PRODUCTIVITY GROWTH IN CAPITAL INTENSIVE SECTORS

REPORT FOR THE OFFICE OF RAIL AND ROAD

JULY 2018

Final Report

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ABBREVIATIONS

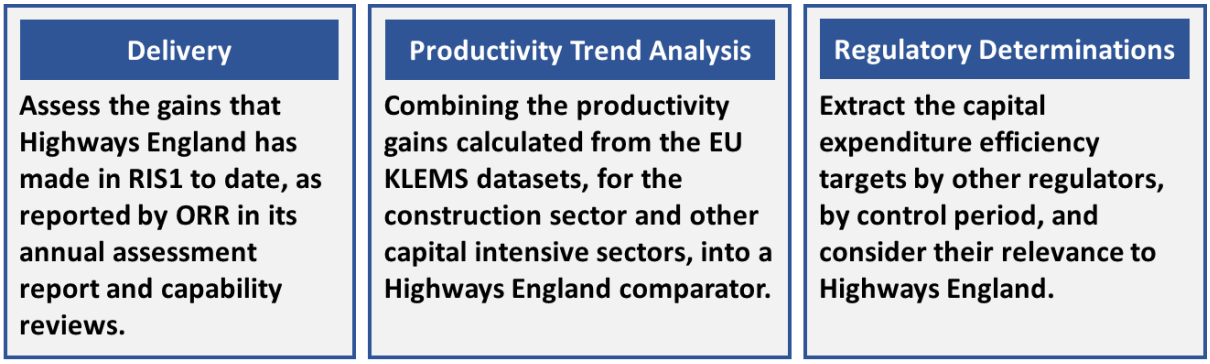
Acronym	Full Description
Capex	Capital Expenditure
CEPA	Cambridge Economic Policy Associates, the prime contractor of this study.
CPI	Consumer Price Index
CU	Catch-Up, efficiency improvements made in order to catch-up to current best practice.
DfT	Department for Transport
EU KLEMS	Database on measures of economic growth, productivity, employment creation, capital formation and technological change at the industry level for all European Union member states from 1970 onwards.
FS	Frontier Shift, ongoing efficiency achieved over time.
GO	Gross Output, measures whereby intermediate input impacts are included.
HMT	HM Treasury
LEMS	Labour, Energy, Material, Services, a partial productivity measure which considers labour and intermediate inputs.
LEMSP	The 'residual' output growth that is not accounted for by the growth of labour and intermediate inputs (LEMS).
LP	Labour Productivity, the growth of output per unit of labour input growth.
NACE	The statistical classification of economic activities in the European Community.
OBR	Office of Budgetary Responsibility
Ofgem	The Office of Gas and Electricity Markets
Ofwat	The Water Services Regulation Authority
OMR	Operating, Maintenance and Renewal
Opex	Operating Expenditure
ORR	Office of Rail and Road
PS	Performance Specification, the objectives that Highways England must deliver.
RIS1	Road Investment Strategy 1 sets out the major strategic road network improvements Highways England is to deliver from 2015/16 to 2019/20.
RIS2	Road Investment Strategy 2, the second road investment period starting in 2020.
RPI	Retail Price Index
RPI-X	Price cap regulation: RPI minus expected efficiency savings (X).
SRN	Strategic Road Network made up of the motorways and the trunk roads in England that are Highways England's responsibility.
TFP	Total Factor Productivity, the 'residual' output growth that is not accounted for by input growth, taking into account all factors of production.
VA	Value-added, a measure whereby the impacts of intermediate inputs are removed.

EXECUTIVE SUMMARY

As part of preparations for the efficiency review it will undertake later this year, the ORR has commissioned CEPA to undertake a small piece of work to assess historical productivity growth in capital intensive sectors. This report includes an analysis of Highways England's capital expenditure performance over RIS1, an assessment of productivity improvements in capital intensive sectors similar to Highways England, and consideration of regulatory precedent. The scope does not include a consideration of operational or resource efficiency, which CEPA has previously reported on, and does not include primary data collection specific to Highways England.

Assessing the scope for capital efficiency is less straightforward than is the case for operating efficiency because capital projects tend to be bespoke, and therefore less amenable to benchmarking, which requires a like for like comparison. We have carried out three pieces of analysis to produce historical ranges for productivity gains in capital intensive sectors (see figure below). It should be noted that the results are initial estimates that require further development prior to application to Highways England, which is out of this project's scope.

Figure 0.1: Analysis components



Efficiencies describe the scenario when a company can produce the same outputs by spending less on inputs (or producing more outputs with the same inputs). Even the most efficient companies (i.e. at the frontier of efficient performance) can be expected to make efficiency improvements over time – this is known as frontier-shift efficiency.

However, at any one time, some companies will lag behind the frontier. This group of companies will need to catch-up to the others if they wish to be considered efficient. This type of efficiency potential is referred to as catch-up efficiency, made by adopting current technology or efficient working practices to catch-up to current best practice.

The three pieces of analysis that we have prepared consider different components of efficiency potential. Productivity trend analysis provides an indication of frontier-shift efficiency, whereas Highways England's RIS1 performance to date (i.e. its delivery) provides an indication of the amount of catch-up efficiency that might be delivered in the future. Regulatory determinations may include both and may not always be split between components.

Results

Productivity Trend Analysis

We examine productivity growth in sectors of the UK economy that we consider act as a proxy for Highways England's capital programme (enhancements and renewals). We do this through the calculation of a series of productivity metrics, which provide an estimate of frontier shift efficiency.

The results below provide a proxy for the level of frontier shift efficiency that a company like Highways England might achieve. They suggest that a company in a reasonably competitive market with similar activities to Highways England's would make frontier-shift productivity gains of:

- Renewals of around **0.0% to 0.2%** per year.
- Enhancements of around **0.0% to 0.4%** per year.

Regulatory Determinations

We briefly look at efficiency targets set in GB regulatory regimes (for comparable networks, often privatised). Where possible, we consider the achieved level of efficiency as well as the targets set by the sector regulator.

We consider regulatory determinations in sectors which we consider to be most relevant to Highways England; they each have a large capex programme. If we consider that the most analogous price control to RIS2 is the third price control in other sectors, then comparable efficiency ranges for RIS2 are as set out below.

Table 0.1: Third control period combined (CU &FS) efficiencies by sector – per annum

Sector	Renewals target	Capex enhancements target
Water (PR04 2005-10)[1]	1.6%-1.9%	3.9-4.4%
Rail (CP5 2014-19)	4.4%	0.8%-1.3%
Energy distribution (DCPR3 2000-05)	3.0% frontier-shift efficiency *(across all cost areas) – catch-up efficiency unknown*	

We note, however, that there are differences between these sectors and Highways England, such as their structure and the nature of their activities, which can affect the potential for efficiencies and, therefore, limit direct comparability to Highways England. Given the lack of direct GB comparators, this analysis is useful high level context that is commonly used by

[1] As discussed further in section 3 it is important to note that the regulator identified a total efficiency scope of 3.7%-4.1% for renewals and 3.9%-4.4% for enhancements per annum. However, Ofwat only applied a proportion of that calculated total (as shown in the table above) to the price limits that companies were expected to achieve. As part of a 'carrot' and 'stick' regulatory framework they used the remaining 'carrot' proportion of this total scope to incentivise the companies to achieve this total efficiency potential, beyond the required 'stick' efficiencies.

sector regulators but more specific evidence relating to Highways England's activities and plans will be important in assessing RIS2 efficiencies.

In relation to delivery against targets, the evidence suggests that regulated companies have tended to make significant savings in the early periods of regulation, with the level of savings reducing over time resulting in some regulators shifting their focus away from narrow efficiency objectives to a wider range of targets.

Highways England's RIS1 performance to date

In this section we consider Highways England's delivery of the RIS1 capital programme to date, drawing on ORR's annual assessments of performance, and the scope for **future**[2] capex efficiencies, referencing a series of capability reviews that ORR has recently commissioned. The results in this section provide a more Highways England specific estimate of efficiency than the productivity metrics or regulatory determinations and should perhaps be given greater weight than the other measures considered in this report.

The annual efficiency estimates identified in the capability analysis seem likely to be predominantly catch-up efficiencies. Therefore, improvements via frontier shift would be additional. The figures below consider the range of efficiency that Highways England may be able to deliver in the remainder of RIS1 and over the course of RIS2. Note that we have taken steps to avoid double counting of the efficiency potential identified in each capability review.

*Table 0.2: Catch-up efficiencies for remainder of **RIS1** based on capability reviews (per annum)*

Area of Capability	Renewals	Enhancements / Improvements
Procurement and Contract Management	c.2%[3]	
Portfolio and Programme Management	0.0%	1.0% to 1.5%
Asset Management	0.5%-4%[4]	0.0%
Total	**2.5-% - 6%**	**3.0%-3.5%**

*Table 0.3: Catch-up efficiencies for **RIS 2** based on capability reviews (per annum)*

Area of Capability	Renewals	Enhancements / Improvements
Procurement and Contract Management	1.2% to 1.8%	1.2% to 1.8%
Portfolio and Programme Management	0.0%	1.0% to 1.5%

[2] This report primarily focuses on historic data as determined by the scope. ORR's capability reviews are however forward looking estimating the scope for efficiency going forward.
[3] Percentage is based on the programme discussed in Rowsell and Wright's review of programme and contract management. 2% is the average per annum improvement over the course of RIS1. In reality the programme is back end loaded and savings are expected to increase in percentage terms towards the end of RIS1
[4] AMCL's review of Asset Management capability states that the figures that it calculates are for the remainder of the RIS1 Period. For simplicity we assume that is 2 years and assign half of the potential saving to each.

Area of Capability	Renewals	Enhancements / Improvements
Asset Management	1.5% to 3.0%	0.0%
Total	**2.7% to 4.8%**	**2.2% to 3.3%**

1. INTRODUCTION AND APPROACH

1.1. Background

Highways England, formerly the Highways Agency, is a government-owned strategic highways company formed in April 2015. Its primary role is operating, maintaining and improving the Strategic Road Network (SRN) in England, totalling around 4300 miles and carrying a third of all road traffic (by mileage). In 2015 a Highways Monitor was established, which then became the Office of Rail and Road (ORR), to monitor progress in delivering a five-year Road Investment Strategy (RIS) and Performance Specification (PS).

Roads investment is planned over five year periods. Highways England is currently halfway through the first Road Investment Strategy (RIS1), which runs from 2015/16 to 2019/20, and is working to deliver the requirements of an associated Performance Specification (PS). Highways England is delivering a challenging and growing investment programme whilst simultaneously seeking to improve performance. The RIS1 strategy defines eight sectors across which Highways England will deliver £12.2 billion of capital expenditure (capex) across the 5 years of RIS1, in addition to on-going operating costs (opex) of roundly £1 billion per year. Its performance, both in terms of outputs and cost-effectiveness, is monitored by ORR. An objective of RIS1 is for Highways England to reduce its costs of delivery so as to achieve, in effect, £1.2bn in capital efficiencies in total over the five year period.

With planning for RIS2 underway, ORR is assessing the level of efficiency that would be challenging but deliverable in RIS2 and comparing this to Highways England's proposals. The aim of RIS2 is to continue to build upon the progress made under RIS1 but with new targets set. ORR's efficiency review of Highways England's proposals for RIS2, which will be undertaken later this year, will be informed by a series of benchmarking activities of which this report is an input.

1.2. Objectives of this study

As part of preparations for the efficiency review it will undertake later this year, the ORR has commissioned CEPA to undertake a small piece of work to assess historical productivity growth in capital intensive sectors. This report includes an analysis of Highways England's capital expenditure performance over RIS1, an assessment of productivity improvements in capital intensive sectors similar to Highways England, and consideration of regulatory precedent.

The scope does not include a consideration of operational or resource efficiency, which CEPA has previously reported on, and does not include primary data collection specific to Highways England.

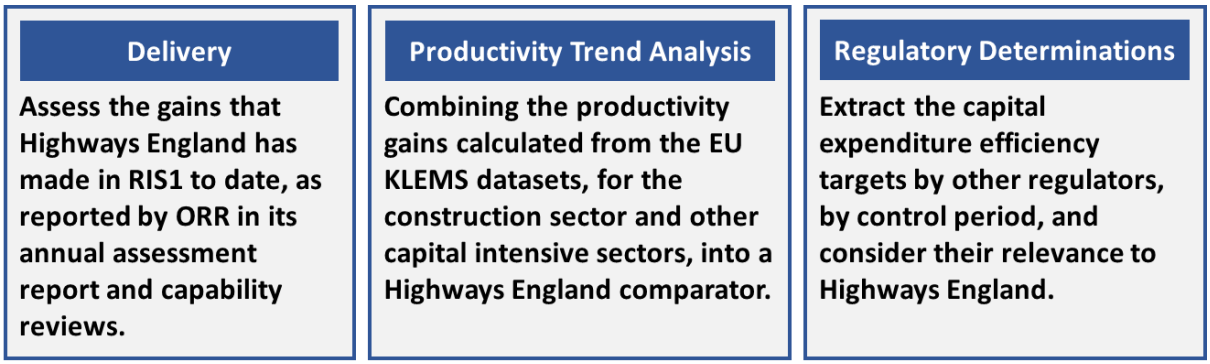
1.3. Approach

Assessing the scope for capital efficiency is less straightforward than is the case for operating efficiency because capital projects tend to be bespoke, and therefore less amenable to benchmarking which requires a like for like comparison.

Given a limited budget for this work, our approach has been to focus on three areas of analysis, which are described in the figure below and discussed further in subsequent sections. Further technical details of our approach to certain components of the analysis are provided in ANNEX A.

These three areas are used to produce historical ranges for productivity gains in capital intensive sectors. It should be noted that the results are initial estimates that require further development prior to application to Highways England, which is out of this project's scope.

Figure 1.1: Analysis components



Efficiencies describe the scenario when a company can produce the same outputs by spending less on inputs (or producing more outputs with the same inputs). Even the most efficient companies (i.e. at the frontier of efficient performance) can be expected to make efficiency improvements over time – this is known as frontier-shift efficiency.

However, at any one time some companies will be lagging behind the frontier. This group of companies will need to catch-up to the others if they wish to be considered efficient. This type of efficiency potential is referred to as catch-up efficiency - made by adopting current technology or efficient working practices to catch-up to current best practice.

The three pieces of analysis that we have prepared considered different components of efficiency potential. Productivity trend analysis provides an indication of frontier-shift efficiency whereas Highways England's RIS1 performance to date (i.e. its delivery) provides an indication of the amount of catch-up efficiency that might be delivered in the future. Regulatory determinations may include both and may not always be split between components. See Annex A.1 for further details on frontier-shift and catch-up efficiencies.

1.4. Structure of the document

The document is structured as follows:

- **Section 2** contains our top down productivity metrics analysis;
- **Section 3** contains our regulatory determinations assessment; and
- **Section 4** provides a high level review of how Highways England has performed in RIS1 to date.

The annexes contain the details underpinning our approach and analysis, as follows:

- **Annex A** contains a detailed explanation of the approach we have taken to productivity measures; and
- **Annex B** contains additional results that support the analysis presented in the main body of this report.

2. PRODUCTIVITY TREND ANALYSIS

2.1. Introduction

In this section we examine productivity growth in sectors of the UK economy that we consider act as a proxy for Highways England's capital programme (enhancements and renewals). We do this through the calculation of a series of productivity metrics which provide an estimate of frontier shift efficiency. This section discusses how they have been calculated and the results.

2.2. The Highways England capital programme

The majority of Highways England's capital expenditure relates to the delivery of enhancements and renewals work. Enhancements are typically larger capital projects that involve improving and modernising the network and account for a greater proportion of capital expenditure. Renewals tend to be smaller capital projects that maintain the existing assets on the network and make up a smaller proportion of overall capital expenditure. The table below provides an indication of the scale of Highways England's capital expenditure.

Table 2.1: Highways England's Funding – Capital Plans

£m		2015/16	2016/17	2017/18	2018/19	2019/20	RIS1	*% of capex*
Modernise/ Enhance	SR10 and SR13 schemes	1022	1218	1026	1466	1510	**6242**	*51%*
	RIS schemes	20	70	120	165	292	**667**	*5%*
	Feasibility studies	4	36	44	63	123	**270**	*2%*
	Air quality		5	18	19	33	**75**	*1%*
	Cycling, safety and integration	17	16	50	32	60	**175**	*1%*
	Environment	6	12	69	42	96	**225**	*2%*
	Innovation Fund	4	20	28	25	43	**120**	*1%*
	Supporting growth schemes		5	23	19	33	**80**	*1%*
Maintain/Renew	Renewals	709	595	788	761	805	**3658**	*30%*
Other	Non-RIS delivery	149	43	115		75	**382**	*3%*
	Autumn Statement 2016			111	111	45	**267**	*2%*
Total		**1931**	**2020**	**2392**	**2703**	**3115**	**12161**	100%

Source: Highways England Delivery Plan 2017-2018

To examine productivity growth, we analyse sectoral rates of UK productivity growth in capital intensive sectors that, as far as possible, mirror activities carried out by Highway's England. We do this separately to reflect the composition of Highways England's renewals and enhancements expenditure. The output is a range of frontier-shift efficiency gains that a company in a reasonably competitive market with similar activities to Highways England might achieve.

2.3. Productivity metrics

We consider productivity growth using three metrics which provide different measures of productivity:

- **Total Factor Productivity (TFP)**: 'Residual' output growth that is not accounted for by input growth, taking into account all factors of production. TFP is calculated using either the gross output or value-added measure – the former includes the contribution from intermediate inputs, whereas these are excluded from the latter.
- **Labour and intermediate inputs (LEMS) Productivity (LEMSP)**: The abbreviation LEMS refers to Labour Energy Materials Services. LEMSP is 'residual' output growth that is not accounted for by the growth of labour and intermediate inputs. This is calculated under both flexible and constant capital assumptions.
- **Labour Productivity (LP)**: The growth of output per unit of labour input growth. Or, consistent with the explanations above, 'residual' output growth that is not accounted for by the growth of labour inputs.

The metrics are based on UK-wide data, sourced from the EU KLEMS dataset[5], across a number of years. Further explanation of how these metrics were calculated is provided below and in Annex A.2.

The analysis included in this report builds upon a short piece of work recently completed for the DfT. In this report, we have updated our dataset to include the latest EU KLEMS data (2017) and split our analysis by renewals and enhancements (for DfT we considered capex as a whole).

2.4. Variants of the productivity metrics

We have calculated a number of variants of each productivity metric. These are summarised in Table 2.2: An overview of the variants of productivity metrics calculated. The variants arise from three distinctions we make when calculating them:

- **The measure of output** – either gross output or value added. Under the gross output measures of productivity, intermediate inputs are assumed to contribute to productivity growth, whereas their impact is removed in the value-added measure. These measures generally give similar results.
- **Capital variability** – either variable capital or constant capital. Capital is an important factor of production. However, the effect of capital growth is sometimes distortionary. To mitigate that, the measures can also be calculated using a constant capital assumption.
- **The period of data coverage** – either using all available years of data (denoted "1") or selected years of data (denoted "2"). The variant "1" is a fixed period. However, for

[5] The EU KLEMS dataset was developed with support from the European Commission (EC), and contains various measures (economic growth, productivity, employment creation, capital formation and technological change) at the industry level for all EU member states from 1970 onwards. See: http://www.euklems.net/

variant "2" there are a number of options available, and these are used as sensitivities. This is explained in more detail in Annex A.2.

2.5. Summary of metrics

The following table describes the variants of the productivity metrics we calculated for both renewals and enhancements expenditure.

Table 2.2: An overview of the variants of productivity metrics calculated

Metric	Factors of production included	Output measure	Capital variability	Period of averaging	Acronym
Total factor productivity (TFP)	Total (Capital, Labour and intermediate inputs)	Gross output	Variable capital	All available years	TFP GO
		Value-added		All available years	TFP VA 1
				Selected years	TFP VA 2
LEMS productivity (LEMSP)	Partial (Labour and intermediate inputs)	Gross output	Variable capital	All available years	LEMSP var K 1
				Selected years	LEMSP var K 2
			Constant capital	All available years	LEMSP con K 1
				Selected years	LEMSP con K 2
Labour productivity (LP)	Partial (Labour only)	Value-added	Variable capital	All available years	LP var K 1
				Selected years	LP var K 2
			Constant capital	All available years	LP con K 1
				Selected years	LP con K 2

2.6. Comparator selection and weighting

In order to assess the level of frontier shift productivity growth that might be expected from a company like Highways England (see Section 2.2), we first identified those sectors of the UK economy that we consider have most similarity to the main components of Highways England's renewals and enhancements expenditure and used these to develop a composite index.

To do this, we examined the composition of Highways England's RIS1 renewals and enhancements expenditure and held discussions with ORR. The EU KLEMS website provides documents which contain a detailed explanation of the types of activities contained within each of the sectors. We reviewed this information alongside data from Highways England to

determine the best comparator sectors for each main component of Highways England's renewals and enhancements capital expenditure.

In some cases, this was relatively straightforward, e.g. there is a sector entitled Transportation and storage, which we consider to be a good proxy for traffic management costs incurred during works. However, choosing comparator sectors is not an exact science and so judgement was required in some cases. The table below details the comparator sectors within the EU KLEMS database sectors that we selected.

Table 2.3: Comparator selection under base case, for 2017 data release[6]

EU KLEMS comparator used	Rationale
Construction	Includes "construction of roads and motorways", "construction of bridges and tunnels" and "electrical installation" which constitutes the majority of Highways England's renewals and enhancements capex.
Transportation and storage	Includes the "operation of roads, bridges, tunnels", etc. Used as a proxy for the traffic management involved during roadworks.
Professional, scientific, technical, administrative and support service activities	Includes "legal, accounting, head office activities, advertising, employment activities, office admin and business support" - used as a proxy for Highways England's business costs. Also includes "architectural and engineering activities" – used as a proxy for feasibility study expenditure, and also the general design and planning costs that improvements and renewals work involves.

Once the comparator sectors were identified, the next stage involved weighting each sector according to the composition of Highways England's renewals and enhancements expenditure. In our base case the weightings are as follows:

Table 2.4: Comparator weightings under base case, for 2017 data release

EU KLEMS comparator used	Weightings	
	Renewals	Enhancements
Construction	75%	70%
Transportation and storage	15%	10%
Professional, scientific, technical, administrative and support service activities	10%	20%

To generate the weightings, we reviewed previous work on cost categorisation e.g. for DfT, and then sense checked this with experience from work undertaken for other clients. We then considered the differing nature of renewals and enhancements and how this would affect the weightings. Following this and discussions with ORR, the weightings set out above were used

[6] We note that the sectors used for the 2012 and 2009 data releases were virtually the same, although with some minor variations, e.g. certain sectors were not available.

to calculate two weighted composite indexes, which act as a comparator for each of renewals and enhancements. The rationale behind the allocations used in the base case is that:

- renewals and enhancements both involve construction works;
- a high proportion of renewals would be accounted for by construction, more so than enhancements, as these works tend to be more generic and straightforward in nature, resulting in less planning and project design work;
- the remainder of renewals costs would be comprised mainly of transport and storage, with only a small portion allocated to professional services, to reflect the fact that traffic management is required for long sections of the network, and less design and planning work is involved;
- enhancements would be comprised of a lower proportion of construction cost, as these works are more unique and complex in nature and therefore, the proportion of costs accounted for by professional services would be higher, reflecting the greater level of design and planning required; and
- the smallest proportion of enhancement would be transportation and storage as these projects tend to require less traffic management expenditure, relative to the overall project cost, than renewals.

We employed judgement in determining the comparator sectors and weightings, so we also considered sensitivities for each variant of the metrics that we calculated. Each sensitivity uses different sectoral weights. For some of the variant "2" metrics, we also calculated sensitivities based on the number of business cycles covered.

We calculated each of the main metric variants using the same comparator sectors and weightings. This produced a range of results. Within that range, we reported the Maximum, Minimum, Average, and our Base Case. Further details of the methodology can be found in Annex A.2.

2.7. Results and analysis

The results for our TFP, LEMS productivity and labour productivity analysis are provided in the figures below. Detailed explanations and further analysis can be found in the Annexes. Note when reading the figures, a positive result indicates an efficiency gain and negative results indicate an efficiency loss.

As noted previously, we calculated three main metrics but also considered which measure is most appropriate to Highways England's renewals and enhancements expenditure:

- TFP, by nature, measures productivity for all factors of production, including capital.
- The difference between LEMS productivity and labour productivity is the efficiency gain made due to intermediate inputs (energy, materials and services). Whilst some intermediate inputs are included within Highways England's operating cost base (i.e.

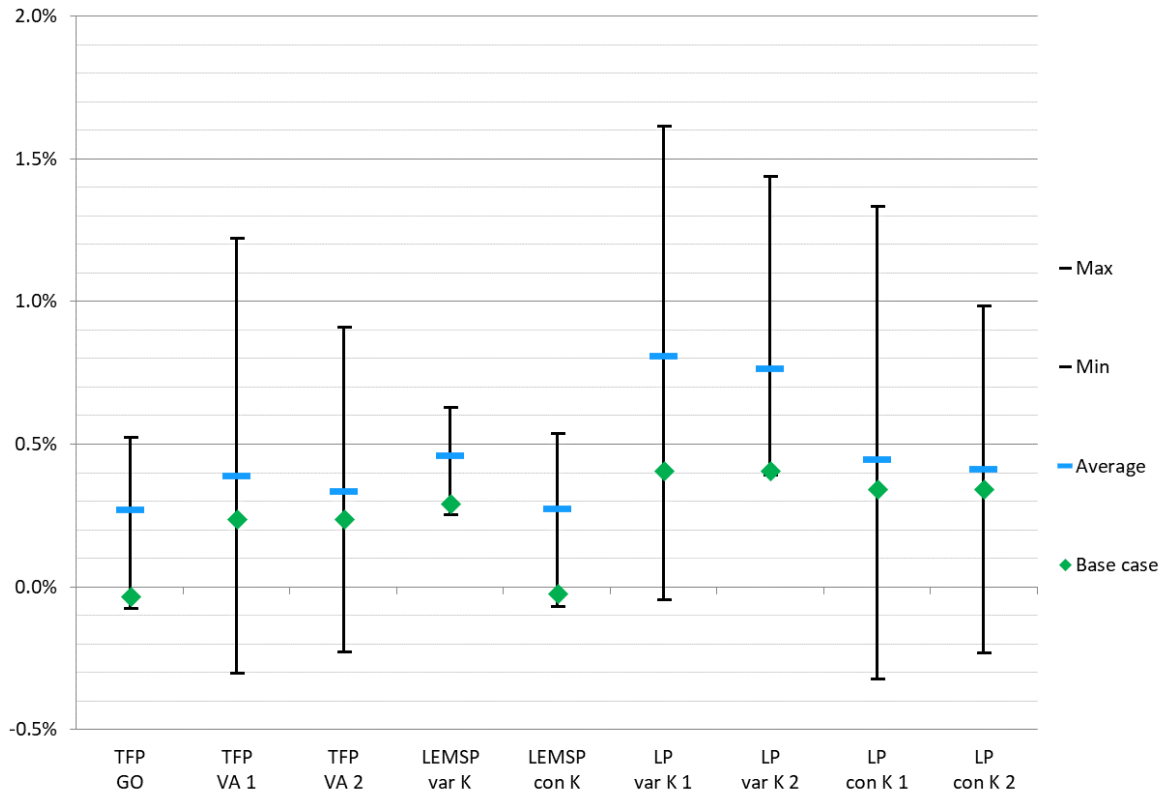
energy for providing signage and materials used for light maintenance), the majority are likely to sit within Highways England's capex base (i.e. materials and capex-related services such as construction).

- As LEMS and labour productivity both calculate growth that is not accounted for by intermediate inputs, these are less appropriate than the TFP metrics.

Results (by metric and variant within that) are set out in Figure 2.1 and Figure 2.2 below. As per the above, we place greatest weight on the TFP results, which is our 'base case'.

2.7.1. Renewals

Figure 2.1: Productivity gain per annum - renewals



Source: EU KLEMS dataset, CEPA analysis

Abbreviations: GO = Gross Output, VA = Value-added; TFP = Total Factor Productivity; LEMSP = LEMS Productivity, LP = Labour Productivity; var K = variable capital, con K = constant capital. "1" and "2" refer to coverage period variants.

All of our base case results are in the range -0.03% to 0.41% per annum.

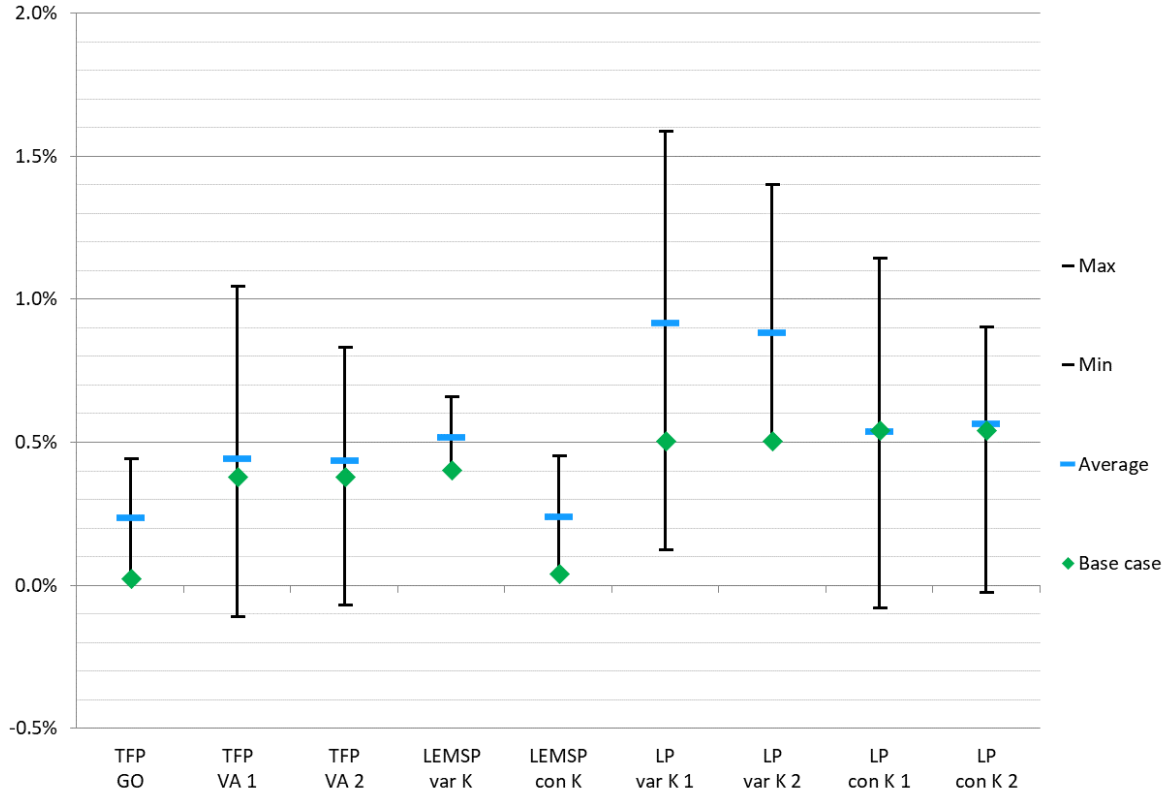
Summary

The 'base case' TFP productivity gains are in the range -0.03% to 0.24% per annum, i.e. outputs grow by -0.03% to 0.24% per annum more than inputs. Given that the TFP gross output implies a range which goes negative, we propose a range of 0% (low end) to 0.24% (high end).

As previously stated, these results are a proxy for the level of frontier shift efficiency that a company like Highways England might achieve. They suggest that a company in a reasonably competitive market with similar activities to Highways England's renewals would make frontier-shift productivity gains on renewals of around 0.0% to 0.2% per year.

2.7.2. Enhancements

Figure 2.2: Productivity gain per annum - enhancements



Source: EU KLEMS dataset, CEPA analysis

Abbreviations: GO = Gross Output, VA = Value-added; TFP = Total Factor Productivity; LEMSP = LEMS Productivity, LP = Labour Productivity; var K = variable capital, con K = constant capital. "1" and "2" refer to coverage period variants.

All of our base case results are in the range 0.02% to 0.54% per annum.

Summary

The 'base case' TFP productivity gains are in the range 0.02% to 0.38% per annum, i.e. outputs grow by 0.02% to 0.38% per annum more than inputs.

As before, these results are a proxy for the level of frontier shift efficiency that a company like Highways England might achieve, suggesting that a company in a reasonably competitive market with similar activities to Highways England's will make frontier-shift productivity gains on enhancements of around 0.0% to 0.4% per year.

2.7.3. Individual EU KLEMS sectors

We have also calculated the productivity metrics for each of the three EU KLEMS sectors included in our weighted comparator in order to understand productivity changes in each individual sector and the influence each may have on the sensitives undertaken. This was undertaken by individually weighting a sector as 100%, and the remaining two at 0%.

The results indicate that in our 'base case', *transportation and storage* and *construction* both experience similar but small productivity growth. *Professional, scientific, technical, administrative and support service activities* however, experience larger productivity changes.

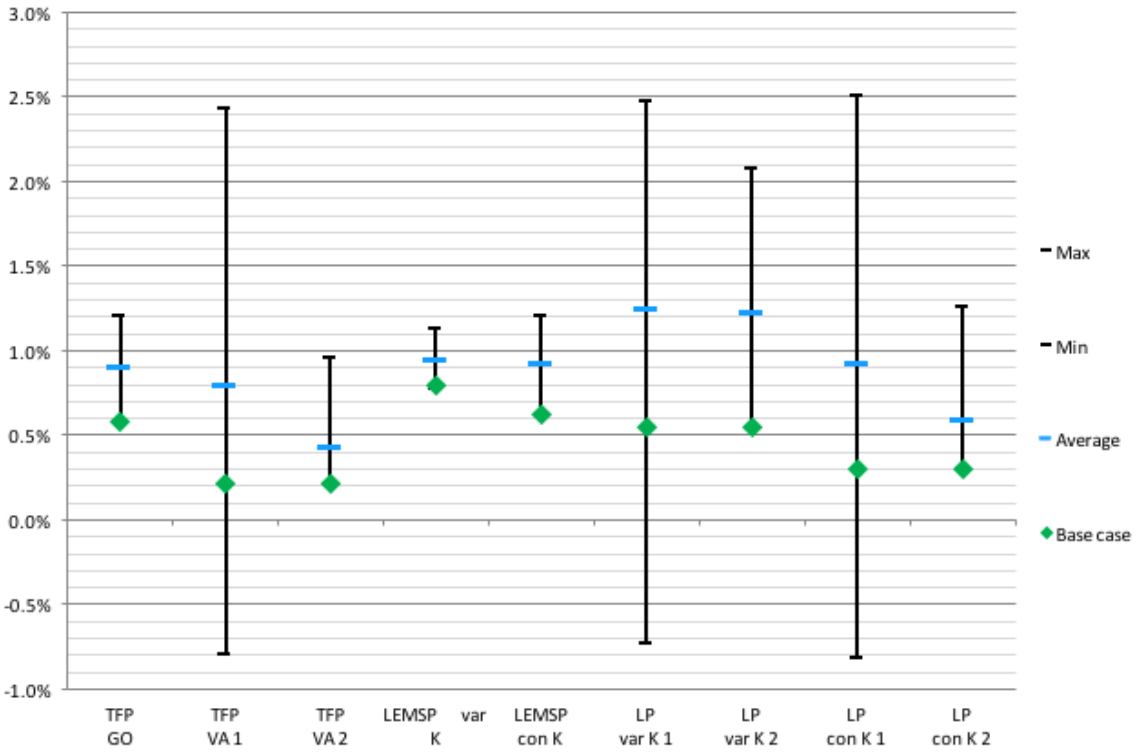
As a result, altering the weighting of *construction* and *transportation and storage* as a sensitivity will have little impact on the overall results, whereas altering the weight of *Professional, scientific, technical, administrative and support service activities* has a greater influence on the weighted comparator results. However, as this sector accounts for only a small proportion of renewals and enhancements expenditure in all cases (i.e. including sensitivities), it is unlikely to have any material impact overall.

These results also indicate that the difference in efficiency ranges between renewals and enhancements is driven by the difference in weighting of *Professional, scientific, technical, administrative and support service activities,* and the higher productivity range within this sector. Enhancements has a higher weighting to this comparator sector and a higher efficiency range.

Detailed results are provided in the figures below.

Transportation and storage

Figure 2.3: Productivity gain per annum – transportation and storage



Source: EU KLEMS dataset, CEPA analysis

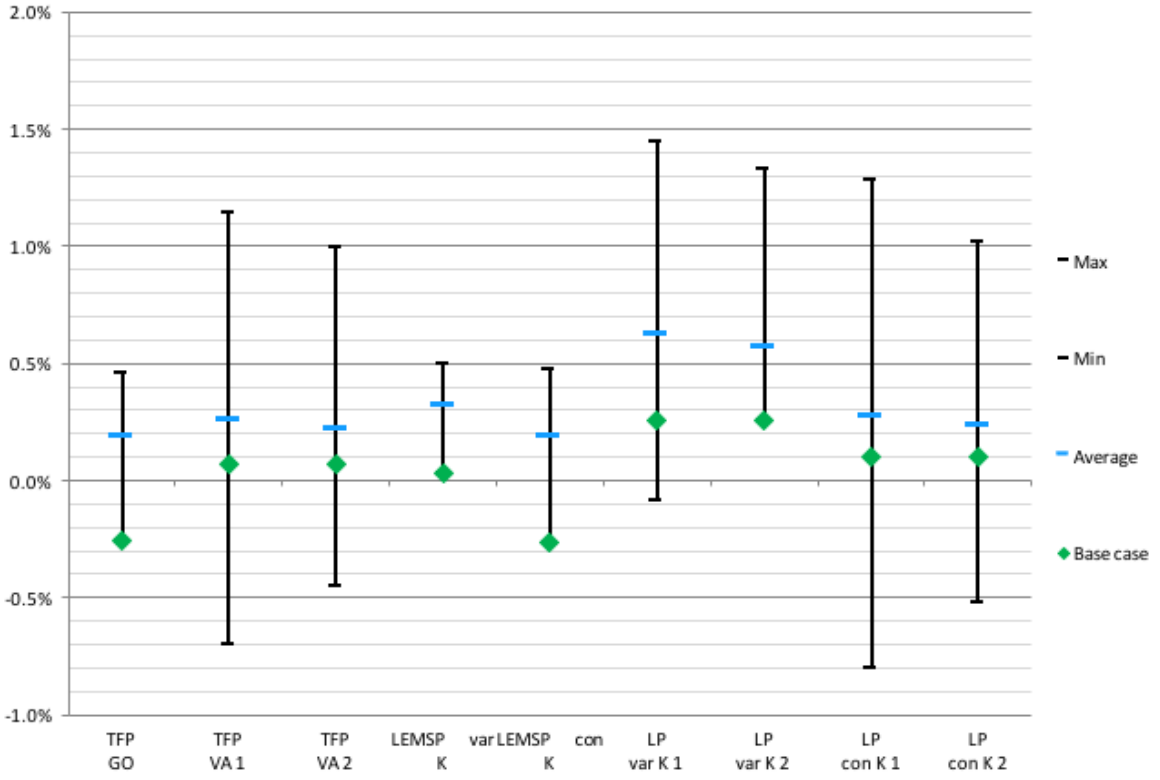
Abbreviations: GO = Gross Output, VA = Value-added; TFP = Total Factor Productivity; LEMSP = LEMS Productivity, LP = Labour Productivity; var K = variable capital, con K = constant capital. "1" and "2" refer to coverage period variants.

All of our base case results are in the range 0.22% to 0.80% per annum.

The 'base case' TFP productivity gains are in the range 0.22% to 0.58% per annum, i.e. outputs grow by 0.22% to 0.58% per annum more than inputs.

Construction

Figure 2.4: Productivity gain per annum - construction



Source: EU KLEMS dataset, CEPA analysis

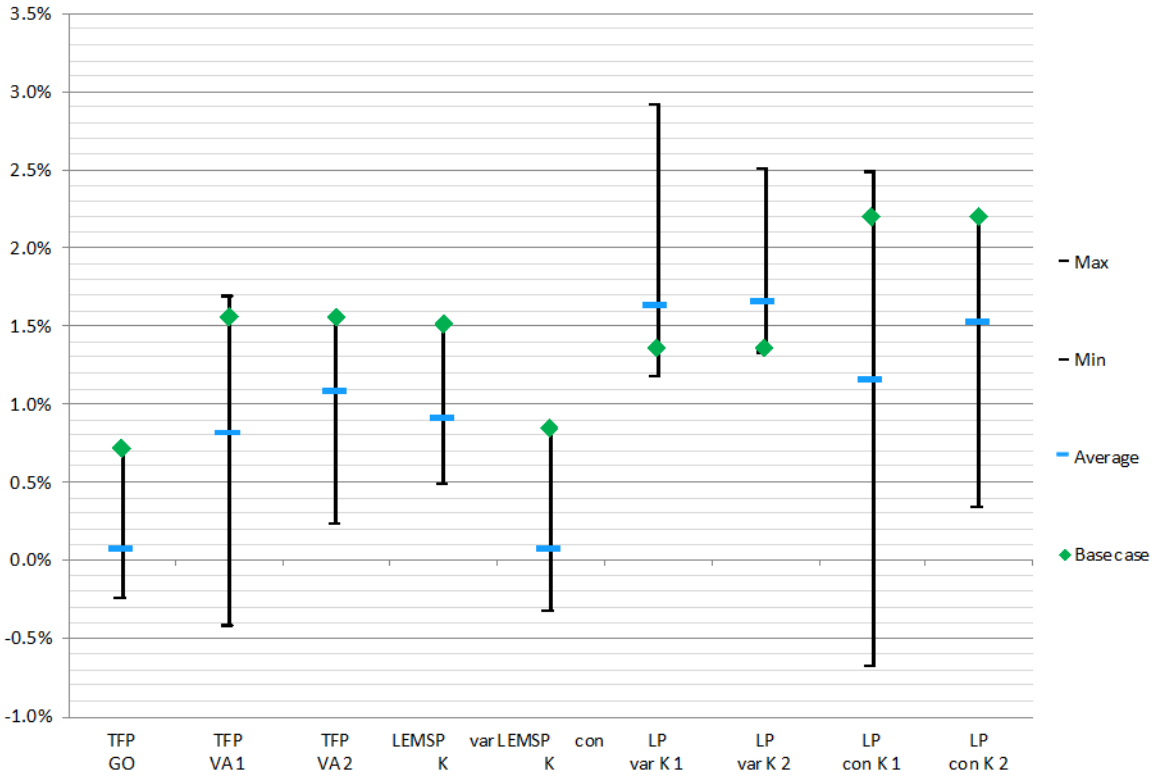
Abbreviations: GO = Gross Output, VA = Value-added; TFP = Total Factor Productivity; LEMSP = LEMS Productivity, LP = Labour Productivity; var K = variable capital, con K = constant capital. "1" and "2" refer to coverage period variants.

All of our base case results are in the range -0.27% to 0.26% per annum.

The 'base case' TFP productivity gains are in the range -0.25% to 0.07% per annum, i.e. outputs grow by -0.25% to 0.07% per annum more than inputs. Given that the TFP gross output implies negative efficiency, we propose a range of 0% (low end) to 0.07% (high end).

Professional, scientific, technical, administrative and support service activities

Figure 2.5: Productivity gain per annum - Professional, scientific, technical, administrative and support service activities



Source: EU KLEMS dataset, CEPA analysis

Abbreviations: GO = Gross Output, VA = Value-added; TFP = Total Factor Productivity; LEMSP = LEMS Productivity, LP = Labour Productivity; var K = variable capital, con K = constant capital. "1" and "2" refer to coverage period variants.

All of our base case results are in the range 0.72% to 2.20% per annum.

The 'base case' TFP productivity gains are in the range 0.72% to 1.57% per annum, i.e. outputs grow by 0.72% to 1.57% per annum more than inputs.

3. REGULATORY DETERMINATIONS

3.1. Introduction

In this section, we briefly look at efficiency targets set in GB regulatory regimes (typically for comparable networks, often privatised). Where possible, we also present the achieved level of efficiency by control period, as well as the targets set by the sector regulator. We consider the following regulatory determinations, which we consider to be most relevant to Highways England on the basis of all having a large capex programme:

- Ofwat's determinations for the England and Wales water and sewerage companies;
- ORR's determinations for Network Rail in GB; and
- Ofgem's determinations for electricity distribution companies in GB.

We then draw out a comparative analysis of the efficiency targets set in each sector over time.

As per our earlier work on operating costs[7], in this section we consider that the most analogous price control to RIS2 for Highway's England is the third price control in other sectors which is therefore, the period our analysis focuses upon.

It should be noted that there are differences between the sectors examined in this section, such as their structure and the nature of their activities. These differences can affect the potential for efficiencies within each sector and therefore limit their direct comparability to Highways England. Given the lack of direct GB comparators, this analysis is useful high level context that is commonly used by sector regulators but more specific evidence relating to Highways England's activities and plans will be important in assessing RIS2 efficiencies.

3.2. Water and sewerage

The water regulator, Ofwat, has set price controls every five years following privatisation in 1994. The first price control was expected to run for ten years but, in response to a rapidly changing environment and much higher water company profits than anticipated, Ofwat

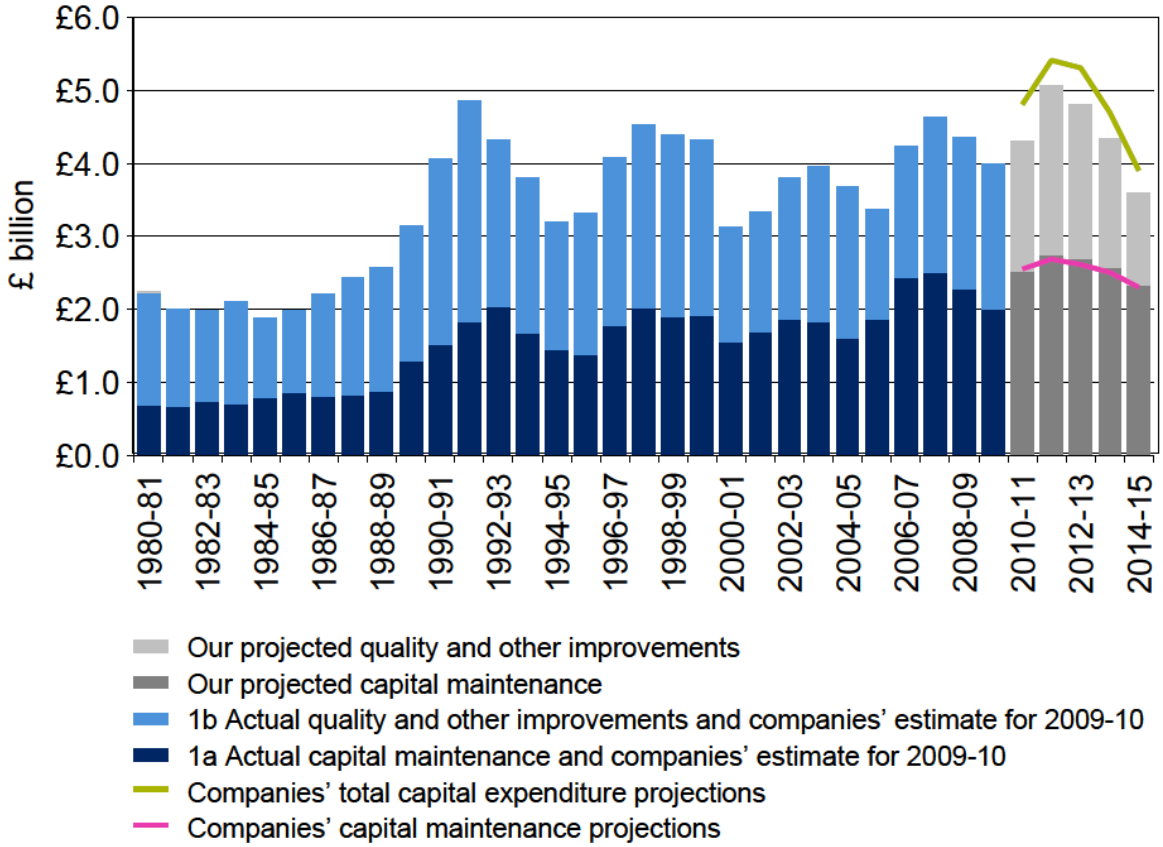
[7] The requirement for ORR to assess the levels of efficiency assumed in Highways England's budget means that the current budget setting process, has some similarity to other regulated environments in GB (such as rail, energy and water). At a high level, we can compare Highways England's recent performance against regulated companies after privatisation. Since Highways England was under significant cost pressure between 2010 and 2015, as a result of the Government Spending Review, we consider 2010-15 to be comparable to the first period post-privatisation for other regulated networks. Following this, we take RIS1 to be comparable to the second 5-year period after privatisation, and RIS2 as comparable to the third. See:

CEPA (Mar 2017) "Efficiency of Highways England's Operating Expenditure: Analysis of productivity and unit cost change"

decided to review price limits at five-yearly intervals.[8] Historically Ofwat applied an RPI-X approach to the price control although recent controls have moved away from this mechanism.

The capital programme in the water industry is large, with £44bn being invested between 2015-2020.[9] While the most recent assessment considered totex (capex and opex combined), for PR09 (covering 2010-15) capex and opex were assessed separately. The figure below, taken from Ofwat's PR09 determination, shows the capital programme for 1980-2015 (2010-15 is the PR09 forecasts) split by capital maintenance and other improvements i.e. enhancements.

Figure 3.1: Actual and projected capital investment, 1981-2015



Source: Ofwat (2009) "Future water and sewerage charges 2010-15: final determinations"

Over time the proportion of capital maintenance versus enhancements has grown, to be of the order of 60:40 although this varies by company and review period.

[8] Ofwat and Defra (Nov 2015) "The development of the water industry in England and Wales" Section 6

[9] Ofwat describe a "£44bn investment in improving services, improving resilience and protecting the environment." Ofwat (Website, accessed June 2018) https://www.ofwat.gov.uk/regulated-companies/price-review/price-review-2014/final-determinations/

3.2.1. Setting efficiency targets

The approach to setting price limits has changed over time:

- Up to and including PR04 (2005-10), Ofwat used a frontier benchmarking approach.
- For PR09 (2010-15), Ofwat used the efficiency frontier for opex but moved to using the median performance as the benchmark for capex.
- For PR14 (2015-20), Ofwat changed to using the 'upper quartile' approach to benchmark all companies.

PR14 also brought a move towards a greater focus on outputs and outcomes in line with regulatory objectives, as opposed to the previous focus on efficiency targets.[10] This is partly facilitated and encouraged by the previous success in increasing efficiency since privatisation - from 1992 to 2017, the industry averaged 1.7 to 1.8% efficiency gains per year.[11] The efficiency targets set by Ofwat are shown in the table below.

Table 3.1: Summary of efficiency targets

Price review	Capex maintenance target	Capex enhancements target
PR94 (1995-00)	1.3% to 1.4% per year until 2005	
PR99 (2000-05)	0.6% to 3.2% per year	1.4% to 5.3% per year
PR04 (2005-10)	1.6%-1.9% per year	3.9%-4.4% per year
PR09 (2010-15)	0.4% to 4.2% per year (range is due to catch-up variations)	
PR14 (2015-20)	Moved to totex approach (capex + opex) – percentage targets not set explicitly.	

Sources: Ofwat final determinations for all price controls. Figures include frontier-shift and catch-up.

Ofwat's PR04 framework, for the third price control and period of focus of our analysis, was designed to encourage outperformance of regulatory expectations, but also to challenge the companies to continually improve year on year. This was administered through a 'carrot' and 'stick' approach. The 'carrot' was an incentive mechanism providing additional rewards for outperformance of cost assumptions. The 'stick' took the form of assumptions, made by Ofwat, regarding the level of efficiency savings to be included in the base price limit.

In implementing this approach, Ofwat took a view on the overall scope for efficiency improvement, which summing both catch-up and frontier-shift efficiencies, was calculated as:

- Capital Maintenance: 3.7%-4.1% per annum
- Enhancements: 3.9%-4.4% per annum

[10] NAO (Oct 2015) "The economic regulation of the water sector"
[11] Oxera (Apr 2008) "Network Rail's scope for efficiency gains in CP4"

In order to achieve an appropriate balance between 'carrot' and 'stick', Ofwat applied a proportion of the total scope for efficiency to the base price limits. This figure provided the efficiency target companies were expected to achieve ('stick'):

- Capital Maintenance: 1.6%-1.9% per annum
- Enhancements: 2.5%-2.7% per annum

The remaining scope for efficiency was applied as a potential outperformance incentive ('carrot'), allowing the companies to retain benefits resulting from outperformance of Ofwat's base assumptions in the price limits. Whilst this encouraged companies to outperform the 'stick' proportion of the scope for efficiency, it was not considered a required target.

Evidence on delivered levels of efficiency (as opposed to targets) is limited. The table below provides a summary of the main estimates of a capital unit costs analysis undertaken by Reckon[12], on the capital expenditure submissions made by water companies to Ofwat. These submissions contain estimates of the unit costs of specific capital projects that have been defined by Ofwat. A positive growth rate indicates that growth in input prices, relative to RPI, is greater than productivity growth: costs are rising relative to RPI. A negative rate indicates that productivity growth is greater than growth in input prices: costs are falling relative to RPI.

The range of reductions observed between 1997/98 to 2002/03 were large but, between 2002/03 and 2007/08 these levelled off. Whilst the time periods considered do not exactly match the regulatory periods, they suggest that for PR04 (2005-10), the third price control period, companies may have struggled to meet Ofwat's annual efficiency targets, at least for the first half of the control period.

Figure 3.2: Main estimates from analysis of cost base and output price indices

Source	Time period	Compound annual growth relative to RPI
Weighted-average growth rates in unit cost estimates from cost base submissions	1997/1998 to 2002/2003	–7.1% to –2.7%
	2002/2003 to 2007/2008	–0.9% to 1.6%
All new construction: output price index	1990 to 2007	–0.5%
New infrastructure construction: output price index	1990 to 2007	–0.7%
Construction repairs and maintenance: price deflator	1990 to 2007	1.4%
Output price indices for selected parts of manufacturing industry	1990 to 2007	–0.8%
	1970 to 2005	–0.5% to –0.2%
Construction industry: output price index	1970 to 2005	1.0%

Source: Page 6, PR09 Scope for efficiency studies, Reckon (2008).

[12]Reckon (2008) "PR09 Scope for efficiency studies"

3.2.2. Setting the capex programme

There are three components to the water and sewerage capex programme:

- *Network environment programme.* This programme is necessary to meet environmental requirements and is determined through negotiations with the Environment Agency.
- *Water abstraction management plan.* This plan involves companies estimating water demand and supply for the coming years, and if supply is lower than demand, identifying which projects will enable the company to meet the anticipated demand.
- Other projects proposed by the company to meet the objectives set by Ofwat, with Ofwat then reviewing the proposals.

This third component means that the companies have a significant degree of control over the capex programme. Although it is limited to meeting objectives set by Ofwat, the company has the freedom to determine how to achieve them.

3.2.3. Incentives

Up to and including the fourth price review, PR09, Ofwat set separate efficiency goals for opex and capex – with some differentiation between capex maintenance and capex enhancements. As noted above, for the fifth price review, PR14, Ofwat moved to a totex approach.

Ofwat uses financial incentives to encourage outperformance of these targets, via a 'sharing factor' – this means that the regulated company may share a portion of any underspend with customers (reducing bills accordingly). The sharing factor can differ by company as it depends, in part, on the accuracy of the information provided by the company to the regulator – Ofwat gives a more favourable sharing factor to companies that provide more accurate information.

3.3. Rail Industry

ORR sets price controls for the GB rail infrastructure manager every five years. The infrastructure manager is currently Network Rail but was previously Railtrack under privatisation. ORR delivers economic regulatory determinations for Network Rail every five years, and the first Control Period 1 (CP1) began in 1994. PR18 is currently ongoing; the draft determination was published in June 2018.[13]

Network Rail's capital programme is large, with approximately £14bn of renewals and £14bn of enhancements forecast for the 2014-19 period.[14] Historically the capital programmes have included a large focus on enhancements but, there have been changes for CP6 following substantial over-programming and consequent delivery issues in CP5. In particular, Network

[13] ORR (Jun 2018) "2018 periodic review. ORR's draft determination – summary of conclusions for England & Wales"

[14] ORR (Oct 2013) "Final determination of Network Rail's outputs and funding for 2014-19" p.505

Rail's Strategic Business Plan for CP6 centres on delivering reprogrammed CP5 capex and greater investment in renewals, with the enhancement programme being commissioned separately to the price review and developed more closely with funders on an ongoing basis throughout CP6.

Previous ORR determinations were set by reference to RPI, in accordance with common regulatory practice and in recognition of Network Rail's RPI-linked debt. For CP6 ORR will use CPI, given the recent de-designation of RPI as a national statistic and the re-categorisation of Network Rail, meaning it no longer has RPI-linked debt.

3.3.1. Setting efficiency targets

In efficiency terms, ORR effectively reset the efficiency clock post Hatfield, with CP3 becoming equivalent to the first control period post privatisation[15]. ORR uses a mix of techniques to set efficiency targets for Network Rail but, the company has a mixed history in terms of delivery against them, in part this results from major changes in the industry e.g. renationalisation and safety incidents such as Hatfield which have acted to break the trend in efficiency results.

In the table below, we present the efficiency targets set for Network Rail over the period 2004-2019.

Table 3.2: Efficiency targets (and actuals) for Network Rail

<table>
<tr><th></th><th colspan="5">Average annual efficiency target (including frontier-shift)</th><th>Efficiency achieved</th></tr>
<tr><td rowspan="2">2003 (2004-2009, CP3, PR03)</td><td>Controllable opex 6.9% per year</td><td>Renewals 6.9% per year</td><td>Maintenance 8.3% per year</td><td>Enhancements
Unclear</td><td rowspan="2">At PR08 ORR stated OMR savings of "nearly 30%" achieved in last five years</td></tr>
<tr><td colspan="3">Average of 7.2% per year - ORR stated this is "challenging but achievable"</td><td></td></tr>
<tr><td rowspan="2">2008 (2009-2014, CP4, PR08)</td><td>Support and opex 3.4% per year</td><td>Renewals 5.3% per year</td><td>Maintenance 3.9% per year</td><td>Enhancements
16% over 5 years (~3.4%-5.6% p.a.)</td><td rowspan="2">At PR13 ORR stated that Network Rail was likely to miss the target, achieving 18% (against a target of 21%) over five years – 3.9% per year on average.</td></tr>
<tr><td colspan="3">Average of 4.6% per year.</td><td></td></tr>
<tr><td rowspan="2">2013 (2014-2019, CP5, PR13)</td><td>Opex 3.9% per year</td><td>Support 5.6% per year</td><td>Renewals 4.4% per year</td><td>Maintenance 3.4% per year</td><td>Enhancements
Nichols suggested 3.7% over 5 years (~0.8-1.3% p.a.)</td><td rowspan="2">In 2017, ORR stated that efficiency had declined by 4% over three years.</td></tr>
<tr><td colspan="4">Average of 4.1% per year.</td><td></td></tr>
</table>

[15] The reset hypothesis is discussed in Oxera (Apr 2008) "Network Rail's scope for efficiency gains in CP4"

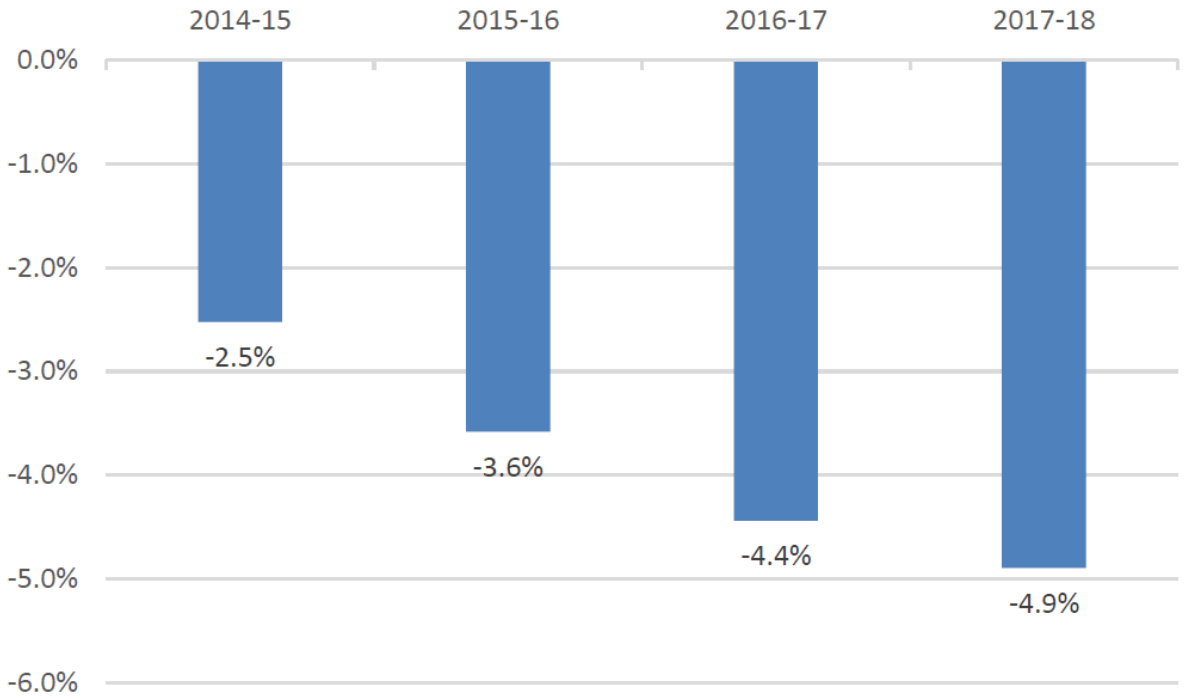
	Average annual efficiency target (including frontier-shift)		Efficiency achieved
2018 (2019-2024)	Average of 2.1% per year.		n/a

Source: ORR final determinations (PR18 draft determination) and interim updates.

Network Rail is very unlikely to meet its CP5 efficiency targets due to poor CP5 performance to date. ORR stated in 2017 that Network Rail's core efficiency had declined by 4.4% over three years (approximately 1.4% per annum), rather than improving as anticipated in the determination. Network Rail did make some efficiency savings in operations support and maintenance (2.7% per annum) but, this was outweighed by the 5.4% per annum decline in the efficiency of renewals. While there are external factors, such as the increasing costs of renewals including electrification, there are also performance concerns. Network Rail anticipates making some efficiency savings on its current position by the end of CP5, but it will remain less efficient than at the start of period.

The graph below, taken from ORR's most recent monitoring report on the performance of Network Rail, illustrates this decline in efficiency performance (negative numbers in this chart refer to a loss of efficiency).

Figure 3.3: Network Rail's efficiency compared to the start of CP5



Source: ORR[16]

[16] ORR (2018) "Network Rail Monitor: Quarters 3-4 of Year 4 of CP5 15 October 2017 to 31 March 2018"

The recently published PR18 draft determination for CP6 raises Network Rail's efficiency target overall from 8%, proposed by the company, to 10%. The draft determination for PR18 aims that by the end of CP6 (2024), Network Rail's efficiency will return to the level achieved at the start of CP5 (2014).

3.3.2. Setting the capex programme

The process for determining the capital enhancements programme in rail is analogous to that which DfT and ORR follow for Highways England. HMT and DfT set a level of funding available to Network Rail and, alongside wider objectives, DfT defines a set of enhancement projects that it expects Network Rail to deliver, i.e. the company has limited freedom to define its own enhancements, though it decides how to deliver them. Historically Network Rail has had greater freedom, within financial limits, to decide what renewals work should be undertaken and how and when that work would be delivered. In this area ORR's focus has been on the delivery of a safe and sustainable network and this process has involved improving the quality of asset management at Network Rail, so that decisions on renewals are underpinned by a strong and evidenced rationale for intervention.

3.3.3. Incentives

ORR highlighted at the most recent completed price control (PR13) that it might be possible for Network Rail to outperform the determination, with financial incentives in place to encourage this – it is able to keep at least part of any efficiency savings it makes beyond the efficiency targets.[17] These sharing mechanisms determine the proportion of outperformance that Network Rail may retain. Efficiencies in enhancements will be shared with the taxpayer/consumers symmetrically – Network Rail keeps 25% of any underspend and is responsible for 25% of any overspend.

At PR13, ORR sought to introduce a new mechanism called "route-level efficiency benefit sharing" (REBS) – where train operators could enter into commercial arrangements with Network Rail to bring about savings. The mechanism was not widely used, in part because operators were concerned about downside risk but also, because DfT was not supportive of a situation in which train operating companies could increase their returns beyond those anticipated in their Franchise Agreements.

In the draft determination for PR18, ORR stated that it will be removing the REBS mechanism as part of an overall approach to simplifying incentives and to allow the industry to develop its own flexible approach. ORR also stated that "the reclassification of Network Rail as a public-sector body has reduced the likely effectiveness of certain financial incentives on the company."

[17] ORR (Oct 2013) "Periodic Review 2013: Final determination of Network Rail's outputs and funding for 2014-19"

3.4. Electricity Distribution

Ofgem operates three network price controls:

- Electricity distribution, currently in RIIO-ED1.
- Gas distribution, currently in RIIO-GD1.
- Electricity and gas transmission, currently in RIIO-T1.

We focus specifically on electricity distribution because we consider that the distribution companies are more relevant as comparators to Highways England. Transmission is a less helpful comparator for efficiency since the transmission investment programme consists of a small number of very large/expensive projects. Ofgem assesses the cost efficiency of those projects on a 'bottom-up' basis, which may not result in a clear year-on-year trend in the efficiency challenge to the companies. In distribution however, the investment programme tends to consist of numerous smaller projects. Additionally, there are multiple distribution companies which can be used as inputs for benchmarking, providing efficiency targets that can be used as a comparison for Highways England.

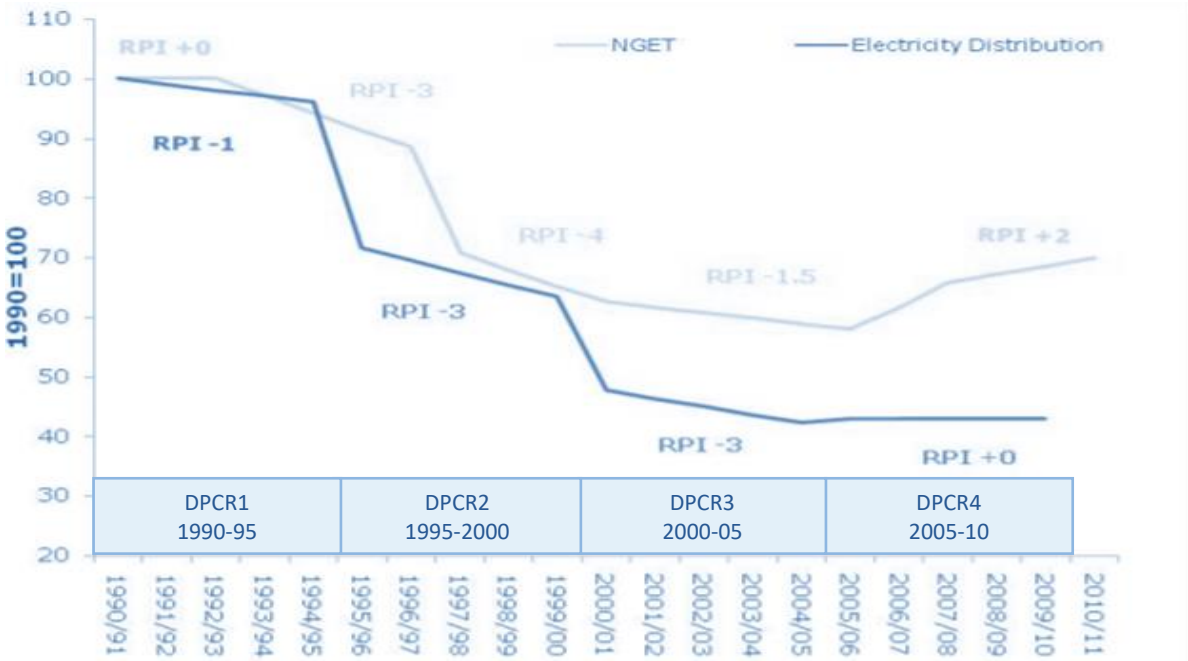
Electricity distribution is the sector that has the longest and most consistent data series on efficiency challenges set by the regulator. The first electricity distribution price control (DPCR1) was in 1990-91 and each price control, until 2015, was five-years long. RIIO-ED1 instead runs for eight years, from 2015 to 2023. The total expenditure allowed over RIIO-ED1 (totex) is around £25bn over eight years and about 70% of this is treated as capex (£17-18bn).

3.4.1. Setting efficiency targets

Efficiency was a key focus of the early regulatory determinations,[18] and the figure below illustrates this over the first three price controls: "RPI-X" demonstrates annual required efficiency savings (frontier-shift) while the jumps between price controls (at 1995-96, 2000-01, and 2005-06) represent catch-up efficiency. A frontier shift target of 3% per annum is relatively large, but was set in the context of a regulatory regime that was heavily focused on bringing down costs given the belief that companies were very inefficient.

[18] Ofgem (Feb 2009) "Regulating energy networks for the future: RPI-X@20. Performance of the energy networks under RPI-X." Executive summary.

Figure 3.4: Revenue adjustments in the first four electricity transmission and distribution price controls



Source: CEPA edits to Figure 2.1 from: Ofgem (Feb 2009) "Regulating energy networks for the future: RPI-X@20. Performance of the energy networks under RPI-X.".

Since the mid-2000s Ofgem's focus has changed. While efficiency remains important, Ofgem's approach has shifted towards wider policy objectives, e.g. facilitating renewable energy. This shift, and the efficiency already achieved, resulted in a slowing of efficiency challenges in recent price controls. This can be seen in the above figure, where stable prices were allowed in DPCR4 ("RPI+0%").

The table below draws out the frontier-shift efficiency savings required of companies. These figures exclude catch-up targets, which are not set out explicitly – Ofgem bases allowed costs going forward on the performance of companies operating at the upper quartile of cost efficiency.[19] Although there are some estimates that may include catch-up efficiency for DPCR1-3, using publicly-available information it is unclear to separate out catch-up efficiency from other sources of cost reductions – and even more difficult to understand what may be applicable to capital expenditure rather than operating expenditure.[20] Therefore, we have taken a conservative view and only present frontier-shift efficiency.

Table 3.3: Efficiency targets in electricity distribution, 1990-2023

Price control	Frontier-shift efficiency
DPCR1: 1990-95	1% per year (see Figure 3.4)

[19] This is assessed by Ofgem's benchmarking models.

[20] There are suggestions that there may have been catch-up efficiency in DPCR1-3 of 1.5%-5% p.a., but it is unclear whether this is purely catch-up and whether this is applicable to capex or just opex. See: Domah, P. and Pollitt, M. G. (2001) "The restructuring and privatisation of electricity distribution and supply businesses in England and Wales: A social cost-benefit analysis"

Price control	Frontier-shift efficiency
DPCR2: 1995-2000	3% per year (see Figure 3.4)
DPCR3: 2000-05	3% per year (see Figure 3.4)
DPCR4: 2005-10	Opex only: 1.5% per year Overall: 0% per year
DPCR5: 2010-15	Opex and capex: 1% per year
RIIO-ED1: 2015-23	Opex and capex: 0.8% to 1.1% per year

Source: Ofgem regulatory determinations; Ofgem (Feb 2009) "Regulating energy networks for the future: RPI-X@20. Performance of the energy networks under RPI-X."; CEPA (Mar 2018) "Review of the RIIO framework and RIIO-1 performance".

For the current control period (RIIO-ED1), Ofgem undertook totex benchmarking, to determine appropriate frontier-shift efficiency targets (referred to as "ongoing efficiency"). It separately undertook bottom-up calculations of various capex and opex categories which provided an additional set of evidence to inform the efficiency targets. The revenue allowance set by Ofgem took into account both of these calculations.[21]

We can calculate an estimate of overall efficiency, including catch-up, for RIIO-ED1. Companies proposed their estimate of required costs for the control period, and the difference between this and the allowance set by Ofgem represents the catch-up efficiency. This ranges from -0.5% per year (for the most efficient company) to 1.4% per year (for the least efficient company).

3.4.2. Setting the capex programme

As mentioned above, the companies propose their estimated required revenue for operating the network including delivering the capex programme. Ofgem separately calculates its estimate using a weighted average benchmarking approach and a bottom-up calculation.

Ofgem does not determine an explicit capex programme, instead it sets required outcomes and outputs (e.g. quality of service, number/length of outages), and allows the companies flexibility in determining the activities required to meet these objectives.

Some outputs may be determined by a party other than Ofgem, for example the Health and Safety Executive sets standards that the industry must adhere to.

3.4.3. Incentives

To incentivise efficiency savings regulators often ensure that some of the savings will be retained by the company as additional revenue for a time-limited period (e.g. five years). In

[21] This is described in more detail in Ofgem (Nov 2014) "RIIO-ED1: Final determinations for the slowtrack electricity distribution companies Business plan expenditure assessment" e.g. Table 2.3.

RIIO-ED1, each company has a 'sharing factor' which determines the percentage of efficiency savings that the regulated company may retain (as opposed to passing through to the consumer in lower bills).[22] A similar process was also implemented in DPCR4-5. Prior to DPCR4, there was no sharing factor – the regulated companies were able to keep 100% of their efficiency savings within their cost allowances for a fixed period of five years.[23]

3.5. Summary

As per our explanation above, if we consider that the most analogous price control to RIS2 for Highway's England is the third price control in other sectors, then comparable efficiency ranges for RIS2 are as set out below:

Table 3.4: Third control period combined (CU &FS) efficiencies by sector – per annum

Sector	Renewals target	Capex enhancements target
Water (PR04 2005-10)[24]	1.6%-1.9%	3.9%-4.4%
Rail (CP5 2014-19)	4.4%	0.8%-1.3%
Energy distribution (DCPR3 2000-05)	3.0% frontier-shift efficiency *(across all cost areas) – catch-up efficiency unknown*	

In relation to delivery against targets, the evidence suggests that companies have tended to make significant savings in the early periods of regulation, with the level of savings reducing over time resulting in some regulators shifting their focus away from narrow efficiency objectives to a wider range of targets.

[22] The sharing factor is symmetric, so will also apply to any overspend.
[23] Ofgem (Mar 2014) "Policy Document: Electricity Distribution Price Control Review"
[24] The regulator identified a total efficiency scope of 3.7%-4.1% for renewals and 3.9%-4.4% for enhancements per annum. However, Ofwat only applied a proportion of that calculated total (as shown in the table above) to the price limits that companies were expected to achieve. As part of a 'carrot' and 'stick' regulatory framework they used the remaining 'carrot' proportion of this total scope to incentivise the companies to achieve this total efficiency potential, beyond the required 'stick' efficiencies.

4. HIGHWAYS ENGLAND'S RIS1 PERFORMANCE TO DATE

4.1. Introduction

In this section we consider:

- Highways England's delivery of the RIS1 capital programme to date, drawing on ORR's annual assessments of performance; and
- The scope for **future**[25] capex efficiencies, referencing a series of capability reviews that ORR has recently commissioned.
- The results in this section provide a more Highways England specific estimate of efficiency than either the productivity metrics or regulatory determinations and should perhaps, be given greater weight than the other measures considered in this report.

The estimates discussed in this section primarily relate to catch up efficiency.

4.2. ORR's reviews of Highways England' capital programme and delivery to date.

In its first review of Highway's England's performance[26] ORR noted that Highways England's capital programme, whilst then on target, was substantially back end loaded. It requested that Highways England reconsider the programme of capital expenditure as the current plan raised questions of deliverability.

ORR's second annual assessment[27] notes that Highway's England has undertaken that review. ORR reports that:

- Highways England has reviewed how it will deliver capital investment during the remainder of the road period.
- It is developing better plans, which are aimed at reducing disruption for road users and delivering better value for money. As a result, some major improvement schemes may now be considered for delivery in the next road period, while other schemes may be brought forward.

A revised capital programme has been developed and in its March 2017 Review ORR stated that:

[25] This report primarily focuses on historic data as determined by the scope. ORR's capability reviews are however forward looking estimating the scope for efficiency going forward.
[26] Covering the period April 2015-March 2016

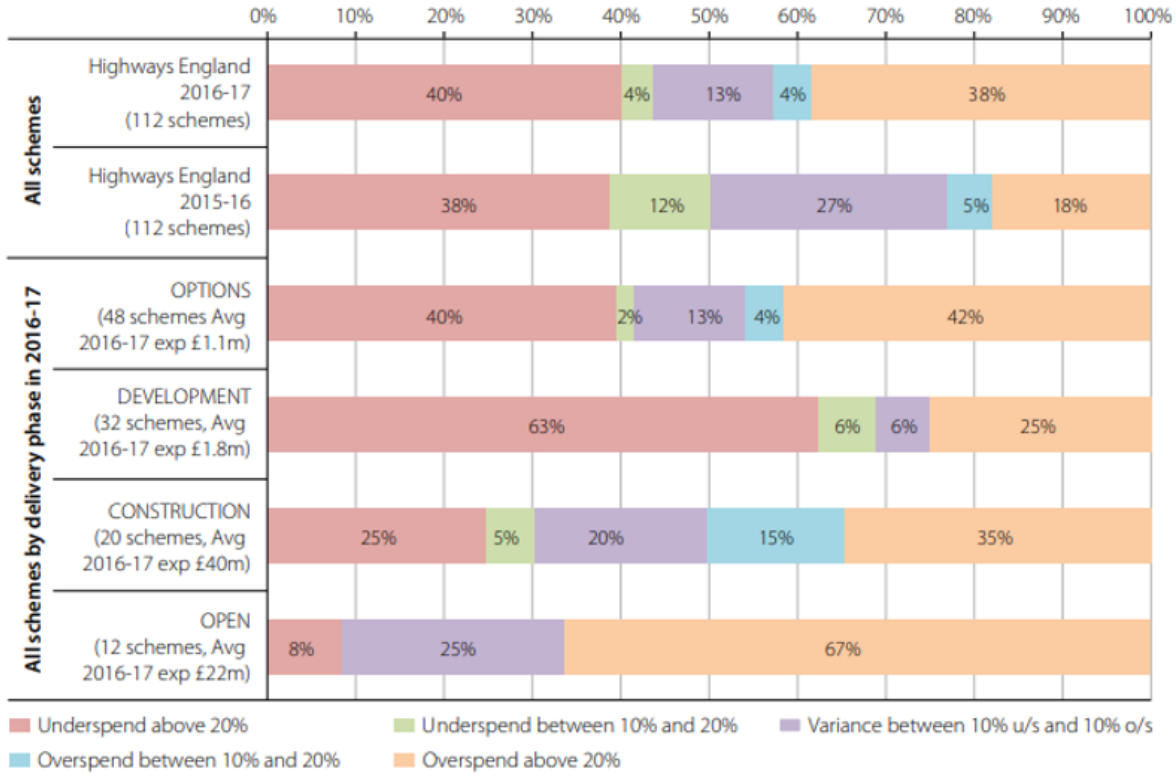
[27] http://orr.gov.uk/__data/assets/pdf_file/0004/25168/annual-assessment-of-highways-englands-performance-2017-web.pdf

'Highways England is now proposing its revised plans to government through the formal change control process. Its engagement with this process has improved during the year, but the rigour of its evidence on the need for, and impact of, change needs continued focus. Once its revised baseline plan is agreed, we expect it to be made publicly available.'

In its more detailed analysis of Highways England's performance metrics, ORR concludes that, at an overall level, the measures of capex efficiency are currently on target when compared to the plan, but it delivers an overall Amber rating for the complete RIS period. This reflects its view that there remains some risk to delivery and/or that plans are not yet fully developed.

ORR also reported on substantial variation to planned expenditures within the overall capital expenditure budget. The figure below is extracted from its annual review report:

Figure 4.1: Proportion of major schemes with large in-year variances in 2015-16 and 2016-17



Source: ORR

It is not unusual for capital project budgets to be volatile in their development period; many capex projects are not fully scoped at the start of a control period and so rely on high level estimates, which can change substantially as detailed plans emerge. However, even with back end loading, we would expect project budgets to be stabilising by the half way point of a control period. ORR indicated that it would expect Highways England to be able to explain budget variations going forward.

4.3. ORR's capability reviews

As part of its role in assessing the efficiency of Highways England, ORR has recently undertaken a series of capability reviews which consider specific business processes, comparing Highways England's approach to good practice elsewhere and estimating the scope for catch-up efficiency based on the gap between Highways England and good practice. **These estimates are not historic, rather they provide efficiency projections for the remainder of RIS1 and over the whole of RIS2**. Table 4.1 below provides a summary of the findings from each report and an estimate of efficiency arising from each process reviewed (bullets in bold):

Table 4.1: Summary of ORR's Capability Reviews:

Procurement and Contract Management	Programme and Portfolio Management	Asset Management

• Reports positively on the level of performance currently in place in Highways England and plans to the end of RP1;
• Suggests that Highways England might consider applying for CIPS Advanced level accreditation around the end of RP1, and that it would likely achieve "Silver" or "Gold" standard at that time;
• Sets out areas for improvement in RP2: most of these address increased engagement and collaboration with suppliers and increased clarity in procurement policies and strategies; and
• **Estimates that savings in RIS1 will be in line with target.**
• **Estimates that capital cost efficiency savings in the range of 1.2% to 1.8% p.a. enabled by procurement capability improvements could potentially be realised during RP2**
• This estimated efficiency range "…includes procurement's role as an enabler for efficiency delivered by other parts of the business."
	• The report concludes that Highways England "has an established and maturing programme management capability", but that capability in this area is more developed than for portfolio management;
	• A review of Highways England's efficiency register indicates that it would not be unreasonable to attribute around half of Highways England's potential savings to improved performance in programme and portfolio management;
	• **Estimates total savings of 10%-15% of Highways England's capital spend and that around half of this will be delivered by the end of RP1;**
	• **Suggests that the remaining savings (i.e. a further 5.0%-7.5%) could be delivered by the end of RP2, equating to improvements of 1.0% to 1.5% p.a. in RP2; and**
	• Indicates that majority of the improvements suggested for RP2 address portfolio management, balancing Highways England's investment programme to deliver strategic objectives.
		• The report concludes that:
		  • while Highways England's current score in key areas is weak, AMCL considers that Highways England's plans are well prioritised to improve in those key areas that are key enablers or drivers of potential Asset Management efficiencies in RP2;
		  • **savings of some 1-8% of capex available to the end of RP1, a further 7.5% - 15% available in RP2, equating to 1.5% to 3.0% p.a. in RP2; and**
		  • the focus of the savings identified is primarily opex and renewals rather than improved delivery of enhancements.

Source: CEPA analysis of reports to ORR

4.4. Overlaps between capability reviews

In considering how these reviews might be applied within an assessment of efficiency for Highway's England, it is necessary first to take into account our view that the savings predicted here may overlap and could result in double counting, if the findings were simply added together. We consider that:

- Areas for improvement of Portfolio Management and Asset Management overlap in some ways: they are both focused on delivering benefits and strategic objectives.
- However, the emphasis of actions set out in the capability reviews for the two areas is somewhat different:

    - The focus of the actions for Asset Management is primarily renewals (and opex) via, for example, optimisation of intervention types and periodicities for pavement renewals to reduce whole life costs and deliver optimum standards.
    - The focus of the actions for Portfolio Management will, for example, include attention on risk management across a portfolio of works. This seems most likely to be most valuable for enhancements/improvements.
- We therefore suggest that, for an initial view of catch-up efficiency, the estimated improvements for Asset Management are applied to renewals capex, while improvements for Programme and Portfolio Management are applied to enhancements/improvements capex.
- There is less overlap between the actions for Procurement and Contract Management with other areas where capability has been examined. At the highest level, procurement and contract management improve the efficiency of delivering specified works, while improved Portfolio and Asset Management better define and focus the specification of what should be delivered.
- Procurement and commercial improvements will apply to both renewals and enhancements/improvements. We therefore suggest that, for an initial view of catch-up efficiency, this is applied to both enhancements/improvements and renewals capex and is in addition to other efficiencies.

4.5. Summary of RIS 2 annual efficiency estimates

The annual efficiency estimates identified in the capability analysis seem likely to be catch-up efficiencies, as the reviews identify areas where Highways England is not currently adopting best practice. Improvements via frontier shift would therefore be in addition to the numbers provided below.

The figures below consider the range of efficiency that Highways England may be able to deliver in the remainder of RIS1 and over the course of RIS2.

*Table 4.2: Catch-up efficiencies for remainder of **RIS1** based on capability reviews (per annum)*

Area of Capability	Renewals	Enhancements / Improvements
Procurement and Contract Management	c.2%[28]	
Portfolio and Programme Management	0.0%	1.0% to 1.5%
Asset Management	0.5%-4%[29]	0.0%
Total	**2.5-% - 6%**	**3.0%-3.5%**

*Table 4.3: Catch-up efficiencies for **RIS 2** based on capability reviews (per annum)*

Area of Capability	Renewals	Enhancements / Improvements
Procurement and Contract Management	1.2% to 1.8%	1.2% to 1.8%
Portfolio and Programme Management	0.0%	1.0% to 1.5%
Asset Management	1.5% to 3.0%	0.0%
Total	**2.7% to 4.8%**	**2.2% to 3.3%**

Although Highways England has some scope to move funds between years, this is more limited perhaps than is the case in other sectors, such as energy and water where, the regulators provide the companies with revenue profiles for the entire control period and the companies can borrow. This provides them with greater flexibility than Highways England currently has with regards to expenditure planning.

It may be that Highways England's funding framework reduces its ability to deliver the Asset Management and Portfolio Management improvements identified, since these require a long-term focus on asset risks, benefits and whole life costs and Highways England's funding is on an annual basis, which requires Highways England to fix its expenditure early on in the financial year. Where Highways England does not have substantial financial flexibility, it may be the case that the most likely improvement for these areas is toward the lower end of the suggested range.

[28] Percentage is based on the programme discussed in Rowsell and Wright's review of programme and contract management. 2% is the average per annum improvement over the course of RIS1. In reality the programme is back end loaded and savings are expected to increase in percentage terms towards the end of RIS1

[29] AMCL's review of Asset Management capability states that the figures that it calculates are for the remainder of the RIS1 Period. For simplicity we assume that is 2 years and assign half of the potential saving to each.

ANNEX A DETAILED EXPLANATION OF PRODUCTIVITY TREND ANALYSIS

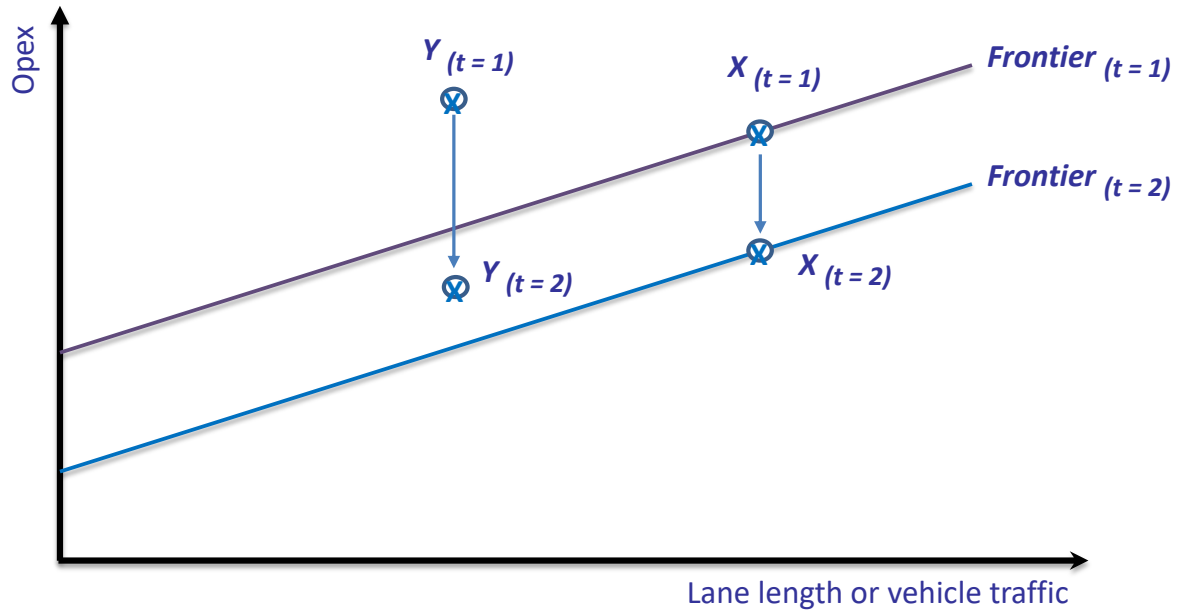
A.1. Frontier shift efficiency and catch-up efficiency

Efficiencies describe the scenario when a company is able to produce the same outputs by spending less on inputs (or producing more outputs with the same inputs). Even the most efficient companies can be expected to make efficiency improvements over time - for example, by employing new technologies or working processes. Typically, regulators assume that a company is able to achieve a degree of ongoing efficiency (or frontier shift) over time, and this is incorporated within the price control allowance.

However, at any one time, some companies will be efficient (i.e. at the frontier of efficient performance), whereas others will be lagging behind. For the latter group of companies, they will need to catch-up to the other companies if they themselves wish to be considered as efficient. This is referred to as catch-up efficiency. It is defined as efficiency improvements which are made by adopting current technology or efficient working practices, in order to catch-up to current best practice.

The chart below illustrates the difference between ongoing and catch-up efficiency improvements. In general, an efficiency is achieved by a movement downwards, i.e. generating the same level of output (e.g. passenger numbers) for lower costs. At t=1, Company X is at the efficient frontier, whereas Company Y is inefficient. At t=2, Company X is still at the efficient frontier – this change between t=1 and t=2 is *frontier shift* efficiency. At t=2, Company Y is closer to the efficient frontier, therefore it has achieved both (i) the ongoing efficiency improvements in line with the shift in the frontier, and (ii) a degree of *catch-up* efficiency, i.e. getting closer to the frontier level of performance.

Figure 4.2: Distinction between ongoing (frontier shift) and catch-up efficiency



However, whilst a relatively clear distinction can be made in theory, in practical terms it is often not possible directly to observe or distinguish between frontier shift and catch-up efficiency. There is debate around what assumptions – if any – are appropriate for identifying each component. However, there are academic studies from which simplifying assumptions can be obtained for the purposes of undertaking top-down benchmarking. In particular, academic studies[30] have suggested that the majority of total factor productivity growth in the wider economy is frontier shift, with the (smaller) remainder due to catch-up efficiency.

[30] For example, Färe et al. (1994), *Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries*, American Economic Review.

A.2. Top-down productivity metrics

We analysed historic UK productivity metrics over different time periods to assess the level of productivity achieved by other industries over time. The aim was to calculate high level productivity metrics for sectors that have similarities with Highways England's enhancements and renewals capex.

We considered several metrics based on UK-wide data across a number of years. For each of these metrics we identified the sectors that would be most similar to the components of enhancements and renewals capex. We considered a number of different permutations, including the type of measure, the choice of relevant comparator sectors, the time period of analysis, etc. These issues are discussed here.

***Data source*.** The EU KLEMS, a database containing productivity data for EU members from 1970 onwards, provided data on variables that were used to develop the productivity metrics. For each country in the database the data is at a sector (or industry) level, e.g. transport and storage.

Data releases. There have been four data releases: In 2009 (updated in 2011, using the NACE 1.1 classification system), in 2012, 2016 and 2017 (all using the NACE 2 classification system). The 2009 release has data for both *Gross output* and *Value-added* metrics (explained below), whilst the 2012, 2016 and 2017 releases only provide data on a *Value-added* basis.

NACE is a statistical classification system for economic activities occurring within the European Union. The sectors under NACE 1.1 are similar – although slightly different – to the sectors under NACE 2.

Gross output and value-added TFP. For the purposes of this study, it is preferable to consider TFP, because TFP is a total factor productivity measure, i.e. it includes capital, as well as labour and intermediate inputs. There are two different types of TFP statistics: gross output TFP and value-added TFP. Under the gross output measures of productivity, intermediate inputs are assumed to contribute to productivity growth, whereas their impact is removed in the value-added measure. Generally, gross output measures of TFP growth are the preferred concept for industry specific studies because the role of intermediates is acknowledged, and so the measure better reflects the business decisions taken by companies. However, the value-added measure has the advantage that it is not impacted by changes in the vertical structure of an industry. We have calculated both in our analysis, where data has been available, i.e. gross output measures could be calculated using the 2009 data, but not using the 2012, 2016 or 2017 data.

Partial productivity measures. Given that we are assessing the efficiency of capital intensive sectors, partial productivity measures, such as labour productivity and LEMS productivity (which considers labour and intermediate inputs), are not as applicable as TFP, as they do not include capital. These metrics however, have still been calculated for completeness, as they give insight into productivity gains and provide an alternative approach to the TFP results.

Variable or constant capital assumption. Partial productivity measures have the potential to create misleading results if substitution between inputs occurs. For example, capital substitution (automation) could results in measured gains in a labour productivity. Therefore, we calculate these partial productivity measures under the assumptions of both variable and constant capital.

Selection of comparators and weightings. The EU KLEMS website provides documents which contain a very detailed explanation of the types of activities contained within each of the sectors. We reviewed this information in detail to determine the likely best comparator sector for each component of Highways England's renewals and enhancements capex. In some cases, this was relatively straightforward, e.g. under NACE 2, there is a sector entitled Transportation and storage, which is a good proxy for Highways England's traffic management costs incurred during works. Choosing comparator sectors is not an exact science, and so judgement was required in some cases.

Table 4.4: Comparator selection and weightings under base case, for 2017 data release[31]

EU KLEMS comparator used	Weightings		Rationale
	Renewals	Enhancements	
Construction	75%	70%	Includes "construction of roads and motorways", "construction of bridges and tunnels" and "electrical installation" which constitutes the majority of Highways England's renewals and enhancements capex.
Transportation and storage	15%	10%	Includes the "operation of roads, bridges, tunnels", etc. Used as a proxy for the traffic management involved during roadworks.
Professional, scientific, technical, administrative and support service activities	10%	20%	Includes "legal, accounting, head office activities, advertising, employment activities, office admin and business support" - used as a proxy for Highways England's business costs. Also includes "architectural and engineering activities" – used as a proxy for feasibility study expenditure, and also the general design and planning costs that improvements and renewals work involves.

Once the comparator sectors were identified, the next stage of the approach involved weighting each sector according to the composition of renewals and enhancements expenditure. We reviewed previous work on cost categories to understand the high-level breakdown between them, and then sense checked this with experience from other clients. We then considered the differing nature of renewals and enhancements and how this would

[31] We note that the sectors used for the 2012 and 2009 data releases were virtually the same, although with some minor variations, e.g. certain sectors were not available.

affect the cost breakdown. Following this and discussion with ORR, the above weightings were used calculate two weighted composite indexes, to act as a suitable comparator for both renewals and enhancements. The rationale for these is as in Section 2.4.

Given that judgement was necessary when selecting comparator sectors, we ran a sensitivity on the weightings for both renewals and enhancements ('Sensitivity 1'). In these sensitivities, we increased the construction weighting for renewals and reduced it for enhancements. This allowed for a sensitivity to be provided either side of the base cases. The impact of this sensitivity on the weightings is shown below. The key changes are highlighted in bold.

Table 4.5: Impact of sensitivity on Renewals sector weightings

Sector	Weightings	
	Base case	Sensitivity 1
Construction	**75%**	**80%**
Transportation and storage	**15%**	**10%**
Professional, scientific, technical, administrative and support service activities	10%	10%

Table 4.6: Impact of sensitivity on Enhancements sector weightings

Sector	Weightings	
	Base case	Sensitivity 1
Construction	**70%**	**65%**
Transportation and storage	10%	10%
Professional, scientific, technical, administrative and support service activities	**20%**	**25%**

Section 5 and Annex B presents the results for our benchmarks for changes in productivity and cost efficiency. Overall, the sensitivity has a noticeable, although not hugely significant impact on the level the changes in productivity/cost efficiency.

A.2.1. Time period of analysis

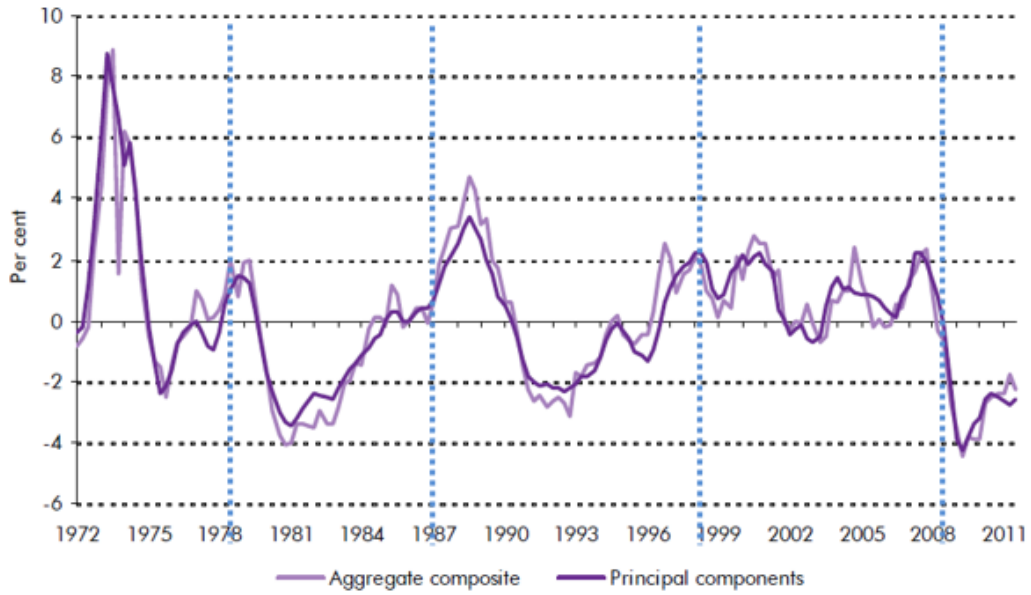
Productivity is a highly cyclical variable which shows marked variation over the business/economic cycle. In general, it is pro-cyclical, as productivity growth tends to accelerate during periods of economic expansion and decelerate during periods of recession.[32] Hence it is standard practice to consider TFP growth over complete economic cycles. Consistent with our previous work for ORR,[33] we consider the following to be complete business cycles, reckoned as a point of zero output gap to another point of zero output gap,

[32] OECD (2001), Measurement of aggregate and industry level productivity growth, p.119

[33] CEPA, Scope for Improvement in the Efficiency of Network Rail's Expenditure on Support and Operations, Report for ORR, March 2012

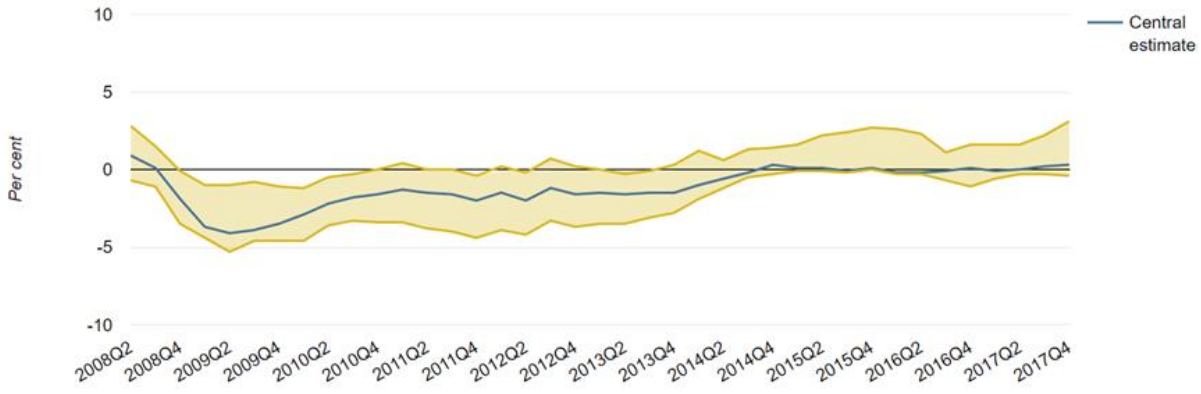
including both a peak and a trough. The business cycles since 1972 are, by this definition 1972 – 1978, 1978 – 1986, 1986 – 1997, and 1997 – 2006. This is based on the Office of Budgetary Responsibility's (OBR) data on the output gap,[34] shown in the chart below.

Figure 4.3: UK Output Gap (%) and identification of complete business cycles



Given that the 2017 EU KLEMS dataset includes data up to 2015, we considered whether it would be appropriate to include the latest data release. We used OBR's latest data to review estimates of the output gap in recent years. As shown by the chart below, the output gap reached zero in late 2014/early 2015 and has remained around that level since. Therefore, when using the 2017 EU KLEMS data, we also include the period 2006 – 2015 as the most recent business cycle in our analysis. However, given this was a period of highly unusual economic conditions, the estimate for this period may not be as precise as for other periods in our analysis.

Figure 4.4: UK Output Gap (%) and identification of complete business cycles



Source: The Output Gap, Office of Budget Responsibility, 2018

[34] Source: OBR, Estimating the UK's historical output gap, Working paper 1, Nov 2011.

We used the following time periods:

- 2017 data release: 2006-2015 (1 business cycle); and 1998-2015 (2 business cycles).
- 2016 data release: 2006-2014 (1 business cycle); and 1998-2014 (2 business cycles).
- 2012 data release: 1997-2006 (1 business cycle); and 1986-2006 (2 business cycles).
- 2009 data release: 1997-2006 (1 business cycle); 1986-2006 (2 business cycles).
- 1978-2006 (3 business cycles); and 1972-2006 (4 business cycles).

Our base case is **1998-2015** (2 business cycles) using the 2017 data, as it uses the most recent data, and does not focus solely on the period 2006-2015 which was unusual from an economic perspective, i.e. due to the global recession.

A.2.2. Data coverage

The EU KLEMS database provides an extended coverage of years, and there are also several releases of the data (2009, 2012, 2016 and 2017) which do not provide the same information each time.

- National productivity data has been released within the EU KLEMS database on several occasions over the last decade – in 2009, 2012, 2016 and 2017. We have used all of these sources in our analysis. We refer to these as different **data releases**.
- Within each data release, the data covers different **time periods**. The 2009 release is the largest dataset and contains data between 1970 and 2007. Given that productivity can be pro-cyclical, we believe it is appropriate to calculate changes in productivity based on complete business cycles, and thus there is an argument for selecting the average of the period rather than simply using all of the available data.

For completeness, our approach has been to calculate productivity benchmarks firstly using all of the available data (variant "1"), and secondly using our view of the most relevant data (variant "2"), but in a number of sensitivities.

- For the value-added (VA) measures, all four data releases provide useful information. In general, we consider the latest data release (2017) to be the most accurate. However, because the 2017 release contains the period 2006-2015, which was unusual from an economic perspective due to the global recession, we do not think it is appropriate to focus solely on the 2017 dataset.

  Therefore, in our variant "1" metrics we have used the 2012, 2016 and 2017 data releases, but have not included the single most recent business cycle on its own (2006-2015).

  For the same reason, our value-added "**base case**" for the variant "2" metrics, is the period 1998-2015. This base case uses the most up-to-date 2017 dataset and calculates an average across the *two* most recent business cycles (1998-2015).

- For the gross output (GO) measures, only the 2009 data release provides useful information, because the 2012, 2016 and 2017 releases only have value-added data. Our "**base case**" for gross output measures for the variant "2" metrics, is therefore the most recent business cycle available in the 2009 release, which is 1997-2006.

We summarise this in the following table.

Table 4.7: Data sources and periods used in different productivity metrics

Gross output or value added	Metrics included	Data releases used	Business cycles covered by the data release
Gross output	TFP GO LEMSP var K LEMSP con K	2009 data release	*1997-2006 (1 business cycle) 1986-2006 (2 cycles) 1978-2006 (3 cycles) 1972-2006 (4 cycles)
Value-added	TFP VA (1 and 2) LP var K (1 and 2) LP con K (1 and 2)	2017 data release	2006-2015 (1 business cycle) *** 1998-2015 (2 cycles)**
		2016 data release	2006-2015 (1 business cycle) **1998-2014 (2 cycles)**
		2012 data release	**1997-2006 (1 business cycle)** **1986-2006 (2 cycles)**
		2009 data release	1997-2006 (1 business cycle) 1986-2006 (2 cycles) 1978-2006 (3 cycles) 1972-2006 (4 cycles)

*Notes: * An asterisk indicates our main estimate or **base case** assumption*
***Bold text** indicates where data has been included within a variant labelled "2", e.g. LP VA 2.*

A.3. Productivity Metric Formulas

For productivity metrics: **TFP** is total factor productivity, **LEMS** represents intermediate inputs (Labour, Energy, Materials and Services), **LEMSP** is LEMS productivity, **LP** is labour productivity, **var K** stands for variable capital, **con K** stands for constant capital, **TFP_{GO}** is gross output TFP, **TFP_{VA}** is value-added TFP, output volume is denoted **Y**, labour volume is denoted **L**, capital volume is denoted **K**, volume of intermediate inputs is denoted **M**, **GO** is the value of gross output, **LAB** is expenditure on labour, **CAP** is expenditure on capital, **II** is expenditure in intermediate inputs, and $\boldsymbol{s_L}$, $\boldsymbol{s_K}$ and $\boldsymbol{s_M}$ are labour, capital and intermediate input's share of value respectively.

TFP GO

$$TFP_{GO} = {Y_{GO}}\Big/{(L^{s_L} \times K^{s_K} \times M^{s_M})}$$

TFP VA

$$TFP_{VA} = {Y_{VA}}\Big/{(L^{s_L} \times K^{s_K})}$$

Where: ΔY_{VA} = ΔY_{GO} – II. i.e. the value of output produced in a sector minus expenditure on intermediate inputs used in their production.

LEMSP var K

$$\Delta LEMSP_{varK} = \Delta Y_{GO} - s_{L2}.\Delta L - s_{M2}.\Delta M$$

Where: $s_{L2} = \frac{LAB}{(LAB+II)}$ and $s_{M2} = \frac{II}{(LAB+II)}$

LEMSP con K

$$\Delta LEMSP_{conK} = \Delta TFP_{GO} \,/\, (1 - \frac{K}{GO})$$

LP var K

$$\Delta LP_{varK} = \Delta Y_{VA} - \Delta L$$

LP con K

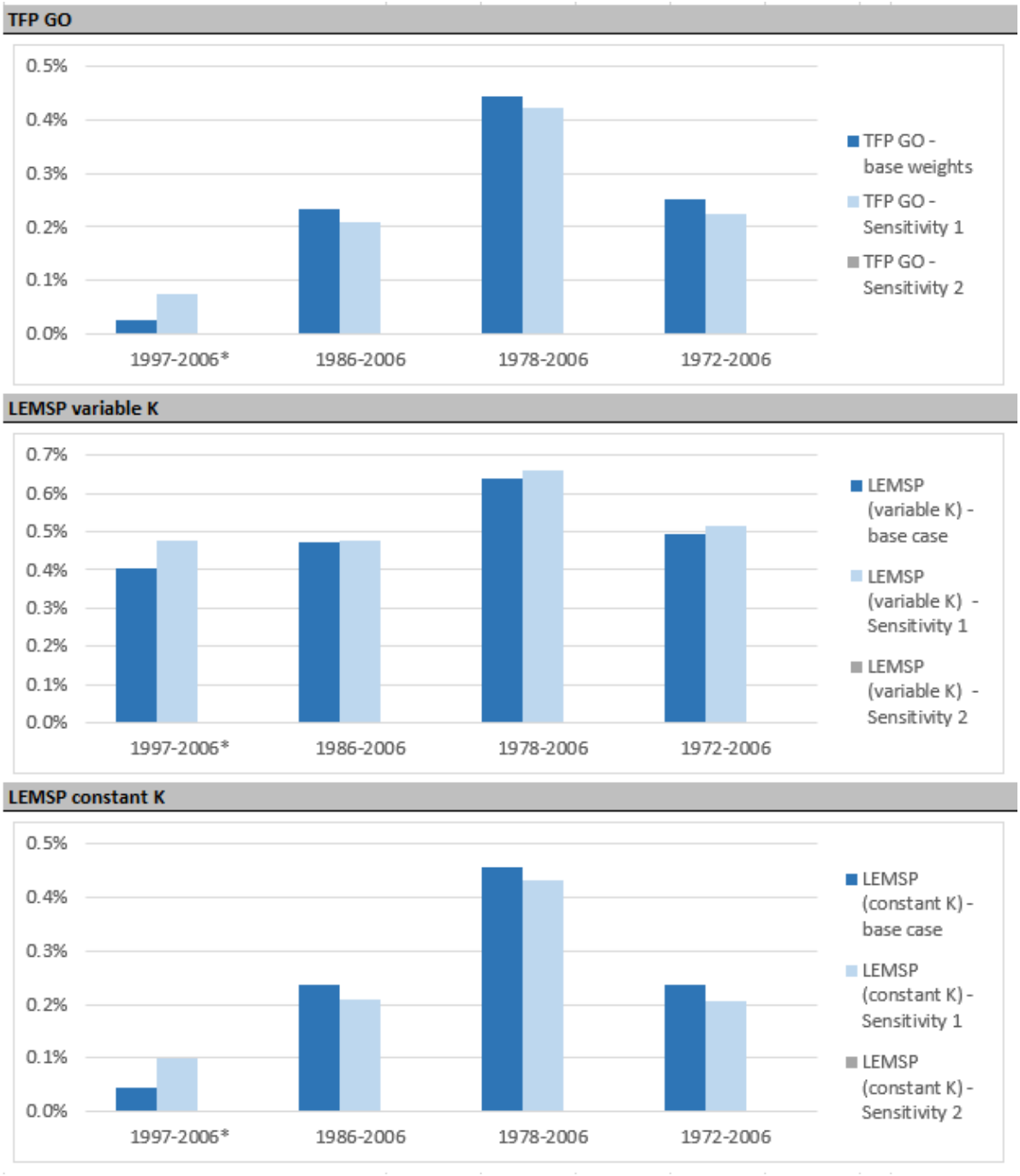
$$\Delta LP_{conK} = \Delta TFP_{VA} \,/\, (1 - \frac{K}{GO})$$

ANNEX B DETAILED ANALYSIS

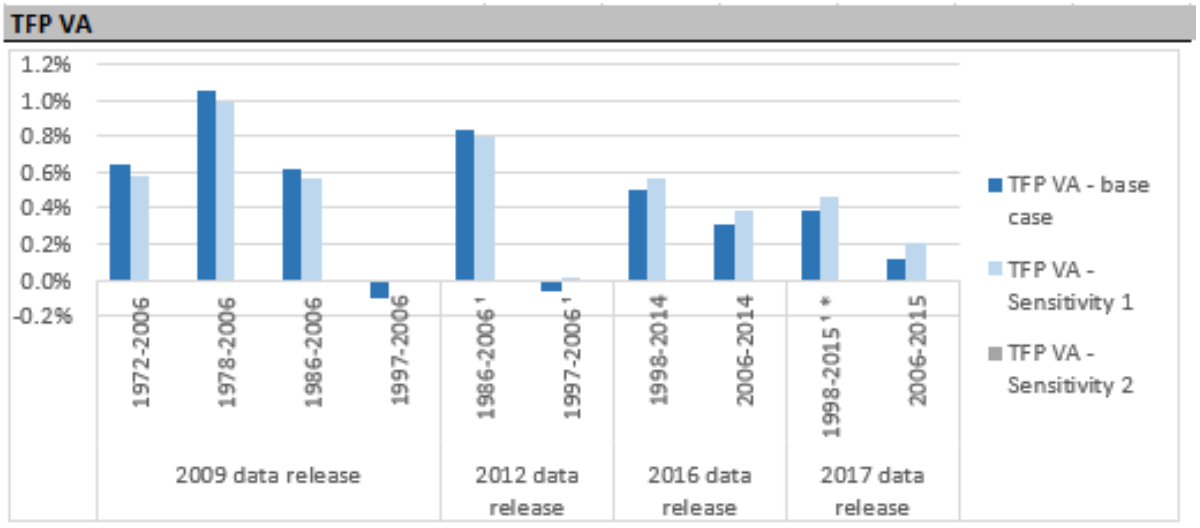
B.1. Top down productivity metrics

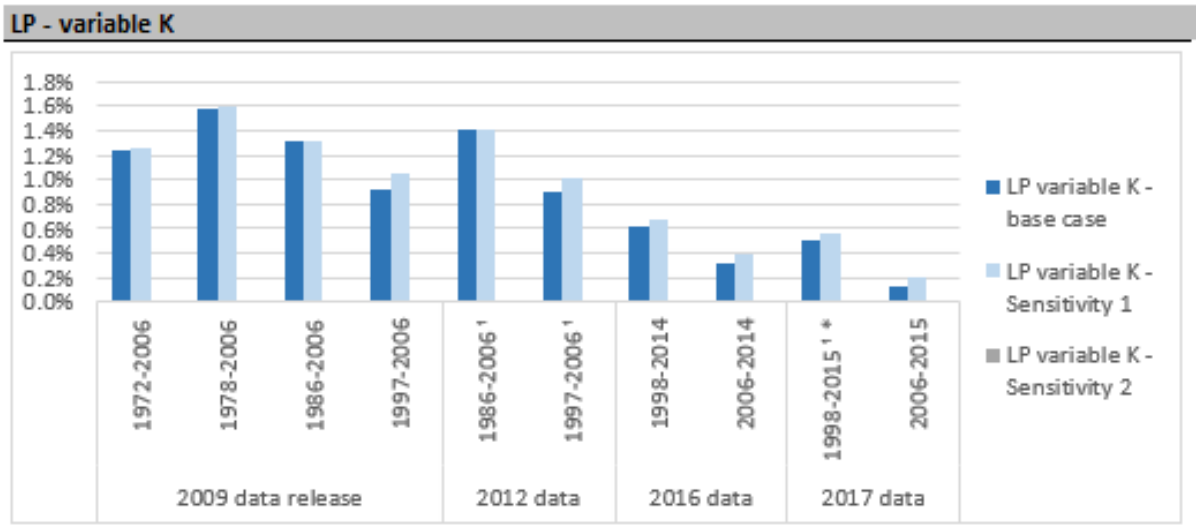
B.1.1. Enhancements

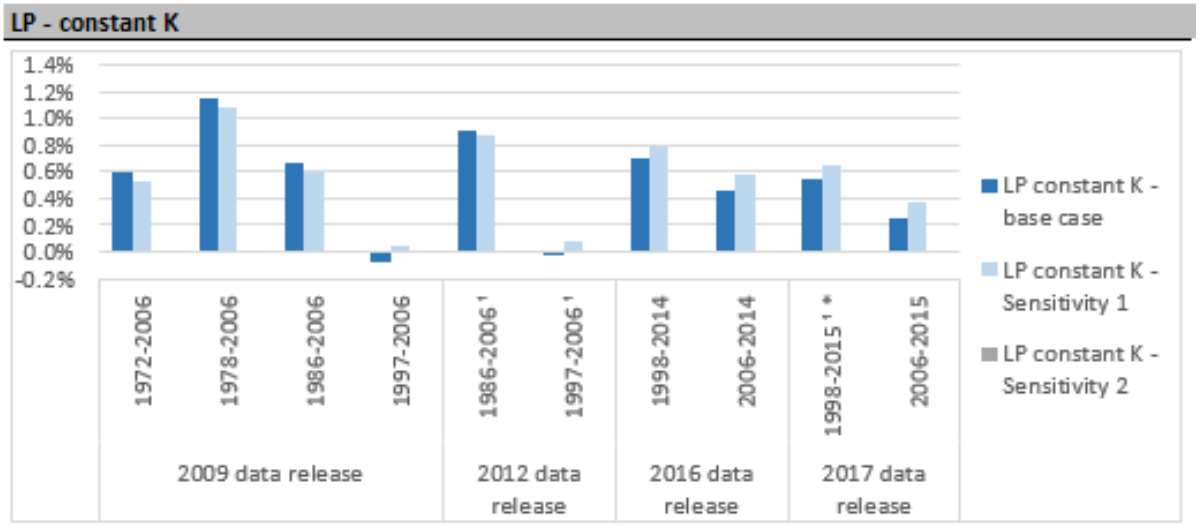
Below, we show the annual productivity gains calculated using several different benchmarks: Total Factor Productivity using the Gross Output measure (TFP GO); LEMS productivity allowing for variable capital (LEMSP variable K); and LEMS productivity under a constant capital assumption (LEMSP constant K).



Below, we show the annual productivity gains calculated using several different benchmarks: Total Factor Productivity using the Value-Added measure (TFP VA); Labour productivity allowing for variable capital (LP variable K); and labour productivity under a constant capital assumption (LP constant K).

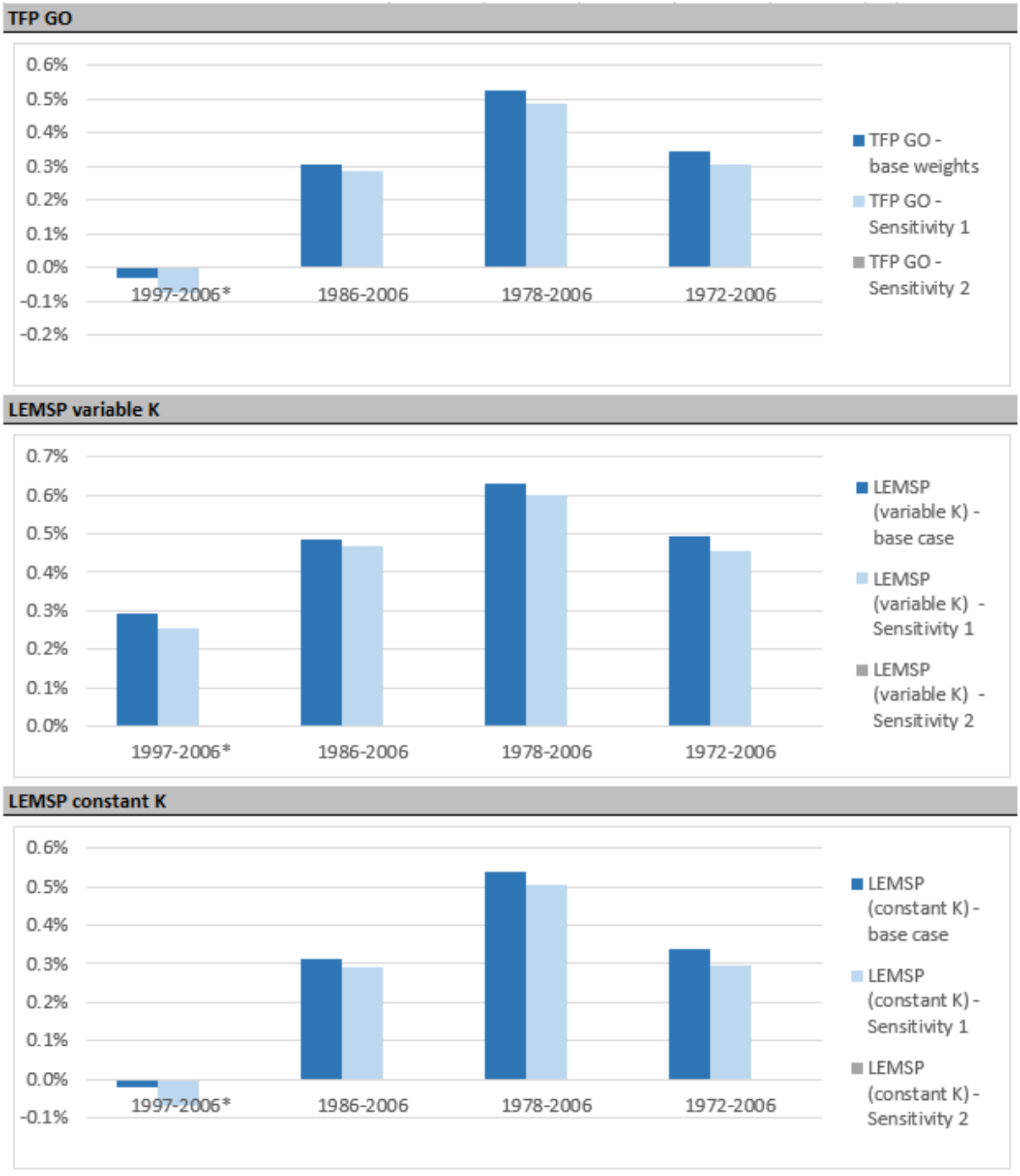






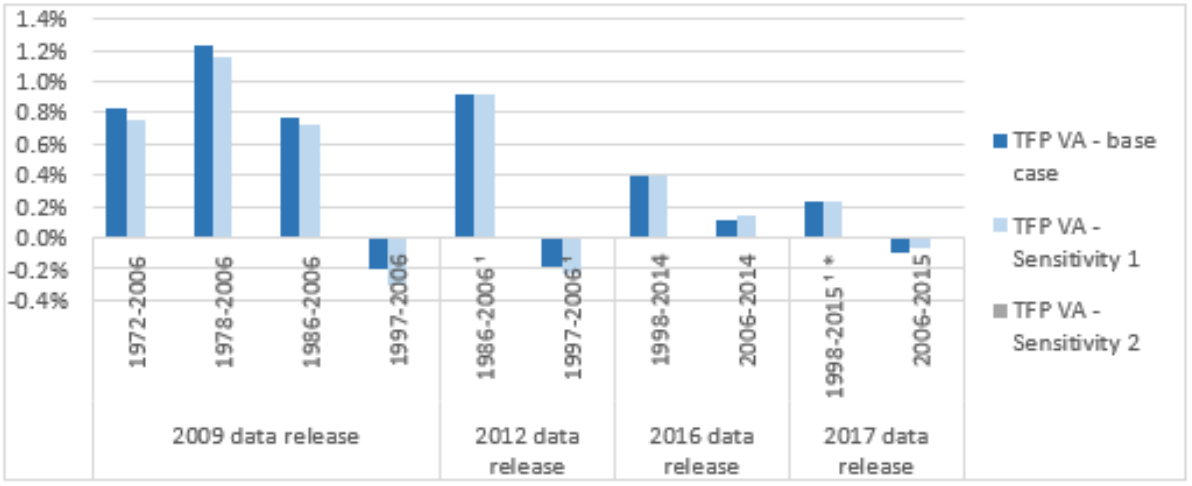
B.1.2. Renewals

Below, we show the annual productivity gains calculated using several different benchmarks: Total Factor Productivity using the Gross Output measure (TFP GO); LEMS productivity allowing for variable capital (LEMSP variable K); and LEMS productivity under a constant capital assumption (LEMSP constant K).

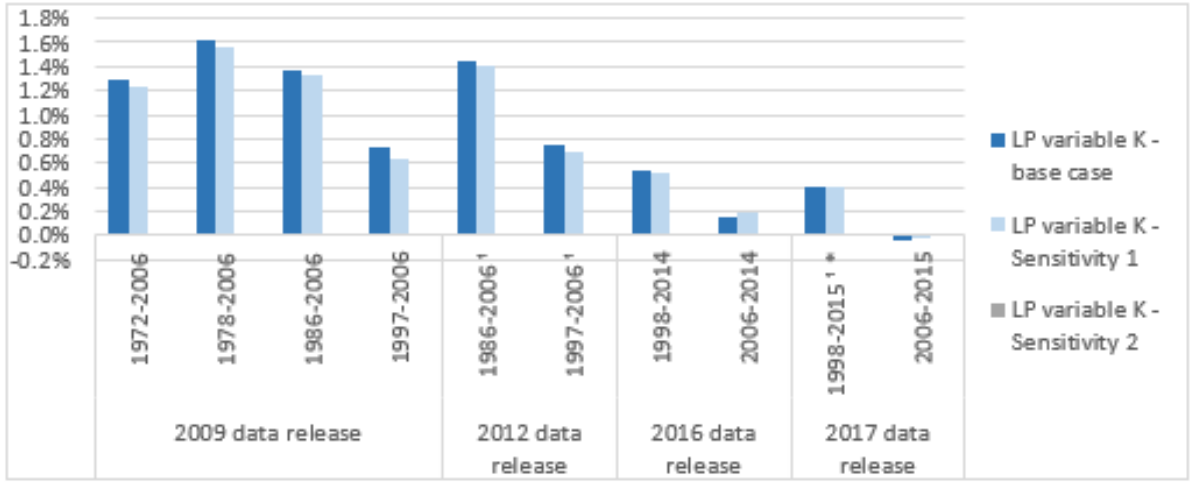


Below, we show the annual productivity gains calculated using several different benchmarks: Total Factor Productivity using the Value-Added measure (TFP VA); Labour productivity allowing for variable capital (LP variable K); and labour productivity under a constant capital assumption (LP constant K).

TFP VA



LP - variable K



LP - constant K