Appendix 8n:

The scope for frontier shift at PR19

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THE SCOPE FOR FRONTIER SHIFT AT PR19

A report for Yorkshire Water

PR19 Business Planning | February 2018

Economic Insight

This report for Yorkshire Water (Yorkshire) provides an analysis of the scope for frontier shift efficiency savings at PR19. This is based on a composite index analysis, using EU KLEMs data. We use this to provide our best view of frontier shift potential, by cost category and by price control area. In turn, this can be used as evidence to support the company's position on likely real price effects over PR19.

1. Executive Summary

THE UK'S FLAT PRODUCTIVITY PERFORMANCE SINCE THE FINANCIAL CRISIS (THE LONGEST SUCH PERIOD OF LOW PERFORMANCE IN HISTORY) MAKES FORECASTING FRONTIER SHIFT AT PR19 COMPLEX. THEREFORE, IN PART, WHETHER YORKSHIRE ELECTS TO USE ESTIMATES FROM THE UPPER END OF OUR RANGE TURNS ON 'HOW CHALLENGING' IT WANTS THIS ELEMENT OF ITS PLAN TO BE.

Our key findings relating to frontier shift at PR19 are:

- **We find that the scope for opex frontier shift savings to be between 0.0% and 1.1% pa.** For capex, we the range is between -0.3% (i.e. negative) and 0.6%.
- **Forecasts for frontier shift at PR19 are highly sensitive to the time-period from which historical data is drawn.** Here, the issue of 'what' time-period is most appropriate turns on whether the objective is to ensure that the resultant forecasts are most likely to be consistent with what might occur during the 5 years of PR19, or whether the intention is to derive forecasts that are more reflective of longer-term productivity.
- **The above issue is particularly pertinent, due to the UK's weak productivity performance since the financial crisis** (which represents the longest ever experienced 'flatline' in UK productivity).
- From an objective perspective, we consider that **most weight should be put on our low and central case scenarios, rather than our 'high' scenario.** This is because the high scenario 'omits' the last decade of low productivity performance for the UK. Therefore, it assumes a fast reversion to the UK's (higher) longer-term productivity performance. We consider this to be unlikely.
- Following from the above, however, when determining the level of frontier shift to include in its Plan (i.e. whether the company should use our central, low, or high scenarios) Yorkshire should take into consideration: (i) "how challenging" it wants this aspect of its Plan to be; and (ii) the consistency of these assumptions with other key elements of its Plan (most notably including assumptions relating to input price inflation and catch-up efficiency).
- **It is important that the overall macroeconomic context assumed in your PR19 Plan is internally consistent.** That is, relating to the above, if (for example) one assumes a cost of capital based primarily on nearer-term data – say for equity returns – then so too, one should ensure that productivity assumptions are also reflective of that same time-period. This is to avoid the possibility of business plans reflecting inconsistent assumptions that might, ultimately,

undermine the credibility and / or deliverability of those plans. As per above, this is particularly important given the post financial crisis performance of the UK economy – and one would clearly wish to avoid 'mixing' low assumed rates of return from the recent past with higher productivity performance from previous time periods.

- It is also important to emphasise that care must be taken (both when analysing productivity data and when reviewing existing studies and regulatory precedent on this issue). This is because TFP is composed of a number of factors, of which frontier shift is only one.

1.1 How 'productivity' relates to frontier shift

At PR19, companies must reach a view on their overall scope to make efficiency savings. This has two elements:

- **catch-up efficiency** (i.e. the efficiency 'gap' between an individual company within the industry and the efficiency frontier); and
- **frontier shift** (the efficiency savings that even a perfectly efficient firm could make – due to assumed productivity gains).

This report for Yorkshire addresses the first of the above issues – and can be used to inform an assessment of real price effects (in conjunction with assumptions about underlying input price inflation and catch up efficiency savings, across the price control areas).

In understanding 'frontier shift', it is helpful to be clear about the various different measures of 'productivity'.

A commonly used measure of productivity is total factor productivity (TFP). TFP provides a measure of the total change in output that is not explained by a change in (labour or capital) inputs. Therefore, TFP allows us to compare the efficiency of how firms, industries or countries deploy inputs in a multi-factor environment. TFP is usually measured by the Solow residual:

$$gY - \alpha * gK - (1 - \alpha) * gL$$

Where:

- gY is the growth rate of aggregate output;
- gK is the growth rate of aggregate capital;
- gL is the growth rate of aggregate labour; and
- α is the capital share.

Here, the crucial point to understand is that observed changes in TFP may be driven by a range of factors – and thus 'frontier shift' will only be one element that makes up total observable TFP. This point is well established in the economics literature. For example:

'An important distinction must be drawn between 'catch-up' and 'frontier shift' effects when setting prices using benchmarking techniques.'

Crew and Parker

- Crew and Parker emphasise the fact that TPF is simply a measure of total observable productivity gains – and that, consequently: *"an important distinction must be drawn between 'catch-up' and 'frontier shift' effects when setting prices using benchmarking techniques."*[1]
- Griffith et al (2006) write: *"Intuitively, there is productivity dispersion within [an] industry because establishments differ in their underlying potential to innovate and it takes time to converge towards the constantly advancing frontier. In steady-state, the frontier will be whichever establishment in the industry has highest capability to innovate. All other establishments will lie an equilibrium distance behind the frontier, such that expected productivity growth as a result of both innovation and catch-up equals expected productivity growth as a result of innovation in the frontier."*[2]
- This point is also made by Li and Waddams Price (2011), who develop an empirical analysis that decomposes TFP in mobile telecoms into its constituent parts, separating out the effects of catch-up from other drivers, such as innovation (i.e. frontier shifting technical efficiency) and competition.[3]
- Similarly, Mastromarco and Zago (2009) develop an empirical analysis to decompose the determinants of TFP shift in Italian manufacturing between: (i) technology; (ii) distance to the frontier; or (iii) frontier shift.[4]
- Coelli et al (2003) note that [an analysis of TFP in the context of economic regulation is] *"quite problematic conceptually, as most of the analytical work underlying the duality between production and cost frontiers assumes perfectly competitive markets, which is rarely the norm among regulated industries."*[5]

Similarly, the above issues are also recognised within historical regulatory determinations and submissions. For example:

- OXERA, in providing evidence relating to ongoing efficiency savings for Dutch gas and electricity transmission companies, set out: *"OPI measures reflect both productivity change and input price effects. As OPI encompasses TFP change, it may also reflect catch-up and scale effects, which may require suitable adjustment."*[6]
- *CEPA notes: "In the economy as a whole, or where there is assumed to be a reasonable amount of competition, if the sample of firms is both (i) large and (ii) random, it seems reasonable to expect that the efficiency improvement [TFP] should be largely driven by frontier shift. In these circumstances, an*

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1 *'International Handbook on Economic Regulation.' Crew and Parker, Edward Elgar Publishing (2008), page 125.*

2 *'Technological Catch-up and the Role of Multinationals.' Rachel Griffith, Stephen Redding, and Helen Simpson; Princeton (2006).*

3 *'Effect of regulatory reform on the efficiency of mobile telecommunications.' Yan Li & Catherine Waddams Price. Centre for Competition Policy and Norwich Business School, University of East Anglia (2011).*

4 *'Technology shape, distance to frontier, or frontier shift? Modeling the determinants of TFP growth.' Mastromarco and Zago. JEL (2009).*

5 *'A Primer on Efficiency Measurement for Utilities and Transport Regulators.' Coelli, Tim; Estache, Antonio; Perelman, Sergio Trujillo, Lourdes; World Bank (2013).*

6 *'Study on ongoing efficiency for Dutch gas and electricity TSOs.' OXERA (2016); page 38.*

equal number of firms ought to be moving closer to the frontier as those that are moving away from it, on average. By contrast, if the sample contains a significant proportion of companies that are commonly recognised to be experiencing catch-up, through the effect of privatisation or comparative competition, then it is appropriate to make an adjustment to the TFP figure to recognise that not all of the efficiency improvement is likely to relate to frontier shift."[7]

These issues have implications that must be addressed when assessing the scope for 'frontier shift' in practice. Methodological options include:

- **Analyse TFP trends in other sectors / countries**. Here, one is implicitly making the assumption that the comparators are competitive. In reality, no comparators will be perfectly competitive – therefore, this approach will never give a true measure of the scope for frontier shift (and, indeed, will typically overstate it). However, so long as the comparators in any index are carefully selected, the presence of 'catch-up' inefficiency is often assumed away as a simplifying assumption.

- **Use adjusted TFP comparators and decompose productivity between 'catch-up' and 'frontier' components.** This represents an augmented version of the above approach, whereby assumptions are overlaid in order to adjust the comparators to 'strip out' the catch-up element of efficiency savings.

- **Explicitly decompose TFP into its constituent parts using statistical analysis.** Methods including stochastic frontier analysis (SFA) and data envelope analysis (DEA) can be used to 'split' TFP into its various parts, so as to identify the 'frontier' element.

- **Analysis of historical productivity delivered within the industry of interest.** In principle, one could identify the scope for future frontier shift by examining historical trends in productivity within the industry of interest (in this case, the water sector). However, as above, if the sector is not considered to be competitive, this approach again raises the challenge as to how the overall observed TFP can be decomposed into its constituent parts. As noted above, the regulated monopoly status of the wholesale elements of the water value chain implies that historical TFP information, in isolation, is unlikely to be a reliable indicator of future frontier shift potential.

The above has two implications for any analysis used to assess frontier shift potential. Firstly, across all methods, it is important that care is taken to interpret the underlying evidence appropriately, so as not to erroneously conflate factors unrelated to frontier shift. Secondly, when using comparative approaches in particular, the choice of benchmark is likely to matter.

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7 *'Office of Rail Regulation (ORR) Scope for Improvement in the Efficiency of Network Rail's Expenditure on Support and Operations: Supplementary analysis of Productivty and Unit Cost Change.' CEPA (2012).*

When comparators are used, further considerations are:

- **How similar the mix of labour and capital are.** Because capital substitution can impact TFP, comparators are likely to be more valid where the underlying mix of inputs (which is sometimes **proxied by activities** undertaken) is similar. Where differences arise, adjusted TFPs can be calculated – typically either: (i) to allow for capital substitution; or (ii) to assume 'constant capital'.

- **Scale economies.** In principle, observed changes in TFP over time within an industry may, in part, be due to the realisation of scale economies, as output grows. As such, comparators are likely to be more valid where expected economies of scale are similar. In some cases, there is precedent for making adjustments, to control for differences in scale. This is typically as follows:

Volume-adjusted TFP = Unadjusted TFP - (1 – E) × (change in outputs over the period)

It is rarely the case that the data need to apply adjustments (such as those described above) is available. Instead, therefore, these issues are often 'taken into account' in the selection of comparators within a composite index.

1.2 The UK's productivity performance

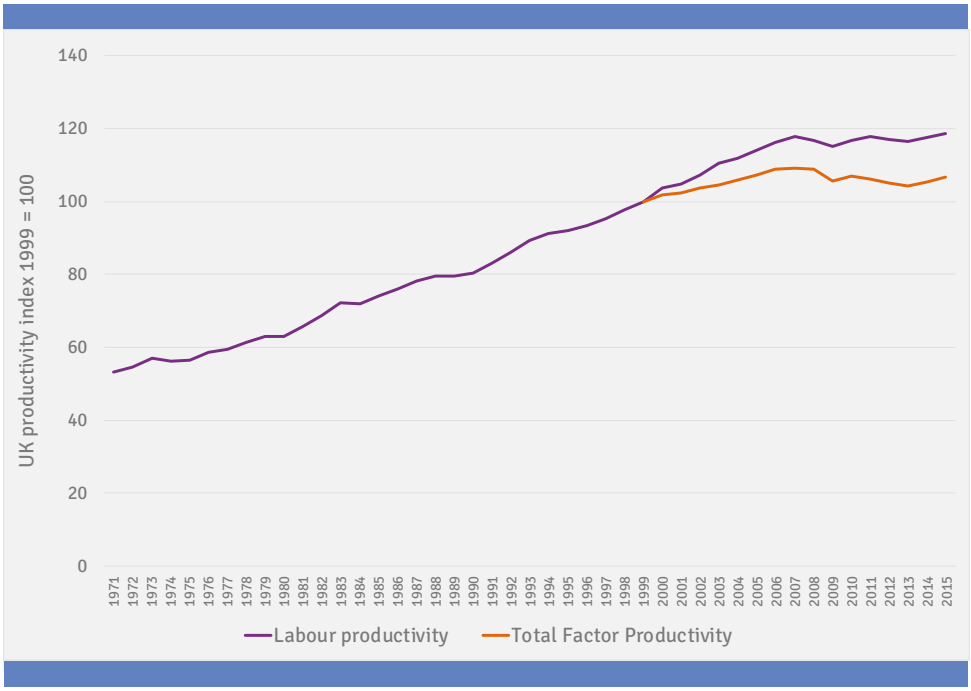
In our view, it is essential that, for any assumptions regarding frontier shift to be plausible, they must be rooted in an understanding of the UK's broader productivity performance. As such, in the following we highlight the key points to be aware of.

1.2.1 The UK's historical productivity position

Figure 1 shows the UK's TFP and labour productivity (output per hour worked) over time. A longer time series is available for the latter; back to 1971. This shows that, in the decade prior to the financial crisis and recession, labour productivity was growing in line with its long-term average (around 2% pa). However, since then, productivity has flatlined, or slightly fallen. Specifically:

- labour productivity has averaged just 0.1% pa since 2008; and
- TFP has averaged -0.3% pa since 2008.

Figure 1: UK productivity levels – annual index



Source: ONS and EU KLEMS

Importantly, the duration of the 'flat line' is longer than any other period previously experienced, including the deep recessions of the late 1980s and early 1990s.

The UK's weak productivity performance since 2008 is well documented – and has become a key policy issue in the recent past – as highlighted in the following:

- In November 2017, the OBR downgraded its GDP forecasts for the UK. This, in turn, was driven by the authority reaching a more pessimistic view regarding the outlook for productivity. *"The main reason for lowering our GDP forecast since March is a significant downward revision to potential productivity growth, reflecting a reassessment of the post-crisis weakness and the hypotheses to explain it."*[8]

'Productivity growth has been weak in almost all sectors of the economy, and negative in some.'

The IFS

- The IFS notes: *"Productivity growth has been weak in almost all sectors of the [UK] economy, and negative in some. The lack of productivity growth in the finance sector has been important, but cannot explain the majority of the recent weakness."*[9]

- In its latest outlook for the UK, the IMF stated*: "since the financial crisis, output growth has been underpinned by strong increases in employment, while productivity growth has been extremely weak…. the challenge the UK faces in this respect is sizable: even under the baseline assumption that labor productivity growth doubles to 1 percent from the ½ percent annual average since the financial crisis, potential growth will be only about 1½ percent per year in the medium run."*[10]

- A paper from the Department for Business, Innovation and Skills finds that *"[t]hanks to rapid productivity growth since the 1980s, the UK has been closing the*

[8] *'Economic and fiscal outlook – November 2017.' OBR (2017).*
[9] *https://www.ifs.org.uk/publications/7821*
[10] *'United Kingdom: Staff Concluding Statement of the 2017.' IMF (December 2017).*

productivity gap with its major competitors, however since the 2000s the rate of progress has slowed. This is reflected in measures of both labour productivity and Total Factor Productivity (TFP). In general, the productivity gap is driven by poor productivity across most sectors, rather than the UK having an unfavourable sector mix, if anything, the UK's sector mix has served to reduce the productivity gap."[11]

- The Financial Times' survey of economists in January 2018 reported that: *"more than half of all respondents said there was unlikely to be any pick-up in productivity this year."*[12]

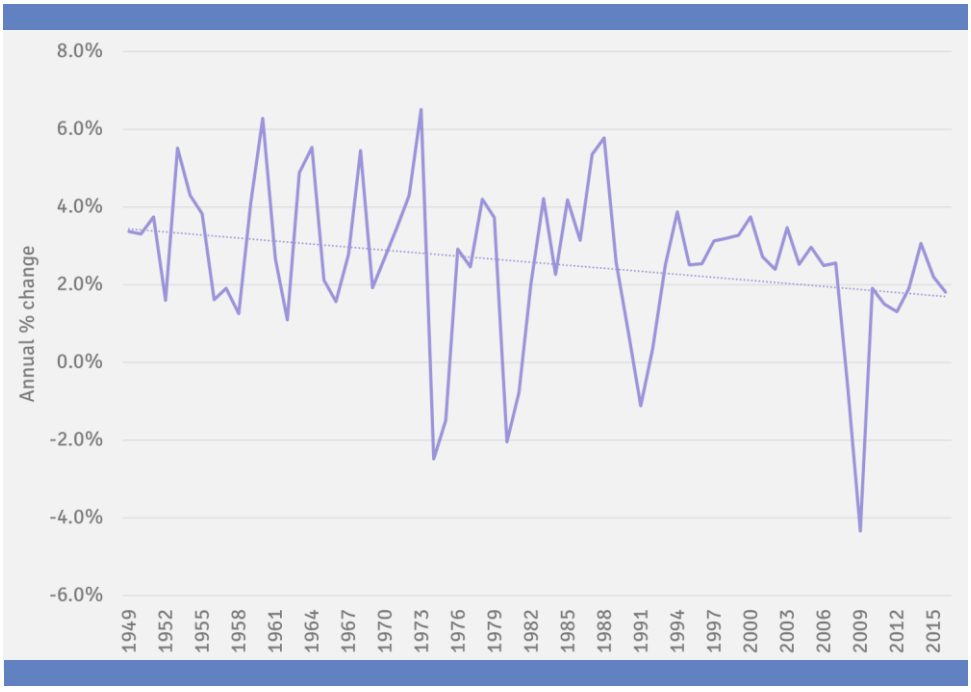
- As Harari (2017) notes: *"the flat level of productivity since the recession is particularly notable given the growth seen in previous decades".*[13]

1.2.2 Business cycles

Following from the above, **business cycles** (alternating periods of recession and recovery) are part of all economies. They are usually measured in terms of the downward and upward movements of GDP around its long-term growth trend. In simple terms, the length of a business cycle is the time-period between a peak and a trough in GDP.

Accordingly, the following chart shows the annual percentage change in real GDP in the UK since 1949, relative to its long-term trend.

Figure 2: Real GDP, UK, annual % change including long-run trend (1949 – 2016)



Source: ONS

The above chart clearly identifies 'peaks' and 'troughs' around the long-term average GDP growth rate – consistent with economic performance in the UK being cyclical.

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11 *'Benchmarking UK Competitiveness in the Global Economy.' BIS Economic Paper No. 19 (October 2012).*
12 *'UK productivity performance will be sluggish, say economists.' The FT, January 1st 2018.*
13 *'Productivity in the UK.' Daniel Harari. House of Commons Library (20 September 2017).*

Indeed, various studies have identified distinct 'cycles' within the UK economy. For example, the Economic Cycle Research Institute (ECRI) has published the peak and trough dates for business cycles across 21 different countries, including the UK, since the 1970s. These are reported in the following table.

Table 1: ECRI UK business cycle peak and trough dates, 1948 - 2016

Business Cycle	Peak or trough	Dates
1974 – 1975	Peak	September 1974
	Trough	August 1975
1979 - 1981	Peak	June 1979
	Trough	May 1981
1990 - 1992	Peak	May 1990
	Trough	March 1992
2008 - 2010	Peak	May 2008
	Trough	January 2010

Source: 'Business Cycle Peak and Trough Dates, 21 Countries, 1948-2016.' ECRI (March 2017).

1.2.3 Implications

The cyclical nature of the UK's economy – coupled with its flatlining productivity performance since the financial crisis – has important implications for any analysis used to set expected 'frontier shift' efficiency in future. In our view, the key considerations are as follows:

- Firstly, to the extent that expected frontier shift must draw on historical data, the time-period over which any such analysis is undertaken will clearly materially impact the conclusions one reaches.

- Secondly, determining 'which' time-period is appropriate thus turns on the purpose for which any forecast frontier shift analysis is being used. Most obviously:

  - If the primary purpose is to inform frontier shift potential over the relative near-term (e.g. say the 5-year period of a price control) then one should most likely attach more weight to the recent past.
  - If, on the other hand, one wanted a view of longer-term frontier shift potential, so in turn, one should use longer-term historical data to inform that analysis.

1.4 EU KLEMS composite index analysis

In this section, we set out an analysis of TFP, as reported in the EU KLEMS data (a commonly used source by regulators in setting price determinations). Here, our methodology is as follows:

- **We identify sectors within EU KLEMS that we consider to be 'comparable'** to the relevant price control areas (reflecting our views on 'input mix' and 'activities' in particular).
- **We then develop a composite TFP index** for each price control area, based on weighting the individual comparators.
- **Finally, we estimate the scope for future frontier shift for each control area,** based on the historical trends implied by our indices. Here, and with reference to the previous discussion of business cycles, a range of time periods are tested.

1.4.1 The EU KLEMS data

The EU KLEMS is the most comprehensive data source relating to TFP estimates. It includes measures of TFP growth at both an overall economy level, as well as disaggregated down to individual sectors or industries by country (including within the UK). The most recent 2017 EU KLEMS databases retains the standard EU KLEMS structure of previous rounds. However, the number of years for which growth accounting data is available is slightly reduced. For example, whereas the 2011 EU KLEMS release allowed one to calculate TFP growth since the 1970s, the current release only goes back to 1998 for the UK.

The EU KLEMS database contains information on 34 industries and eight more aggregate categories. These are set out in the following table.

Table 2: EU KLEMS industries, based on NACE Rev.2 / ISIC Rev.4

No	Description	Code
Agg	**Total industries** (all industries excluding T and U)	**TOT**
Agg	**Market economy** (all industries excluding L, O, P, Q, T and U)	**MARKT**
1	Agriculture, forestry and fishing	A
2	Mining and quarrying	B
Agg	**Total manufacturing**	**C**
3	Food products, beverages and tobacco	10-12
4	Textiles, wearing apparel, leather and related products	13-15
5	Wood and paper products, printing and reproduction of recorded media	16-18
6	Coke and refined petroleum products	19
7	Chemicals and chemical products	20-21
8	Rubber and plastics product, other non-metallic mineral products	22-23
9	Basic metals and fabricated metal products, except machinery and equipment	24-25
10	Electrical and optical equipment	26-27
11	Machinery and equipment n.e.c.	28
12	Transport equipment	29-30
13	Other manufacturing; repair and installation of machinery and equipment	31-33
14	Electricity, gas and water supply	D-E
15	Construction	F
Agg	**Wholesale and retail trade; repair of motor vehicles and motorcycles**	**G**
16	Wholesale and retail trade and repair of motor vehicles and motorcycles	45
17	Wholesale trade, except of motor vehicles and motorcycles	46
18	Retail trade, except of motor vehicles and motorcycles	47
Agg	**Transportation and storage**	**H**
19	Transport and storage	49-52

20	Postal and courier activities	53
21	Accommodation and food service activities	I
Agg	**Information and communication**	**J**
22	Publishing, audio-visual and broadcasting activities	58-60
23	Telecommunications	61
24	IT and other information services	62-63
25	Financial and insurance activities	K
26	Real estate activities	L
27	Professional, scientific, technical, administrative and support service activities	M-N
Agg	**Community social and personal services** (O-U excluding T and U)	**O-U**
28	Public administration and defence; compulsory social security	O
29	Education	P
30	Health and social work	Q
Agg	**Arts, entertainment, recreation and other service activities**	**R-S**
31	Arts, entertainment and recreation	R
32	Other service activities	S
33	Activities of households as employers; undifferentiated goods and services producing activities of households for won use	T
34	Activities of extraterritorial organisations and bodies	U

Source: 'EU KLEMS Growth and Productivity Accounts 2017 Release, Statistical Module.' Kirsten Jaeger (2017).

1.4.2 Our composite index assumptions

As frontier shift assumptions are required for each price control area, for opex we created a composite index, whereby we 'weighted' sectors within EU KLEMS based on our assessment of their comparability.

As explained previously, in considering what comparators are appropriate, a critical issue is the mix of labour and capital that are used as inputs to production. Consequently, we calculated the ratio of capex to the sum of capex and labour costs, by price control area for the industry – the results of which are shown below.

Table 3: Capex as a % of capex + labour costs

Price control area	Water resources	Water network plus	Wastewater network plus	Wastewater bioresources
Ratio of capex to capex plus labour	60% - 70%	80% - 90%	80% - 90%	80% - 90%

Source: Economic Insight analysis

As can be seen, in practice the mix of labour and capital is very similar for the network plus controls and bioresources. However, water resources is less capex intensive in relative terms. Given this, we consider that:

- the comparators included in our index for water network plus, wastewater network plus and bioresources should be the same; however
- it would be appropriate to use a somewhat different mix for water resources, drawing on sectors with lower capital intensity.

Following from the above, we used ONS data from the Annual Business Survey to calculate equivalent ratios by sector. We then 'ranked' these by relevance to the price control areas to help identify the most suitable comparators. We also took into account the similarity of the activities undertaken within the sectors. Following these steps, we arrived at the weightings set out in the table overleaf – which provided us with our composite TFP indices for opex. In the case of capex, we applied a 50/50 weighing to the construction and transport and storage sectors across all price control areas.

Table 4: Weightings used in composite EU KLEMS index – for use in opex

Sectors used for composite opex index and % weightings	Price control areas				
	Wholesale Water resource	Wholesale water network plus	Wholesale waste-water network plus	Wholesale waste-water bio-resources	Retail
Total industries (whole UK)	75%	75%	75%	75%	75%
Agriculture, forestry and fishing		12.5%	12.5%	12.5%	
Total manufacturing	12.5%				
Wholesale trade, except of motor vehicles and motorcycles	12.5%				
Real estate activities		12.5%	12.5%	12.5%	
Financial and insurance activities					12.5%
Retail trade, except of motor vehicles and motorcycles					12.5%

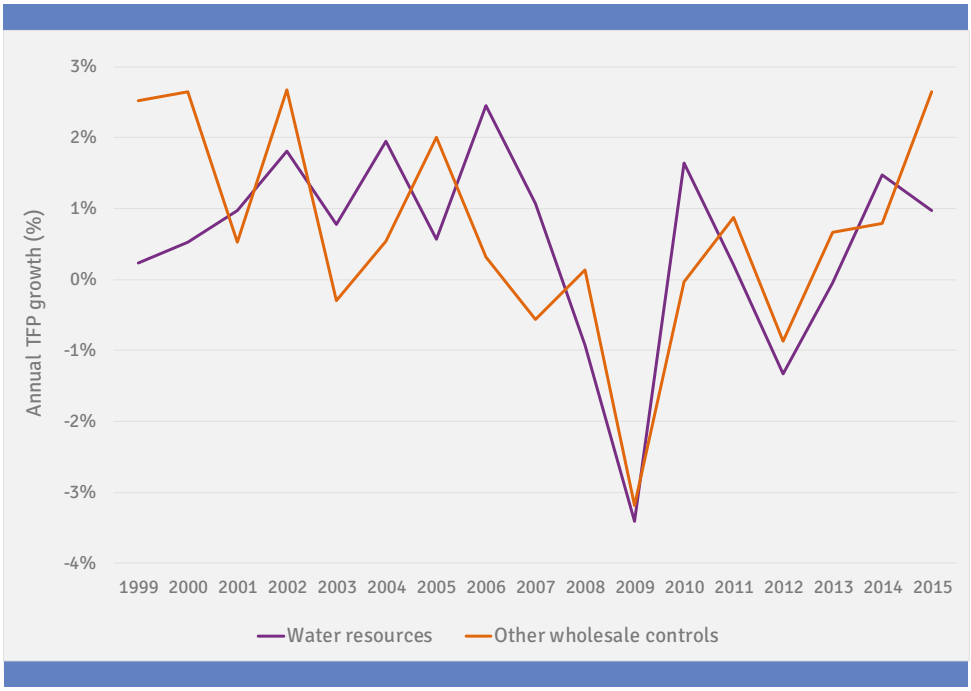
Source: Economic Insight analysis

It should be noted that, across all the control areas, we attach a 75% weight to the 'whole UK' index. This reflects:

- the subjectivity inherent in selecting comparators – and a desire not to make our results overly sensitive to the choices we made; and
- the fact that, whilst one can make arguments one way or another as to whether the water industry should either out or underperform relative to overall UK TFP, we consider that the wider economy's productivity performance provides a sensible benchmark.

The chart below shows the historical TFP performance of our opex indices. As noted above, separate figures are shown for water resources and 'all other wholesale controls'.

Figure 3: Historical TFP performance – composite opex index



Source: Economic Insight analysis

1.5 Results

Based on the evidence set in the preceding sections, the following tables set out our forecasts for the scope for frontier shift efficiency savings over PR19. These are set out by price control area; and by 'opex' and 'capex'.

We further present figures based on a 'central case'; a 'high case' and a 'low case'. In all cases, the makeup of the composite index for opex is the same. What varies is the time-period from which the data is drawn. Specifically:

- **Our central case is based on the last 16 years from 1999 to 2015.** We have chosen this period as our central estimate because it attaches an equal balance of weight to the 8-year period of low productivity growth since the financial crisis and the eight preceding years. As the EU KLEMS data does not contain a 'whole' business cycle (and because one cannot be certain when the next one will occur) we consider this to be a neutral and balanced interpretation of the data. Implicit in this assumption is that the UK's productivity will improve over PR19 relative to current performance.

- **Our high case is based on the 9 years from 1999 – 2008**. This includes the period of growth since the early 90s recession (albeit not the whole period), and the start of the 2007 recession. This is our high scenario, because it effectively 'ignores' the last decade of low productivity performance. As such, this scenario implicitly assumes that the UK quickly returns to its longer-term productivity growth trend.

- **Our low case is based on the last 8 years from 2007 to 2015**. Our low scenario assumes that the UK's productivity performance since 2007 persists in the near-term. Given the unusual length of the current 'flatlining' productivity performance, and the uncertainty arising from Brexit, we also consider this to be a plausible basis for forecasting frontier shift over PR19.

The following tables set out the results of our analysis, for each scenario above, by price control area. For business planning purposes, we consider that:

- In relation to capital related costs, Ofwat's data tables distinguish between infrastructure and non-infrastructure, capex and maintenance. In practice, we do not think it is meaningful to identify 'different' frontier shift estimates across these dimensions. As such, our frontier shift estimates for capex should be used.
- Similarly, we do not consider it appropriate to forecast any particular 'profile' of frontier shift by year. Rather, our analysis provides an indication of the 'average' amount of frontier shift productivity gain that can be achieved per annum. As such, we have reported a constant frontier shift numbers over PR19.

1.5.1 Central case frontier shift estimates

Table 5: scope for frontier shift efficiency savings **(central case)**

Year / price control area	Cost type	2020-21	2021-22	2022-23	2023-24	2024-25
Wholesale Water resources	Opex	0.53%	0.53%	0.53%	0.53%	0.53%
	Capex	0.28%	0.28%	0.28%	0.28%	0.28%
Wholesale water network plus	Opex	0.67%	0.67%	0.67%	0.67%	0.67%
	Capex	0.28%	0.28%	0.28%	0.28%	0.28%
Wholesale wastewater network plus	Opex	0.67%	0.67%	0.67%	0.67%	0.67%
	Capex	0.28%	0.28%	0.28%	0.28%	0.28%
Wholesale bioresources	Opex	0.67%	0.67%	0.67%	0.67%	0.67%
	Capex	0.28%	0.28%	0.28%	0.28%	0.28%
Retail	Opex	0.42%	0.42%	0.42%	0.42%	0.42%
	Capex	0.28%	0.28%	0.28%	0.28%	0.28%

Source: Economic Insight analysis

1.5.2 High case frontier shift estimates

Table 6: scope for frontier shift efficiency savings **(high case)**

Year / price control area	Cost type	2020-21	2021-22	2022-23	2023-24	2024-25
Wholesale Water resources	Opex	0.94%	0.94%	0.94%	0.94%	0.94%
	Capex	0.56%	0.56%	0.56%	0.56%	0.56%
Wholesale water network plus	Opex	1.05%	1.05%	1.05%	1.05%	1.05%
	Capex	0.56%	0.56%	0.56%	0.56%	0.56%
Wholesale wastewater network plus	Opex	1.05%	1.05%	1.05%	1.05%	1.05%
	Capex	0.56%	0.56%	0.56%	0.56%	0.56%
Wholesale bioresources	Opex	1.05%	1.05%	1.05%	1.05%	1.05%
	Capex	0.56%	0.56%	0.56%	0.56%	0.56%
Retail	Opex	1.10%	1.10%	1.10%	1.10%	1.10%
	Capex	0.56%	0.56%	0.56%	0.56%	0.56%

Source: Economic Insight analysis

1.5.3 Low case frontier shift estimates

Table 7: scope for frontier shift efficiency savings **(low case)**

Year / price control area	Cost type	2020-21	2021-22	2022-23	2023-24	2024-25
Wholesale Water resources	Opex	-0.04%	-0.04%	-0.04%	-0.04%	-0.04%
	Capex	-0.31%	-0.31%	-0.31%	-0.31%	-0.31%
Wholesale water network plus	Opex	0.05%	0.05%	0.05%	0.05%	0.05%
	Capex	-0.31%	-0.31%	-0.31%	-0.31%	-0.31%
Wholesale wastewater network plus	Opex	0.05%	0.05%	0.05%	0.05%	0.05%
	Capex	-0.31%	-0.31%	-0.31%	-0.31%	-0.31%
Wholesale bioresources	Opex	0.05%	0.05%	0.05%	0.05%	0.05%
	Capex	-0.31%	-0.31%	-0.31%	-0.31%	-0.31%
Retail	Opex	-0.42%	-0.42%	-0.42%	-0.42%	-0.42%
	Capex	-0.31%	-0.31%	-0.31%	-0.31%	-0.31%

Source: Economic Insight analysis

3. Evidence on productivity gains in the water sector post-privatisation

Frontier Economics (Frontier) developed a long-term analysis of productivity performance in the water industry, on behalf of Water UK.[14] The scope of Frontier's work included estimating TFP growth achieved from 1992/93 through to 2016/17. For the purpose of their work, and consistent with our comments regarding what is included in TFP set out previously in this paper, Frontier stated that producticity gains (i.e. TFP) can include:

"Efficiency improvements (i.e. fewer resources are needed as they are used more efficiently given the existing technology), technological change which reduces the efficient level of inputs requires and / or improves the characteristics and quality of the output produced, and changes in the operating environment."[15] Or, put simply, TFP can include both 'catch-up' and 'frontier shirt' – and furthermore, frontier shift (due to tehcbnological change) could maniefest itself in either or both of lower costs or improved quality / more output.

Frontier developed two TFP measures, one with no quality adjustment (i.e. it just captures 'costs' and 'output'); and one with a quality adjustment (i.e. it explicitly captures changes in quality performance over time).

The results of Frontier's TFP anlaysis for the water industry are set out in the following table.

Table 8: Summary of Frontier Economics TFP estimates for the water industry in England

Period	TFP average growth (no quality adjustment)	TFP average growth (quality adjustment)
1994-1995	2.9%	3.5%
1996-2000	2.2%	4.5%
2001-2005	0.7%	2.0%
2006-2010	1.4%	2.2%
2011-2015	-0.5%	-0.2%
2016-2017	-0.2%	0.0%
1994-2008 (Business Cycle 1)	1.6%	3.2%
2009-2017 (Business Cycle 2)	-0.1%	0.1%
1994-2017	1.0%	2.1%

Source: Frontier Economics

[14] *'Productivity improvement in the water and sewerage industry in England since Privatisation.' Frontier Economics (September 2017).*

[15] *'Productivity improvement in the water and sewerage industry in England since Privatisation.' Frontier Economics (September 2017); page1.*

From the above, it should be noted that, over the entirity of the time period looked at, the water industry delivered average annual TFP of 1.0% (no quality adjustment) and 2.1% (with quality adjustment). Of relevance to our work here, the above give an indication of a plaussible upper bound for frontier shift. That is to say, as noted elsewhere, because TFP also includes some element of catch up, it would be 'incorrect' to assume that the entirity of these figures reflect 'productivity' alone. As such, this data implies:

- Using the 'no quality adjustment' **method, historical frontier shift must have been less than 1.0% pa.**
- Using the 'quality adjustment' method, **historical frontier shift must have been less than 2.1% pa.**

FRONTIER ECONOMICS' STUDY IMPLIES THAT FRONTIER SHIFT MUST HAVE BEEN LESS THAN 0.1% PA IN THE POST CRISIS PERIOD.

Focusing more on the post crisis period, Frontier's report implies:

- Using the 'no quality adjustment' **method, historical frontier shift must have been less than -0.1% pa.**
- Using the 'quality adjustment' method, **historical frontier shift must have been less than 0.1% pa.**

So, relating Frontier's analysis back to our anlaysis set out previously, we would suggest that this implies that:

- Figures of around 1.0% should very much be considered as an 'upper bound' on frontier shift – and require one to effectively 'ignore' the post-crisis era.
- If equal weight is placed on the pre and post crisis era (i.e. an average of business cycle 1 and 2 as labelled by Frontier above), frontier shift must be below 0.75% (no quality adj) and below 1.65% (with quality adj).
- If one places more weight on the post crisis era, frontier shfit must have been flat to negative.

Because the Frontier analysis of TFP captures all elements of productivity gain – interesting and important inferences can also be drawn from it regarding what Yorkshire might consider plaussible assumptions for:

- catch up efficiency across the control areas; and
- outcomer performance (ODIs).

As the scope of this paper is focused on frontier shift, however, we do not explore these matters further here.

1.6 Regulatory precedent

We recommend that Yorkshire base its efficiency assumptions relating to frontier shift on the analysis set out in the previous sections. However, as a further source of evidence – and also as a 'cross check' – we have undertaken a review of regulatory precedent.

Here, and as noted above, a key issue is that care must be taken as to the interpretation of existing evidence and precedent. In particular, one must distinguish between:

- explicitly set assumptions regarding **frontier shift** for opex of capex (which are directly relevant);
- **expectations for overall opex and capex productivity gains** in regulated sectors (which may be indirectly relevant, if inferences relating to the frontier element can be drawn); and
- analysis of **actual productivity gains achieved** in industries (again, where the relevance of these will turn on whether frontier shift can be meaningfully inferred from the data).

In the following we summarise our review of the precedent of relevance.

1.6.1 Evidence relating to opex

The following table summarises recent regulatory decisions in relation to network companies' opex.

Table 9: Opex productivity assumptions (frontier shift) in other price control reviews

Regulator - price control	% reduction in opex per annum	What is being measured	Notes on adjustments
ORR – Network Rail, opex (CP4)[16]	0.2%	*Ongoing productivity improvements* ('frontier shift') that even the best performing companies would be expected to achieve, above that reflected in general inflation. Measured as *TFP (net of economy TFP)* based on Oxera (2007) study on the scope for CP4 efficiency improvement.	Lowered amount for maintenance and renewals (60%) of Oxera's estimate as a prudent value, to account for the possibility of double counting productivity improvements in the TFP estimates and in the input price estimates produced by LEK for Network Rail.
ORR – Network Rail, maintenance (CP4)[17]	0.7%		
Ofwat – water and sewerage (PR09)[18]	0.25%	*Continuing efficiency* - a continuing improvement factor linked to the improvement that can be expected from the leading or frontier companies.	N/A
CC - Bristol Water PR09[19]	0.9%	*Productivity improvement*	Marginally lower than the 1 per cent figure, which appeared to be the consensus view. This downward adjustment reflected the CC's view of the balance between two offsetting factors: (i) the scale of the industry capital investment programme, which at £22 billion was higher than in any other previous five-year period, presenting an opportunity for continuing efficiency improvements for the water sector; and (ii) the fact that some of the forecasts of productivity improvements reviewed were based in part on historic averages that incorporate the catch-up element of improvement in productivity which needs to be netted out from our estimate.
PPP Arbiter – underground infracos,	0.7%	unclear	unclear

16 *'Periodic Review 2008: Determination of Network Rail's outputs and funding for 2009-14.' Office of Rail and Road (October 2008).*

17 *'Periodic Review 2008: Determination of Network Rail's outputs and funding for 2009-14.' Office of Rail and Road (October 2008).*

18 *'Future water and sewerage charges 2010-15: Final determinations.' Ofwat (2009)*

19 *'Bristol Water plc: A reference under section 12(3)(a) of the Water Industry Act 1991 Report.' Competition Commission (4 August 2010).*

central costs (2010)[20]			
PPP Arbiter – underground infracos, opex (2010)[21]	0.9%	unclear	unclear
UR – water and sewerage (PC13)[22]	0.9%	*Productivity improvement* measured by EU KLEMS TFP growth rates in comparator sectors.	Adjustments for capital substitution and catch-up efficiency cancel each other out.
Ofgem – electricity and gas transmission (T1)[23]	1.0%	The *ongoing efficiency assumption* is a measure of the *productivity improvements* that are expected to be made by the network companies over the price control period. EU KLEMS sector comparators on total factor productivity (TFP) measures and partial factor productivity (PFP) measures. Review of recent regulatory reports, including a report by Reckon commissioned by the ORR in May 2011.[24]	Excluded industries (namely, utilities) from EU KLEMS comparator set where systematic catch-up was expected, i.e. where the historic productivity improvements for these industries will reflect a material element of movement to the efficiency frontier (which Ofgem's comparative efficiency assessment addresses), as well as movement of the efficiency frontier (which is the element Ofgem needs to identify).
Ofgem – gas distribution (GD1)[25]	1.0%		
UR – gas distribution (GD14)[26]	1.0%	The move of the frontier – or frontier shift – describes the *efficiency gains* resulting from companies becoming more efficient over time, e.g. through technological progress. The frontier shift in real terms can be measured as follows: *input price inflation – forecast RPI (measured inflation) – productivity increase.*	This 1.0% is the estimated average annual productivity increase.
CC – NIE (RP5)[27]	1.0%	*Annual productivity growth* based on the following evidence: (i) review of regulatory precedent; (ii) EU KLEMS growth and productivity accounts based on comparator analysis; and (iii) recent	

20 *'Northern Ireland Electricity Limited price determination A reference under Article 15 of the Electricity (Northern Ireland) Order 1992 – Final Determination.' Competition Commission (26 March 2014) Table 11.1.*

21 *'Northern Ireland Electricity Limited price determination A reference under Article 15 of the Electricity (Northern Ireland) Order 1992 – Final Determination.' Competition Commission (26 March 2014) Table 11.1.*

22 *'PC13 Annex D The Rate of Frontier Shift Affecting Water Industry Costs.' First Economics (December 2012).*

23 *'RIIO-T1/GD1: Real price effects and ongoing efficiency appendix.' Ofgem (17 December 2012).*

24 *'Productivity and unit cost change in UK regulated network industries and other UK sectors: initial analysis for Network Rail's periodic review.' Reckon (May 2011).*

25 *'RIIO-GD1: Final Proposals – Supporting document - Cost efficiency.' Ofgem (17 December 2012).*

26 *'GD14 Price Control for northern Ireland's Gas Distribution Networks for 2014-2016 Final Determination.' Utility Regulator (20 December 2013).*

27 *'Northern Ireland Electricity Limited price determination A reference under Article 15 of the Electricity (Northern Ireland) Order 1992 – Final Determination.' Competition Commission (26 March 2014).*

		business plans submitted by GB DNOs.	
Ofgem – electricity distribution (ED1)[28]	1.0% (midpoint of 0.8% and 1.1%)	*Ongoing efficiency assumption*, whereby even the most efficient DNO should make *productivity improvements* over the price control period, such as by employing new technologies. These improvements are captured by the ongoing efficiency assumption which represents the potential reduction in input volumes that can be achieved while delivering the same outputs.	
UR – water and sewerage (PC15)[29]	0.9%	*Productivity gains* which the frontier companies are expected to deliver over the price control period.	
CMA - Bristol Water PR14 (totex)[30]	1.0%	*Productivity improvements*	
UR – gas distribution (GD17)[31]	1.0% (midpoint of 0.5% and 1.5%)	*Productivity growth*: it is necessary to apply a productivity assumption to both opex and capex so as to take account of continuing efficiencies which the industry can achieve over the price control period. This is a base level of efficiency which even frontier companies would be expected to achieve as they continually improve their business over time (with new technologies and working practices for example).	
UR – electricity networks (RP6)[32]	1.0% (midpoint of 0.5% and 1.5%)	*Productivity assumption* applied to opex and capex so as to take account of continuing efficiencies which the industry can achieve over the price control period. This is a base level of efficiency which even frontier companies would be expected to achieve as they continually improve their	

[28] *'RIIO-ED1: Final determinations for the slowtrack electricity distribution companies.' Ofgem (28 November 2014).*

[29] *'Water & Sewerage Services Price Control 2015-21 Final Determination – Main Report.' Utility Regulator (December 2014).*

[30] *'Bristol Water plc: A reference under section 12(3)(1) of the Water Industry Act 1991 Report.' Competition and Markets Authority (6 October 2015).*

[31] *'Annex 6: Real Price Effects & Frontier Shift GD17 Final Determination.' Utility Regulator (15 September 2016).*

[32] *'Annex C Frontier Shift: Real Price Effects & Productivity RP6 Final Determination.' Utility Regulator (30 June 2017).*

		business over time. For example with the use of new technologies, new working practices or other means to enable their businesses to run more efficiently.	

Source: various, see footnotes

In relation to the precedent set out in the above table, some key points to note include:

- The average frontier shift assumed by regulators across all the decisions relating to opex is 0.85%.
- There seems to be a general pattern of more recent decisions settling on figures of around 1.0% pa (i.e. consistent with the upper bound of our forecast). However, older decisions seem to include lower assumptions (for example, opex frontier shift as low as 0.2% pa has been assumed by regulators during the last decade).

1.6.2 Evidence relating to capex

The following table illustrates recent regulatory decisions in relation to capex ongoing productivity.

Table 10: Capex productivity assumptions (frontier shift) in other price control reviews

Regulator - price control	% reduction in capex per annum	What is being measured	Notes on adjustments
ORR – Network Rail, renewals (CP4)[33]	0.7%	See previous table.	See previous table.
Ofwat – water and sewerage (PR09)[34]	0.4%	See previous table.	See previous table.
PPP Arbiter – underground infracos, central costs (2010)[35]	1.2%	unclear	unclear
Ofgem – electricity and gas transmission (T1)[36]	0.7%	See previous table.	See previous table.
Ofgem – gas distribution (GD1)[37]	0.7%		
ORR – Network Rail, enhancements (CP5)[38]	0.4%	*Frontier shift*: on-going productivity improvements that even the best performing companies would expect to achieve above that reflected in general inflation. In other words, over time, even the best companies can get better at what they do.	Adopted an approach that assesses Network Rail's expenditure as a whole, rather than separating out elements of expenditure
UR – gas distribution (GD14)[39]	1.0%	See previous table.	See previous table.
CC – NIE (RP5)[40]	1.0%	See previous table.	See previous table.
Ofgem – electricity distribution (ED1)[41]	1.0% (midpoint of 0.8% and 1.1%)	See previous table.	See previous table.

33 *'Periodic Review 2008: Determination of Network Rail's outputs and funding for 2009-14.' Office of Rail and Road (October 2008).*

34 *'Future water and sewerage charges 2010-15: Final determinations.' Ofwat (2009)*

35 *'Northern Ireland Electricity Limited price determination A reference under Article 15 of the Electricity (Northern Ireland) Order 1992 – Final Determination.' Competition Commission (26 March 2014) Table 11.1.*

36 *'RIIO-T1/GD1: Real price effects and ongoing efficiency appendix.' Ofgem (17 December 2012).*

37 *'RIIO-GD1: Final Proposals – Supporting document - Cost efficiency.' Ofgem (17 December 2012).*

38 *'Periodic Review 2013: Final determination of Network Rail's outputs and funding for 2014-19.' Office of Rail Regulation (October 2013).*

39 *'GD14 Price Control for northern Ireland's Gas Distribution Networks for 2014-2016 Final Determination.' Utility Regulator (20 December 2013).*

40 *'Northern Ireland Electricity Limited price determination A reference under Article 15 of the Electricity (Northern Ireland) Order 1992 – Final Determination.' Competition Commission (26 March 2014).*

41 *'RIIO-ED1: Final determinations for the slowtrack electricity distribution companies.' Ofgem (28 November 2014).*

UR – water and sewerage (PC15)[42]	0.6%	See previous table.	See previous table.
CMA - Bristol Water PR14 (totex)[43]	1.0%	See previous table.	See previous table.
UR – gas distribution (GD17)[44]	1.0% (midpoint of 0.5% and 1.5%)	See previous table.	See previous table.
UR – electricity networks (RP6)[45]	1.0% (midpoint of 0.5% and 1.5%)	See previous table.	See previous table.

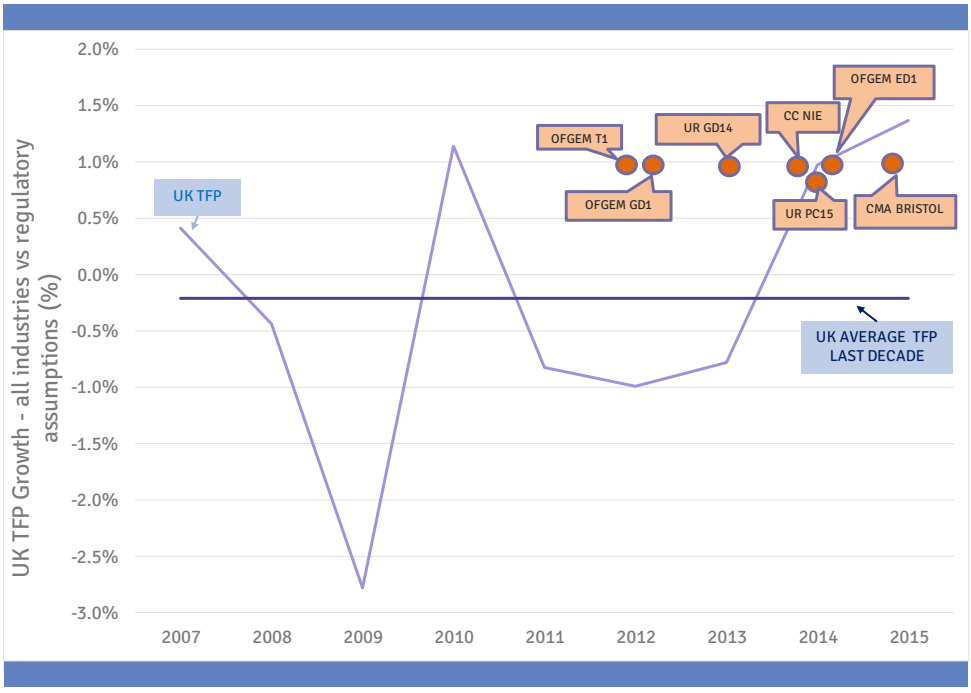
Source: various, see footnotes

1.6.3 Comparison of regulatory assumptions on productivity relative to outturn UK performance

RECENT REGULATORY ASSUMPTIONS ON PRODUCTIVITY HAVE OVERSHOT THE UK'S ACTUAL PERFORMANCE, AND ARE WELL ABOVE THE 10 YEAR AVERAGE TFP FOR THE UK OVERALL.

As noted above, in recent determinations, regulatory assumptions regarding the scope for frontier shift have seemed to converge on a figure of 1.0%pa. However, in the post-financial crisis era, and as shown in the following figure, these assumptions have systematically overshot the UK's overall productivity performance.

Figure 4: UK TFP performance vs regulatory assumptions (opex)



Source: Economic Insight analysis

In relation to the above, it is important to note that, not only have recent regaultory determinations overshot outturn UK productivity performance, they have also been

[42] *'Water & Sewerage Services Price Control 2015-21 Final Determination – Main Report.' Utility Regulator (December 2014).*

[43] *'Bristol Water plc: A reference under section 12(3)(1) of the Water Industry Act 1991 Report.' Competition and Markets Authority (6 October 2015).*

[44] *'Annex 6: Real Price Effects & Frontier Shift GD17 Final Determination.' Utility Regulator (15 September 2016).*

[45] *'Annex C Frontier Shift: Real Price Effects & Productivity RP6 Final Determination.' Utility Regulator (30 June 2017).*

well above the 10-year average TFP performance of the UK. This raises the following issues:

- It is possible that regulators have yet to appropriately recalibrate their view on productivity to reflect the post crisis climate in the UK.

- Alternatively, it could be that regualtors are (intentionally) placing more weight on longer-term evidence and / or are (intentionally) ignoring the post-crisis period.

- However, if the latter explanation is the case, as a matter of economics, the follwing would need to hold for such decisions to be credible:

    - **Firstly, regulators must be of the view that, in the determinations of relevance, it is appropriate that the core macroeconomic assumptions should reflect a long term view.** This raises important issues regarding how financeability duties should be interpreted.
    - Secondly, **following from the above other macroeconomic parameters** (most notably the WACC) determined by regulators **should be set with a similarly long-term perspective for that to be valid.**
    - Thirdly, the **regulators must believe that the "true" long-term productivity position of the UK will reflect the pre-crisis position, rather than the post-crisis position.** However, at present, economists are uncertain on this issue.

1.7 Conclusions

In conclusion, our findings are:

- Our composite index analysis implies frontier shift for opex of around 0.0% to 1.1% pa (with some variation by price control area). Similarly, for capex we find frontier shift potential to be between -0.3% to 0.6%.

- This is based on a careful consideration of comparators, consistent with the theory regarding drivers of TFP.

- Which assumptions Yorkshire should select depend on a number of considerations, including how challenging it wishes this element of its Plan to be. Objectively, however, **we think perhaps more weight should be placed on our central and low estimates, rather than our high estimates.** This is because:

  - Our low case is based on themost recent available years of data. Here, it is important to emphasise that the UK's overall productivity has flatlined since 2008 – and there are no immediate signs that this is likely to change near-term. As such, data over this period may, in fact, provide a very plausible indication of likely performance potential for PR19.
  - Our central case is based on the 16 most recently available years of data. As such, whilst still including the UK's recent low productivity performance, it also includes years prior to this. Thus, from a forecasting perspective, it implicitly includes some reversion to a longer-term average over PR19. This too, is plausible.
  - Our high case, however, omits all years after 2008 – and so ignores the current productivity slump. From a forecasting perspective, this is akin to assuming the UK will have fully returned to its long-term productivity position by PR19. This, in our view, seems unlikely.

- The Frontier Economics Report for Water UK is broadly consistent with our findings. Specifically, it found that long-term TFP in the sector has been between 1.0% and 2.1% pa (depending on the method). As the TFP measure will include the (substantial) catch-up inefficiency in the sector that has been reduced since privatisation, this **implies that frontier shift must be well below those numbers.**

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