.3%	0.3%
Other services (O)	1.8%	1.3%	0.8%	-0.8%	-0.9%
Whole economy	-0.1%	-0.4%	-0.3%	0.2%	0.3%

Results from EU KLEMS analysis between 1997 and 2007 (average annual logarithmic growth)					
Sector	**LEMS cost at constant capital**	**LEMS cost unadjusted**	**Output price index**	**Gross output TFP growth**	**LEMS productivity growth at constant capital**
Agriculture (A-B)	-0.8%	-0.9%	-2.2%	1.3%	1.4%
Mining (C)	6.6%	4.0%	4.7%	-2.0%	-5.1%
Food & drink (15-16)	-1.0%	-1.1%	-1.5%	0.2%	0.3%
Leather & textiles (17-19)	-1.8%	-2.0%	-3.0%	1.6%	1.6%
Wood (20)	-0.4%	-0.5%	-0.7%	0.1%	0.1%
Publishing (21-22)	-0.6%	-0.7%	-1.3%	0.3%	0.3%
Fuels (23)	4.9%	4.8%	4.4%	0.1%	0.0%
Chemicals & drugs (24)	0.9%	0.6%	0.3%	1.1%	1.2%
Plastics (25)	-1.1%	-1.2%	-2.2%	0.7%	0.7%
Glass & bricks (26)	-0.4%	-0.4%	-1.3%	1.2%	1.3%
Metal (27-28)	-1.1%	-1.2%	-1.9%	1.0%	1.0%
Machinery (29)	-1.5%	-1.6%	-2.4%	1.3%	1.4%
Electricals (30-33)	-4.2%	-4.1%	-4.4%	2.1%	2.4%
Vehicles (34-35)	-1.4%	-1.5%	-1.9%	0.7%	0.7%
Other manufacturing (36-37)	-1.1%	-1.2%	-1.4%	0.4%	0.4%
Utilities (E)	3.9%	3.3%	2.8%	0.1%	0.2%
Construction (F)	1.4%	1.1%	1.4%	-0.2%	-0.2%
Car dealers/garages (50)	-1.4%	-1.8%	-1.8%	1.9%	2.2%
Wholesale (51)	-1.5%	-1.7%	-2.2%	0.3%	0.4%
Retail (52)	-1.1%	-1.3%	-1.4%	0.7%	0.9%
Hotels & restaurants (H)	-0.3%	-0.7%	-0.6%	-0.2%	-0.2%
Transportation (60-63)	-0.8%	-1.0%	-0.9%	0.6%	0.6%
Telecoms & post (64)	-3.3%	-3.9%	-4.1%	2.5%	3.1%
Bank & insurance (J)	-0.6%	-0.7%	0.2%	0.6%	0.7%
Real estate (70)	3.7%	3.0%	1.6%	-2.7%	-5.9%
Business services (71-74)	-0.3%	-0.9%	-1.1%	0.7%	0.9%
Public administration (L)	0.6%	0.5%	0.3%	-0.4%	-0.4%
Education (M)	2.3%	2.2%	2.2%	-2.0%	-2.0%
Healthcare (N)	0.2%	0.3%	0.3%	0.3%	0.3%
Other services (O)	1.7%	1.3%	1.2%	-1.2%	-1.3%
Whole economy	0.0%	-0.3%	-0.4%	0.1%	0.2%

Coefficients from OLS regressions

1970 - 2007	LEMS cost adjusted		LEMS cost unadjusted		Output price index		Gross output TFP growth		LEMS productivity growth at constant	
Sector	**Coefficient**	**RMSE**	**Coefficient**	**RMSE**	**Coefficient**	**RMSE**	**Coefficient**	**RMSE**	**Coefficient**	**RMSE**
Agriculture (A-B)	-2.2%	*0.087*	-2.1%	*0.077*	-2.6%	*0.084*	1.0%	*0.024*	1.1%	*0.028*
Mining (C)	3.9%	*0.358*	0.3%	*0.216*	1.6%	*0.452*	-0.2%	*0.104*	-1.2%	*0.208*
Food & drink (15-16)	-1.0%	*0.036*	-1.2%	*0.036*	-1.1%	*0.037*	0.1%	*0.014*	0.2%	*0.016*
Leather & textiles (17-19)	-1.0%	*0.040*	-1.1%	*0.040*	-1.2%	*0.051*	0.6%	*0.028*	0.7%	*0.029*
Wood (20)	-0.6%	*0.035*	-0.5%	*0.033*	-0.7%	*0.036*	0.2%	*0.030*	0.2%	*0.034*
Publishing (21-22)	0.2%	*0.044*	0.0%	*0.045*	0.0%	*0.051*	0.4%	*0.025*	0.4%	*0.029*
Fuels (23)	-0.5%	*0.330*	-0.9%	*0.325*	-0.9%	*0.323*	-0.1%	*0.013*	-0.1%	*0.014*
Chemicals & drugs (24)	-1.3%	*0.061*	-1.3%	*0.056*	-1.2%	*0.057*	1.3%	*0.024*	1.5%	*0.028*
Plastics (25)	-0.9%	*0.036*	-0.9%	*0.033*	-1.0%	*0.037*	0.9%	*0.032*	1.0%	*0.036*
Glass & bricks (26)	0.3%	*0.095*	-0.1%	*0.070*	0.0%	*0.095*	0.6%	*0.037*	0.7%	*0.042*
Metal (27-28)	-0.6%	*0.050*	-0.6%	*0.048*	-0.7%	*0.055*	0.8%	*0.028*	0.8%	*0.030*
Machinery (29)	-0.1%	*0.073*	-0.2%	*0.066*	-0.1%	*0.071*	0.3%	*0.030*	0.4%	*0.033*
Electricals (30-33)	-2.0%	*0.092*	-2.1%	*0.081*	-2.2%	*0.090*	1.5%	*0.035*	1.8%	*0.039*
Vehicles (34-35)	-1.0%	*0.046*	-0.8%	*0.057*	-0.5%	*0.055*	1.3%	*0.044*	1.3%	*0.043*
Other manufacturing (36-37)	1.0%	*0.078*	0.7%	*0.069*	0.6%	*0.064*	-0.7%	*0.042*	-0.8%	*0.045*
Utilities (E)	-2.2%	*0.154*	-1.7%	*0.150*	-2.0%	*0.131*	0.8%	*0.027*	1.0%	*0.038*
Construction (F)	0.7%	*0.076*	0.7%	*0.069*	0.5%	*0.068*	0.5%	*0.031*	0.5%	*0.034*
Car dealers/garages (50)	-0.1%	*0.073*	-0.3%	*0.070*	-0.1%	*0.051*	1.2%	*0.061*	1.3%	*0.067*
Wholesale (51)	0.6%	*0.093*	0.0%	*0.066*	-0.2%	*0.062*	-0.2%	*0.055*	-0.2%	*0.066*
Retail (52)	0.1%	*0.088*	-0.3%	*0.070*	0.1%	*0.047*	0.7%	*0.054*	0.7%	*0.061*
Hotels & restaurants (H)	2.6%	*0.090*	1.9%	*0.087*	1.2%	*0.067*	-0.4%	*0.020*	-0.5%	*0.026*
Transportation (60-63)	-0.8%	*0.060*	-0.7%	*0.061*	-0.7%	*0.042*	1.3%	*0.032*	1.3%	*0.030*
Telecoms & post (64)	-1.4%	*0.134*	-2.2%	*0.121*	-2.5%	*0.118*	1.8%	*0.074*	2.4%	*0.090*
Bank & insurance (J)	1.0%	*0.107*	0.3%	*0.086*	0.3%	*0.080*	-0.2%	*0.048*	-0.3%	*0.057*
Real estate (70)	1.8%	*0.089*	1.1%	*0.078*	2.5%	*0.087*	-1.0%	*0.058*	-1.8%	*0.116*
Business services (71-74)	1.6%	*0.062*	0.5%	*0.055*	0.3%	*0.098*	-0.4%	*0.042*	-0.5%	*0.049*
Public administration (L)	1.3%	*0.052*	1.0%	*0.048*	0.9%	*0.052*	-0.3%	*0.018*	-0.3%	*0.020*
Education (M)	1.4%	*0.081*	1.4%	*0.077*	0.9%	*0.099*	-0.9%	*0.031*	-1.0%	*0.031*
Healthcare (N)	1.2%	*0.041*	1.1%	*0.035*	1.3%	*0.051*	0.0%	*0.024*	0.0%	*0.026*
Other services (O)	1.5%	*0.046*	1.0%	*0.055*	0.6%	*0.041*	-0.4%	*0.024*	-0.4%	*0.026*
Whole economy	0.3%	*0.044*	-0.1%	*0.037*	0.0%	*0.036*	0.3%	*0.013*	0.3%	*0.014*

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