Europe Economics

Real Price Effects and Frontier Shift – Updated Assessment

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Europe Economics
Chancery House
53-64 Chancery Lane
London WC2A 1QU

Tel: (+44) (0) 20 7831 4717
Fax: (+44) (0) 20 7831 4515

www.europe-economics.com

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Executive Summary

This report assesses the ongoing cost reductions that the water and wastewater sector should be expected to achieve over the forthcoming price control period from April 2020 to March 2025. In particular, it assesses the scope for ongoing cost reductions by analysing, for the forthcoming control period:

- Whether there is a robust case for any real price effects (RPEs).
- The scale of frontier shift the sector can be expected to achieve.

We present our methodology and results for each of these two components for wholesale controls.

This is a revised version of our work that has been updated to take account of responses from water companies and their consultants to our earlier report.[1]

Real price effects

We developed a framework to assess the case for RPEs in a robust and transparent manner. Given the existing risk-sharing mechanisms that companies benefit from and the informational advantages they possess, the framework was designed so that an RPE mechanism would only be recommended if there were a clear and robust case for including such a mechanism.

The first stage of this framework (Stage 1A) uses a set of criteria to assess the case for RPEs on an individual cost item basis to evaluate whether there are any RPEs outside management control that are not captured by indexation to CPIH.[2] The following criteria are used to assess this, with each criterion needing to be passed[3] for a given cost item for there to be a material RPE:

1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control? To assess cost items against this criterion, we consider two things:
   A. Is the expected value of the wedge between the input price and CPIH materially different from zero?
   B. OR, does the wedge between the input price and CPIH exhibit high volatility over time?
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?
3. Is the input price and exposure to that input price outside management control during the duration of the price control?

We assessed each of the following cost items separately against these criteria:

- Labour costs,
- Energy costs,
- Chemical costs, and
- Materials, plant and equipment costs.

The results of our assessment are shown in Table 0.1. This assessment has been updated to take account of responses from companies and their consultants to our earlier work. In particular:

[1] Europe Economics, "Real Price Effects and Frontier Shift", 2 January

[2] Ofwat is proposing to index prices during the next price control period to the Consumer Price Index including owner occupiers' housing costs (CPIH).

[3] Criterion 1 is divided into two sub-criteria, with only one of these sub-criteria needing to be passed in order to pass Criterion 1 as a whole.

- We have removed the materiality criterion that we used in our previous report.
- For criterion 1A, we acknowledge that the answer for labour depends on whether reliance is placed on OBR forecasts, and that the answer for energy depends on whether reliance is placed on BEIS forecasts and on the weight that is placed on pre-2010 data.
- For criterion 1B, we have extended the volatility analysis back to 2006, and acknowledge that the assessment for energy depends on the weight that is placed on pre-2011 data.
- For criterion 2, we now only consider comparable items in CPIH — such as domestic energy prices in the case of companies' energy costs — and not input costs in other sectors.
- We have applied a more systematic framework for assessing whether input prices and exposure to those input prices are outside management control, with the answer for materials, plant and equipment changing from "Fail" to "Partial pass".

The table shows that whether labour qualifies for an RPE mechanism depends crucially on whether reliance is placed on OBR forecasts of real wage growth. Historically, OBR forecasts of real wages have proved to be inaccurate and biased upwards, and hence we do not recommend an ex ante RPE allowance for labour costs. We do, however, recommend that Ofwat considers an ex post indexation mechanism for labour, using either all employees or manufacturing sector wages as a comparator, so that if there is real wage growth, the additional wage costs will automatically feed through into price limits.

Whether energy qualifies for an RPE mechanism depends on whether reliance is placed on BEIS forecasts for industrial electricity prices and on the weight that Ofwat attaches to the high wedge between growth in industrial electricity prices and CPIH prior to 2010. An ex post indexation mechanism could also be considered for energy, although it should be noted that energy is partially captured by CPIH and energy costs represent a lower share (9.4 per cent) of water company totex than labour costs (33.3. per cent).

For the other two cost items (chemicals and materials, plant and equipment costs), our framework unambiguously suggests that Ofwat should not make any RPE allowance.

Table 0.1: Summary of RPEs assessment, July 2019

Cost Item		Labour	Energy	Chemicals	Materials, plant and equipment
1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	A. Is the expected value of the wedge between the input price and CPIH materially different from zero?	Depends on whether reliance is placed on OBR forecasts	Depends on whether reliance is placed on BEIS forecasts and on weight placed on pre-2010 data	Fail	Fail
	B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Depends on weight placed on pre-2011 data	Fail	Fail
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?		Pass	Partial Pass	Pass	Partial Pass
3. Is the input price and exposure to that input price outside management control during the duration of the price control?		Partial Pass	Partial Pass	Pass	Partial Pass
Overall		**Depends on whether reliance is placed on OBR forecasts**	**Depends on whether reliance is placed on BEIS forecasts, and on weight placed on pre-2010 data**	**Fail**	**Fail**

Note: The materiality threshold (previously criterion 1) has been dropped. For criterion 2, we now only consider comparable items in CPIH.
Source: Europe Economics' analysis.

Stage 2 of the assessment framework considers the case for an RPE for wholesale totex in aggregate by analysing a relevant input Producer Price Inflation (PPI) for the water sector as a whole ('Gross Sector Input (GSI) groups input PPI for water collection, treatment and supply'). This did not find sufficiently strong evidence for an RPE, again supporting our conclusion that there should not be any ex ante RPE allowance.

Frontier shift

Our assessment of wholesale frontier shift used an approach based on Total Factor Productivity (TFP) analysis in comparator sectors using EU KLEMS[4] data on productivity. Our selection of comparators was based on two key criteria:

- The sector is competitive.
- The sector is similar in nature to the water and wastewater sector.

A different set of comparators were selected for wholesale EU KLEMS NACE 1 and NACE 2 datasets due to differences in the definition of sectors. Our final selections are set out in the Table 0.2 below.

Table 0.2: Comparator sectors

Comparator sectors in NACE 2	NACE 1 closest equivalent
Construction	Construction
Transport and storage	Transport and storage
Chemicals and chemical products	Chemicals and chemical products
Professional, scientific, technical, administrative and support service activities	*(No NACE 1 equivalent)*
Machinery and equipment n.e.c.	Machinery, n.e.c.
Other manufacturing; repair and installation of machinery and equipment	*(No NACE 1 equivalent)*
Total manufacturing	Total manufacturing

As is common practice, we undertook the TFP analysis over different time periods to account for the fact that productivity (as measured by TFP) may have some cyclical element to it. Our choice of time periods takes account of data availability in EU KLEMS. We carried out TFP growth analysis for all of the time periods shown in Table 0.3 below, and use the data in the round to derive our recommended ranges for frontier shift, with our lower bound figures informed particularly by the data for the post-crisis period (i.e. 2010-2014) in which TFP growth has been low by historical standards.

[4] The EU KLEMS Growth and Productivity Accounts dataset provides includes data on growth and productivity variables for most of EU28 countries and industries over different time periods. Available at: http://www.euklems.net/.

Table 0.3: Summary of datasets and time periods analysed

Dataset	Time periods analysed
EU KLEMS November 2009 release (March 2011 revision) **(NACE 1 dataset)**	• 1971-2007 – the entire period. • 1990-2007 – the most recent full business cycle. • 1980-1989 – the previous full business cycle. • 1980-2007 – the last two full business cycles.
EU KLEMS September 2017 release (July 2018 revision) **(NACE 2 dataset)**	• 1999-2014 – the entire period. • 1999-2007 – pre-crisis period. • 2010-2014 – post-crisis period.

Based on analysis of these comparator sectors and time periods, we derived our proposed frontier shift ranges in the water industry, as shown in Table 0.4 below.

Table 0.4: Proposed range of frontier shift in the water industry

Part of water sector	Frontier shift range
Wholesale totex	**0.6% - 1.2%**
Wholesale botex*	**0.6% - 1.4%**

Source: Europe Economics' analysis. *Includes adjustment for partial capital substitution effect.

The wholesale botex range includes an addition for a partial capital substitution effect. This adjustment is appropriate if a frontier shift estimate is applied to botex, as frontier shift estimates using TFP growth are more directly applicable to totex. For a frontier shift estimate applied to opex a full capital substitution effect would need to be applied. For botex, which includes capital maintenance as well as opex, only a partial capital substitution effect is required. Specifically, this partial adjustment represents the extra productivity gains associated with capital enhancement expenditure substituting for botex expenditure over time. This partial capital substitution effect is estimated to lie in the range of 0 to 0.2 per cent (hence the increase in the upper bound for wholesale botex of 0.2 per cent compared with the wholesale totex range).

We investigated the effect of adjusting productivity growth estimates in other sectors for scale effects, and found that the adjustment for scale effects averaged out at zero.

Our recommendation is that Ofwat should select a number towards the upper end of our range. The reasons for selecting a number towards the upper end of the range are twofold:

- Some weight should be placed on TFP growth in value added terms. We believe TFP growth measured in gross output terms is a more accurate measure of frontier shift if applied to botex or totex (which includes spending on intermediate inputs), but nevertheless that some lesser weight should also be placed on TFP growth in value added terms. Since TFP growth estimates in value added terms are by definition higher in magnitude than the corresponding TFP gross output measure, by placing some weight on the former we move towards the upper end of the range for TFP growth in gross output terms.
- Our TFP estimates exclude embodied technical change. A true measure of frontier shift should take into account the potential cost savings from quality improvements 'embodied' in the inputs used by the sector – labour, capital and intermediate inputs. However, the TFP estimates using EU KLEMS data reflect primarily 'disembodied' technical change. Though research on this issue is limited, we have found some illustrative evidence to suggest that TFP growth estimates might need to be uplifted by as much

as 60 per cent to account for embodied technical change. While we do not wish to place emphasis on the limited quantitative evidence available, this does suggest that, in order to account for the effects of embodied technical change, a number towards the upper end of each range should be chosen.

We also note that consultancies working for the water companies have also presented several sectors in their analyses with annual TFP growth rates exceeding 1.2 per cent. For example:

- NERA on behalf of Bristol Water presented data showing that TFP growth in two of its selected comparator sectors exceeded 1.2 per cent in gross output terms, when looking at data between 1970 and 2007. In particular, NERA found the annual average TFP growth rate to be 1.3 per cent for 'manufacture of chemicals and chemical products' and 1.6 per cent for 'manufacture of electrical and optical equipment'.
- Furthermore, Oxera on behalf of both South East Water and Southern Water found that the average annual growth rate in value added TFP from 1996 to 2014 for 'chemicals and chemical products' was 1.4 per cent and for 'other manufacturing; repair and installation of machinery and equipment' was 1.3 per cent.

1 Introduction

Aims of the study

This report provides an assessment of the ongoing cost reductions that the water and wastewater sector should be expected to achieve over the forthcoming price control period from April 2020 to March 2025. It considers the scope for cost reductions in wholesale.

The assessment of the potential for ongoing cost reductions is broken down into two key components:

- An assessment of whether there is a robust case for any real price effects (RPEs) over the forthcoming control period. RPEs relate to input prices increasing or decreasing in real terms relative to general consumer price inflation (as measured, for example, by CPIH). Positive RPEs would increase costs in the next control period (other things being equal), while negative RPEs would decrease costs.
- An assessment of the frontier shift the water and wastewater sector can be expected to achieve over the next control period. Frontier shift represents the ability of even the most efficient firms in the sector to increase their efficiency over time, producing more output for a given volume of inputs (or, similarly, to maintain outputs but with a lower volume of inputs and thus costs).

The net effect of RPEs and frontier shift can be used to consider the cost reductions that are achievable over the next control period if the water sector performed in line with the competitive sectors that we have selected as our benchmarks. This report does not consider additional efficiency savings that can be achieved through company-specific catch-up, i.e. the ability of companies to become more efficient over time by catching up with the industry frontier. It also does not include any additional one-off efficiencies that companies could achieve if they faced the direct effect of full competition rather than of economic regulation that tries (though imperfectly) to mimic it. Finally, it does not take account of any temporary period of additional efficiency gains associated with the shift to the totex and outcomes-based framework.[5]

Estimating future efficiency savings is important in the context of Ofwat's overall regulatory duties, insofar as price limits must be set so as to "further the consumer objective to protect the interests of consumers", while at the same time ensuring that water companies can properly finance, and carry out, their statutory functions. If required efficiency savings are too ambitious and these are reflected in revenue allowances, then this could hinder water companies' ability to finance their statutory functions. On the other hand, if estimated efficiency savings are too conservative then customers can lose out, as they could face prices in excess of the efficient level.

Data and methodology

Our assessment makes use of publicly available data and information, as well as information and data submitted to Ofwat in water company business plans and company responses to our first RPEs and frontier shift report. We have reflected on the data and reasoning provided by water companies (and, where appropriate, consultants who have worked for them) with respect to both RPEs and frontier shift. We also present our own preferred approach and data, indicating where and, if so why, our approach deviates from that proposed by water companies.

For our assessment of RPEs, we have developed a framework which is applied to assess the case for RPEs in a transparent, consistent and robust manner. The framework is designed so that an RPE allowance is only

[5] See KPMG and Aqua Consultants, "Innovation and efficiency gains from the totex and outcomes framework", June 2018. https://www.ofwat.gov.uk/wp-content/uploads/2019/01/Ofwat_totexoutcomes_FINAL_30012019.pdf

recommended if there is a clear and robust case for including such an allowance. The case must be seen as compelling for two key reasons: firstly, due to the information advantage of regulated companies, there is a danger that allowed costs may be set above expected efficient costs; and, secondly, there are existing protections against cost increases that companies benefit from, including cost sharing rates, interim determinations and the substantial effects clause. The principal data used in the assessment of RPEs are various published input price indices, government projections of wage growth and industrial electricity prices, and the breakdown of costs submitted in company business plans.

The assessment of frontier shift follows a similar structure, by first describing the frontier shift estimates proposed by companies and their methodologies underpinning these estimates. We then proceed to develop our own preferred approach to estimating frontier shift, based on analysis of TFP in relevant comparator sectors. The key sources of data for our frontier shift analysis are EU KLEMS productivity datasets. These datasets are commonly used by other regulators in conducting frontier shift analysis. Our study produces frontier shift estimates for both wholesale totex and wholesale botex.

Data and methodological choices are described further in Chapters 2 and 3, with all data sources clearly referenced.

Key changes compared with previous report

In this section we summarise the key changes we have made to our original report.[6] These key changes relate to our assessment of RPEs rather than our analysis of frontier shift. Below, we first discuss changes to our framework for assessing RPEs, and then the implications of these changes for our findings.

Throughout the report, we have removed the retail cost analysis that was in the previous version. This reflects the fact that our analysis of RPEs and frontier shift for retail businesses is no longer relevant given the approach to retail costs that Ofwat adopted in its Initial Assessment of Plans.

Changes in the framework for assessing RPEs

We have made the following changes to our criteria for assessing whether there is a compelling case for an RPE mechanism for any given cost area:

- We have removed the materiality criterion (labelled as criterion 1 in our original report) from our RPEs assessment to reflect the concerns expressed by companies and their consultants about this criterion. This means that we are no longer rejecting an RPE mechanism on the basis that a cost area accounts for less than 10 per cent of totex.
- In response to one of John Earwaker's critiques, we have removed the consideration of input cost shares in other sectors from our assessment against criterion 2 of whether CPIH indexation adequately captures the relevant input price. The revised report continues to employ a modified version of criterion 2 in which we assess whether CPIH indexation captures the input price by looking (only) at the share of comparable items in CPIH.
- We continue to apply criteria 3A and 3B from our original assessment, although they are now labelled as 1A and 1B.
- To assist with the analysis of whether input costs are outside management control, we have developed a typology of hypothetical ways in which companies might limit their exposure to increases in input prices. This considers whether companies are able to control the level of the price paid for the input, whether companies are able to protect themselves against volatility in the price of the input, or whether companies can respond to increases in an input price by reducing the volume of the input that they use.

[6] Europe Economics, "Real Price Effects and Frontier Shift", 2 January

These adjustments have led to changes in how we number our criteria, as shown in the **Error! Reference source not found.** below.

Table 1.1: Changes in the numbering of our criteria

Criterion	Numbering in	
	Original report	**Revised report**
Is the input cost item to which the RPE would be applied a material proportion of total company costs?	1	No longer used
Are there compelling reasons to think that CPIH does not adequately capture the input price?	2	2
Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	3	1
Is the expected value of the wedge between the input price and CPIH materially different from zero?	3A	1A
Does the wedge between the input price and CPIH exhibit high volatility over time?	3B	1B
4. Is the input price and exposure to that input price outside management control during the duration of the price control?	4	3

Changes in the assessment of RPEs

The changes to our RPEs assessment framework described above led to the following changes in our findings against each of the criteria:

- For criterion 1A in our revised report, we acknowledge that the answer for labour and energy depends respectively on whether reliance is placed on forecasts from OBR and BEIS, and in the case of energy on the weight that is placed on pre-2010 data.
- For criterion 1B in our revised report, we acknowledge that the answer for energy depends on whether weight is placed on pre-2011 data.
- For criterion 2, labour and chemical prices now pass the second criterion as CPIH does not adequately capture changes in labour and chemical costs when the focus is restricted to comparable items in CPIH (rather than also taking into account input cost shares in other sectors). Energy and materials, plant and equipment partially pass the criterion as the available evidence suggests that CPIH does not fully capture these prices, although it does so on a partial basis.
- For criterion 3, materials, plant and equipment costs now partially passes this criterion as companies have some ability to protect against input price volatility, but cannot necessarily avoid the expected value of future input price increases.

For labour and energy, we now apply Stage 1B of our assessment framework to identify what (if anything) should be done about possible real price changes in these cost areas.

Overall, we now conclude that whether labour qualifies for an RPE mechanism depends crucially on whether reliance is placed on OBR forecasts of real wage growth. Historically, OBR forecasts of real wages have proved to be inaccurate and biased upwards, and hence we still do not recommend an ex ante RPE

allowance for labour costs. However, we do recommend that Ofwat considers an ex post indexation mechanism for labour, using all employees or manufacturing sector wages as a comparator.

In relation to energy prices, our report now concludes that whether energy qualifies for an RPE mechanism depends on whether reliance is placed on BEIS forecasts for industrial electricity prices and on the weight that Ofwat attaches to the high wedge between growth in industrial electricity prices and CPIH prior to 2011. Our revised report accepts that an ex post indexation mechanism could also be considered for energy, although we note that for a number of reasons the case for such a mechanism is less clear-cut than for labour.

Other changes

We have added Appendix 3 to the report, which responds in detail to the various points that companies and their consultants have made in relation to our original report.

Structure of the report

Our report is structured as follows:

- Chapter 2 sets out and implements our framework for assessing the case for RPEs.
- Chapter 3 provides our assessment of frontier shift by way of TFP analysis in comparator sectors.
- Chapter 4 concludes.

The report also contains three appendices: the first discusses what wage index should be used for an indexation mechanism; the second describes in more detail our estimation of scale effect adjustments for TFP; and the third summarises the points made by companies and their consultants in relation to Europe Economics' report on RPEs and frontier shift, along with our response to those points.

2 Real Price Effects

In this chapter we set out our assessment of real price effects (RPEs) for the forthcoming price control period. RPEs relate to input prices increasing or decreasing in real terms relative to general consumer price inflation (as measured, for example, by CPIH). We undertake the assessment of RPEs for the wholesale segment of the water sector.

RPEs are important in the context of Ofwat's overall regulatory duties, insofar as price limits must be set so as to "further the consumer objective to protect the interests of consumers", while at the same time ensuring that water companies can properly finance, and carry out, their statutory functions. If RPE allowances are not made, and input costs in aggregate change materially relative to CPIH indexation, then this could hinder water companies' abilities to finance their statutory functions. On the other hand, if RPEs are set too generously then customers lose out, as they could face price changes in excess of underlying realised input price changes.

We have developed a framework for assessing the case for including RPEs in a transparent, consistent and robust manner. The framework is designed so that an RPE allowance is only recommended if there is a clear and robust case for including such an allowance. The case for providing an RPE allowance needs to be compelling because:

- Due to the information advantage of regulated companies, there is a danger that allowed costs may be set above expected efficient costs. For the price control as a whole, revenues should be set to recover expected efficient costs. This is the result achieved by competitive markets. However, regulators face an inherent difficulty in establishing what these expected efficient costs should be given the information asymmetry between the regulator and the regulated companies. In order to form a view on expected efficient costs the regulator must rely on data from water companies. These water companies as profit maximisers can, and would be expected to, use their information advantage for the purpose of achieving higher cost allowances. Given the informational asymmetry intrinsic to regulated sectors, there is an inherent risk that regulators set allowed costs above their competitive level. To prevent RPEs being another area of the price control where companies can take advantage of information asymmetry, the case for including them therefore needs to be compelling.[7]
- There are existing protections against cost increases that companies benefit from. If costs overrun, there is a cost sharing mechanism in place which specifies cost sharing rates, i.e. the proportion of any cost overrun that companies will have to bear, with the remainder being passed onto consumers. Interim determinations and the substantial effects clause provide other routes by which companies are to some extent shielded from significant cost increases.

The chapter is structured as follows:

- In Section 2.1, we analyse water company proposals on RPEs.
- In Section 2.2, we summarise the points made by water companies in response to our first report.

[7] The RIIO-1 price controls highlight the need for caution when including RPEs. CEPA analysed outturn values for the indices used by Ofgem in determining RPE allowances and found a material difference between outturn values and those forecast by Ofgem. See: CEPA (2018), "Review of the RIIO Framework and RIIO-1 Performance". Report prepared by CEPA for Ofgem. Available at: https://www.ofgem.gov.uk/system/files/docs/2018/03/cepa_review_of_the_riio_framework_and_riio-1_performance.pdf

- In Section 2.3, we set out our own framework for assessing RPEs.
- In Sections 2.4 and 2.5, we implement that framework.
- In Section 2.6, we present our conclusions on RPEs, comparing our own findings with what companies are asking for in their business plans.

2.1 Water company proposals on RPEs

In this section we summarise water company proposals with respect to key cost items, namely:

- labour costs;
- energy costs;
- chemical costs; and
- materials, plant and equipment costs.

We consider the evidence submitted by companies, and assess the robustness of that evidence, at appropriate points in Sections 2.4 and 2.5 in the course of implementing our framework for assessing whether RPEs should be included.

Common approaches adopted in generating estimates for RPEs are:

- Examining the relationship between the input cost and economic fundamentals (e.g. through analysing the wedge between the input cost and inflation, and/or through the use of econometrics to analyse the relationship with other macroeconomic variables like GDP).
- Extrapolating forward past trends in the input cost.
- Using independent third-party forecasts of the input cost.

In some cases, companies propose figures for input price inflation (IPI), which must be deflated by companies' CPIH estimates in order to obtain the RPEs.

2.1.1 Labour

The average[8] RPE for labour costs proposed across companies is 0.7 per cent, with a lower bound varying between -0.2 and 0.3 per cent and an upper bound varying between 1.4 and 1.9 per cent depending on year.

Table 2.1: Analysis of wholesale RPE for labour costs proposed by companies

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	-0.2%	0.3%	0.2%	0.2%	0.2%
Max	1.9%	1.8%	1.4%	1.4%	1.4%
Average	0.7%	0.8%	0.8%	0.7%	0.7%

Source: Europe Economics' analysis of revised company business plans submitted in response to Ofwat's Initial Assessment of Plans.

Below, we discuss the analysis put forward by companies to support their projections (which we evaluate later in Section 2.4.1 in assessing whether there is a material wedge in expectation between wage growth and CPIH).

Analysis of relationship with economic fundamentals

Economic Insight (on behalf of Affinity Water, Northumbrian Water, Welsh Water, Wessex Water and Yorkshire Water) generated RPE estimates for labour costs by developing company specific wage indices,

[8] In all instances in this report, where we use the term 'average' we are referring to the mean of the data in question.

which it did by mapping company specific employee data to ONS wage data[9] on occupations by Standard Occupational Classification (SOC) codes. These data have then been compared with historical wage and price inflation indices to evaluate the wedge. Economic Insight's preferred method is to focus on the wedge between the company specific labour cost index and the average UK wage inflation index rather than looking at the wedge with CPIH, on the grounds that the inflation index utilised is specific to the labour market, rather than economy-wide demand and supply conditions.

These wedges are then applied to forecasts for future wage and/or price inflation to estimate changes in the company specific labour cost index. Where forecasts are not available for the full price control period, Economic Insight assumed that the growth rate will persist at the same rate as in the last available year of data. Econometric approaches are also used to explore the relationship between company specific labour cost indices and wider macroeconomic variables, specifically GDP and average wages.

For the case of Welsh Water, Economic Insight noted existing or planned large scale infrastructure projects due to take place during the next price control period that could increase demand for skilled labour in the area and thus place upward pressure on wages. It did not quantify this local 'labour-tightening' effect but in some cases used it as a rationale for selecting slightly higher estimates.

Extrapolating forward past trends in the input cost

Another approach considered by Economic Insight (on behalf of Affinity Water, Northumbrian Water, Welsh Water, Wessex Water and Yorkshire Water) is to extrapolate recent trends in input cost indices, in effect assuming that the future is a continuation of the past. This clearly fails to capture how changes in the macroeconomic environment could influence the input cost moving forward, and is therefore clearly a more limited approach. Economic Insight place less weight on the estimates generated using this approach.

NERA (on behalf of Bristol Water) extrapolates forward trends in specialised labour cost inflation. This includes the 'Labour and Supervision in Civil Engineering' Price Adjustment Formulae Indices (PAFI) index published by the Building Cost Information Service (BCIS) and the Construction Average Weekly Earnings (AWE) index (published by the ONS). NERA notes that in extrapolating these specialised labour cost indices it makes no adjustment to reflect the divergence in specialist labour costs due to pressures created by other major construction projects in the region. NERA states that it was unable to quantify this effect due to the lack of regional wage data. As such, it considers the RPE estimates generated by these indices to be highly conservative.

NERA also used other methods to generate long-term forecasts of wage indices by extrapolating historical data. This included calculating long-run historical arithmetic and geometric averages, noting downsides with each approach: the arithmetic average is not accurate as it does not take account of the compounding effect of growth rates; and the geometric average is sensitive to the time period chosen for estimation. NERA's preferred approach is to use OLS regression to estimate a time trend for the natural logarithm of index levels. NERA's rationale is that an OLS regression based on index levels avoids the issue of the compound effect of growth rates which would be present in an approach based on taking the arithmetic average of growth rates. To avoid subjectivity in the selecting an economic cycle, NERA opts to use the longest history of available data.

Using independent third-party forecasts of the input cost

In the case of labour costs, third party sources of independent wage growth forecasts include forecasts by the OBR and Oxford Economics. Economic Insight (on behalf of Affinity Water, Northumbrian Water, Welsh Water, Wessex Water and Yorkshire Water) place most weight on the OBR forecasts, on the basis that these tend to be towards the middle range of other short-term forecasts. Where forecasts are not

[9] Wage data from the Annual Survey of Hours and Earnings (ASHE) published by ONS.

available for the full period, Economic Insight assumes that wage inflation persists at the same rate as in the last available year of forecast data.

NERA (on behalf of Bristol Water) notes, however, that OBR and HM Treasury labour cost forecasts suffer from a similar drawback in that they capture economy-wide rather than private sector earnings. NERA uses forecast OBR data on economy-wide and public sector wage growth, and the assumption that public sector employees account for 17 per cent of the workforce, in order to estimate private sector wage growth over the next control period.

2.1.2 Energy

The RPEs proposed by water companies for energy costs are more variable.

Table 2.2: Analysis of wholesale RPE for energy costs proposed by companies

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	-0.5%	-0.5%	-2.2%	-3.5%	0.0%
Max	12.6%	9.0%	2.5%	3.0%	3.9%
Average	4.0%	1.6%	0.4%	0.6%	1.8%

Source: Europe Economics' analysis of revised company business plans submitted in response to Ofwat's Initial Assessment of Plans.

We summarise below the analysis put forward by companies to support these projections. (This analysis is evaluated later in Section 2.4.2 in assessing whether there is a material wedge in expectation between energy prices and CPIH.)

Analysis of relationship with economic fundamentals

Economic Insight (on behalf of Northumbrian Water, Wessex Water and Yorkshire Water) follows a similar approach to that used for labour, by constructing a company specific energy cost index (by mapping historical energy price purchases to relevant energy and fuel indices), and then calculating the wedge between this constructed index and relevant inflation indices. In doing so it makes use of nominal GDP inflation as its measure of price inflation rather than CPIH, on the grounds that the drivers of nominal GDP inflation and energy costs are more alike. The estimated wedge is then applied to OBR forecasts for nominal GDP inflation to 2022/23, and then up to 2024/25 assuming the nominal GDP inflation remains constant (i.e. the same as in 2022/23).

Oxera (on behalf of South East Water and Southern Water) analyses the wedge between the National Grid Future Energy Scenarios for power costs and CPI.

Extrapolating forward past trends in the input cost

Economic Insight (on behalf of Northumbrian Water, Wessex Water and Yorkshire Water) used its constructed company-specific energy cost indices to extrapolate forward energy costs using historical data. In doing so, it looked at different time periods – the last year, the last five years, and from 1992 to 2016.

Using independent third-party forecasts of the input cost

In many cases companies (in particular, Affinity Water, Anglian Water, Portsmouth Water, Sutton and East Surrey Water, South Staffordshire Water, Severn Trent Water, South West Water, Thames Water, United Utilities Water and Welsh Water) have relied on independent third party forecasts. The primary source in this respect is the Updated Energy and Emissions Projections bulletin published by BEIS (2017 Annex M Growth and Price Projections statistical). This includes forecasts values of energy (electricity, natural gas and gas oil) prices for industrial customers up to 2035. Forecasts are available for a range of scenarios. In some cases, Economic Insight (on behalf of Northumbrian Water, Wessex Water and Yorkshire Water) has applied weights to different energy forecasts in line with input cost weights for different types of energy for the company in question.

In addition to the above, Severn Trent submitted a cost adjustment claim for energy prices as part of its May 2018 submission to Ofwat. This is based on supporting data and analysis from a variety of sources, including BEIS and its consultant Cornwall Insight. Severn Trent's main basis for its cost adjustment claim is that, according to BEIS forecast data, wholesale electricity prices will increase much faster than suggested by historical trend data over the next price control period, with the implication that the historical growth rate is no longer an appropriate benchmark. Severn Trent provides input price inflation figures in relation to RPEs, while for the energy price cost adjustment claim it submitted in May 2018 it gives numbers on the materiality of this claim as a percentage of the totex of the relevant controls. Though it is difficult to compare these figures directly, Severn Trent appears to have relied on a similar evidence base for both, including a report it commissioned from Cornwall Insight and forecast wholesale electricity price data published by BEIS. This raises the possibility of double-counting (through both an RPE and cost adjustment claim).

2.1.3 Chemicals

The average RPE for chemicals costs proposed across companies is 0.6 per cent, with a lower bound varying between -1.1 and -1.2 per cent depending on the year and an upper bound of 3.0 per cent.

Table 2.3: Analysis of wholesale RPE for chemicals costs proposed by companies

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	-1.1%	-1.2%	-1.2%	-1.2%	-1.2%
Max	2.8%	3.0%	2.7%	2.9%	2.9%
Average	0.6%	0.6%	0.6%	0.6%	0.6%

Source: Europe Economics' analysis of revised company business plans submitted in response to Ofwat's Initial Assessment of Plans.

We describe below the analysis put forward by companies to support these projections. (This analysis is evaluated later in Section 2.4.2 in assessing whether there is a material wedge in expectation between chemicals prices and CPIH.)

Analysis of relationship with economic fundamentals

As for labour and energy, Economic Insight (on behalf of Northumbrian Water, Welsh Water, Wessex Water and Yorkshire Water) constructed a company-specific chemicals cost index, by matching historical chemicals purchases data with the US Producer Price Index published by the Bureau of Labour Statistics. This is preferred to ONS PPI data because it allows for a more granular breakdown from which to construct an index. Economic Insight then ran regressions to estimate the relationship between this index and underlying cost drivers, including nominal GDP growth (from the IMF), historical oil prices (from the World Bank) and data on construction activity (from the OECD). In turn, it made use of independent forecasts of these cost drivers to forecast chemical costs using the coefficients estimated in the regressions, and finally adjusted into GBP by using forecast GBP/USD exchange rates.

Oxera (on behalf of South East Water and Southern Water) investigates the historical wedge between the 'Chemicals and Chemical Products' PPI produced by the ONS and the CPI.

Extrapolating forward past trends in the input cost

In some cases, Economic Insight (on behalf of Northumbrian Water, Welsh Water, Wessex Water and Yorkshire Water) extrapolated forward the historical company-specific chemical costs index. It notes that a key drawback of this approach could be a significant rise in crude oil prices in 2017/18 which it identifies as one of the key drivers of chemical costs (as described above).

Affinity Water estimated changes in 'materials and consumables, including chemicals' rather than purely changes in chemicals costs. To estimate the change in costs it extrapolates forward past trends in the 'Input for Water Collection, Treatment and Supply' PPI published by the ONS.

NERA (on behalf of Bristol Water) also investigates cost changes for 'materials' rather than specifically chemicals. That said, one specific index it looks at to do so is the 'Chemicals and Chemical Products' PPI produced by the ONS. To forecast future costs it makes use of OLS regression techniques, like those used to forecast future labour costs.

Using independent third-party forecasts of the input cost

Economic Insight (on behalf of Northumbrian Water, Welsh Water, Wessex Water and Yorkshire Water) notes that few forecasts are available for the chemical costs specific to water companies. However, it investigated some forecast data from the World Bank relevant to chemicals costs, but principally for benchmarking purposes rather than as actual estimates.

2.1.4 Materials, plant and equipment

The average RPE for materials, plant and equipment costs proposed across companies is 0.2 per cent, with a lower bound of -0.2 per cent and an upper bound of 0.7 per cent.

Table 2.4: Analysis of wholesale RPE for materials, plant and equipment costs proposed by companies

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
Max	0.7%	0.5%	0.5%	0.5%	0.5%
Average	0.2%	0.2%	0.2%	0.1%	0.1%

Source: Europe Economics' analysis of revised company business plans submitted in response to Ofwat's Initial Assessment of Plans.

We describe below the analysis put forward by companies to support the above projections. (This analysis is evaluated later in Section 2.4.4 in assessing whether there is a material wedge in expectation between materials, plant and equipment prices and CPIH.)

Analysis of relationship with economic fundamentals

When assessing capital costs, Economic Insight (on behalf of Northumbrian Water) undertakes wedge analysis, comparing general price inflation (nominal GDP and CPIH inflation measures) with changes in relevant indices used to capture maintenance and capex spending on infrastructure and non-infrastructure. Specifically, it makes use of the 'Resource Cost Index of Maintenance of Building Non-Housing (NOMACOS)' as a proxy for capital maintenance inflation and 'Resource Cost Index of Building Non-Housing (NOCOS)' as a proxy for capex inflation. Both of these indices are published by the BCIS. It then applies the estimated wedge to forecast values for nominal GDP inflation and CPIH, consistent with the methodology used for other cost items.

Oxera investigates the historical wedge between the ONS Machinery and Equipment Price Index and CPI.

Extrapolating forward past trends in the input cost

Affinity Water does not estimate the change in materials, plant and equipment costs together. One relevant input cost it does investigate, however, is construction costs. To do so, it extrapolated past trends in the 'Construction Output Price Inflation (COPI)' which is published quarterly by the ONS.

NERA (on behalf of Bristol Water) uses OLS regression techniques to forecast future plant and equipment costs, specifically looking at the 'Plant and Road Vehicles' PAFI index from BCIS and ONS PPIs for 'Machinery and Equipment', 'Inputs for Water Collection, Treatment and Supply' and 'Other Pumps and Compressors'. NERA also forecasts materials costs using OLS regression techniques and making use of the

following price indices: 'Resource Cost Index: Infrastructure Materials (FOCOS)' index and 'Resource Cost Index: Building Non-Housing Materials (NOCOS)' index from BEIS, the 'Pipes and Accessories: Plastics' PAFI Index from BCIS and the PPI 'Chemicals and Chemical Products' from ONS.

2.2 Points made by water companies and their consultants in IAP responses

Below we briefly summarise the points made by companies in response to our first report in relation to our RPEs analysis. (The points made by companies in relation to our frontier shift assessment are summarised in Section 3.3.)

Water companies and their consultants raised points regarding both the consistency of our RPEs and frontier shift analysis and our RPEs assessment in itself.

Eight companies (Affinity Water, Anglian Water, SES Water, South Staffs Water, Thames Water, Dwr Cymru, Wessex Water and Yorkshire Water) cited a report by John Earwaker[10] that commented that while both Europe Economics and Ofwat acknowledge that CPIH inflation reflects input price inflation across the economy, it also captures productivity growth, which is not taken into account in Europe Economics' frontier shift analysis. Two consultancies (Oxera on behalf of South East Water and Southern Water and Economic Insight on behalf of Wessex Water and Yorkshire Water) were of the view that assuming no real wage growth and growing productivity are at odds with each other and hence that no RPE allowance for labour costs could be inconsistent with a 1.5 per cent per annum frontier shift assumption. A further comment made by John Earwaker and Economic Insight (on behalf of Yorkshire Water) was that we required different levels of evidence for the RPEs analysis compared with the frontier shift analysis, by requiring a compelling case for any RPE allowance to be made but not making such a requirement for frontier shift.

Regarding our RPEs assessment, Economic Insight on behalf of both Wessex Water and Yorkshire Water claimed that we had adopted an inappropriate null hypothesis in our work, arguing that the 'true' null hypothesis should allow for positive RPEs.

With respect to the first criterion (materiality of cost item), both John Earwaker and Economic Insight on behalf of Wessex Water claimed that the materiality threshold adopted was arbitrary and NERA on behalf of Bristol Water argued that it was prohibitively high and sensitive to the choice of aggregation used. A further comment by John Earwaker stated that our analysis was limited to two cost categories accounting for only 55 per cent of totex and hence did not consider the remaining 45 per cent of company costs.

Concerning the second criterion (whether costs are adequately captured in CPIH), NERA on behalf of Bristol Water and Economic Insight on behalf of Yorkshire Water argued that this criterion does not test whether the level and movement of CPIH adequately tracks the inputs in the water sector and NERA also argued that since CPIH also includes imports it is illogical to conclude that CPIH captures wage inflation as wage pressures abroad could be different from those experienced in the UK.

As regards the third criterion (whether there is a significant likelihood of wedge), John Earwaker, NERA on behalf of Bristol Water and Economic Insight on behalf of Yorkshire Water have all argued that the dismissal of OBR and BEIS forecasts by Europe Economics on the basis of a lack of reliability is an odd position to take. Economic Insight on behalf of Wessex Water and NERA on behalf of Bristol Water claimed that examining whether the wedge is statistically different from zero is irrelevant as it is just a measure of probability. NERA stated that Europe Economics appears to be "data mining"; that we had not presented the detailed results of the statistical wedge analysis (such as the significance level used); and that

[10] Earwaker (2019): "A review of Ofwat's PR19 Approach to Estimating Frontier Shift".

the rationale for our consideration of gas prices was unclear as water companies' primary energy cost is electricity.

Regarding the fourth criterion (whether costs are outside management control), John Earwaker argued that our interpretation of controllability was not very intuitive, while Economic Insight on behalf of Yorkshire Water argued that the criterion was applied in an erroneous way.

Further details on the points made by companies and their consultants and our response to these comments is available in Appendix 3.

2.3 Framework for assessing RPEs

Our framework for assessing RPEs consists of two broad stages:

- Stage 1: Assessment of RPEs in each cost area (labour, energy etc.).
- Stage 2: Check on overall RPEs 'package' implied by Stage 1 results.

2.3.1 Stage 1: Assessment of RPEs in each cost area

The purpose of Stage 1 is to assess the case for RPEs for individual cost items. This assessment is carried out for each of the major wholesale cost items, i.e.:

- labour costs;
- energy costs;
- chemical costs; and
- materials, plant and equipment costs.

These are the major wholesale cost areas used by Ofwat in Table App24 on input proportions in the PR19 Business Plan data tables.

Stage 1 is itself broken down into two sub-stages:

- Stage 1A: Are there any material RPEs outside management control that are not captured by CPIH indexation?
- Stage 1B (if relevant): What, if anything, should be done about these RPEs?

In this section we set out the criteria we apply in conducting Stage 1A of the assessment. If any cost items pass Stage 1A of the framework then they would advance to Stage 1B.

Stage 1A: Are there any material RPEs outside management control that are not captured by CPIH indexation?

The first part of Stage 1 is to assess whether there are any RPEs that can be deemed material relative to CPIH indexation and which are outside management control. This stage is used to identify those cost items for which there may be a case for providing an RPE allowance (though it may later be determined in Stage 1B that not providing an RPE allowance is the best approach in practice). The criteria for this stage of the assessment are:

1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control? The wedge may differ substantially from zero over the course of a five-year control period for either of two reasons: firstly, it may be because in expectation the wedge is significantly different from zero; or, secondly, it may be because, even if in long-run expectation the wedge is not significantly different from zero, the cost exhibits sufficient variability such that over the course of a five-year control period the wedge may differ substantially from zero. Therefore, we assess this criterion by analysing two separate sub-criteria, namely:

A. Is the expected value of the wedge between the input price and CPIH materially different from zero? To assess this sub-criterion, we assess the statistical significance of the wedge between the input price and CPIH (based on historical values) as well as considering forecast data where available.[11] If this criterion holds true then there may be a case for either an ex ante RPE allowance or an ex post indexation mechanism if other necessary criteria are also met.

B. Does the wedge between the input price and CPIH exhibit high volatility over time? To assess this sub-criterion, we evaluate the volatility of the wedge over five-year periods (the length of the price control), rather than looking at short-term (e.g. month-to-month) volatility that may average out over a price control period. We analyse this variability as a share of totex, and consider that a wedge exhibits high volatility if the five-year rolling average wedge frequently exceeds 1 per cent of totex. If this criterion holds true then there may be a case for an ex post mechanism if other necessary criteria are also met.[12]

For the criterion to be passed as a whole, only one of the above two sub-criteria need to be passed, i.e. either there is a material real price effect in expectation, or the rolling 5-year average of the input price exhibits high volatility over time.

2. Are there compelling reasons to think that CPIH does not adequately capture the input price? To assess cost items against this criterion, we consider the share of a cost item in totex with the share of the most relatable cost item(s) in the CPIH basket. The logic is that if the share of a cost item in totex is similar to the share of that cost item in CPIH, then CPIH indexation should already be capturing well the evolution of that cost item in company costs.
A cost item fails against this criterion if there is no conclusive evidence that CPIH fails to adequately capture the input price while a cost item partially passes against this criterion if the input price is partly, but not fully, captured by CPIH.

3. Is the input price and exposure to that input price outside management control during the duration of the price control? This criterion asks whether the company management could make changes to mitigate the risk of RPEs for different cost items. To assist our analysis of whether input costs are outside management control, we have developed the following typology of hypothetical ways in which companies might limit their exposure to increases in input prices. (Note that these are only hypothetical possibilities — what companies can actually do in response to increases in input prices is discussed later when we asses each input cost area against this criterion.)

   A. Companies may be able to control the level of the price paid for the input, either because:

      – They have buyer power in that market for that input, perhaps because the market for that input is local and they are a major local purchaser; or
      – Due to inefficient management, they were initially paying above the competitive market price and are able to reduce the price they pay down towards the competitive level.

   B. Companies may protect themselves against volatility in the price of the input through long-term contracts which fix input prices. Companies are likely to still be exposed to input price pressures on an expected value basis, as suppliers will build their expectations of future price movements into what they bid for long-term contracts. Therefore, we would consider it a 'partial pass' where companies have the ability to protect themselves against input price volatility (for example, through

[11] More specifically, we perform a t test on the wedge to assess whether it is significantly different from zero.

[12] Passing the second sub-criterion (3B) is weaker as evidence for an RPE than passing the first, because Ofwat could decide to leave the risk of unexpected changes in the input price on the companies and their investors rather than implementing an ex post RPE allowance which would transfer the risk to customers. The decision of who is best placed to bear the risk is part of the Stage 1B criteria.

long-term contracts), even though they cannot avoid input price pressure on an expected value basis.

C. Companies may respond to increases in an input price that is outside their control by reducing the volume of the input that they use. That could be achieved by:

   - Greater efficiency in the use of that input. The increase in the input price will incentivise greater investment (e.g. in new processes) that will reduce the use of that input. We would still expect an increase in overall cost as such investment will not be costless, but the cost increase would be lower than if the firm paid the increased input price on the initial volume of the input.
   - Substitution to other inputs as companies re-optimise their mix of inputs in response to the change in relative input prices. Again, in this case total costs are still likely to increase — since with at least one input price being higher and other input prices being unchanged, the efficient cost must have gone up. However, the increase in total cost will be less than would be the case if companies had kept their input mix fixed and been exposed to the full effect of the increase in the price of the input.

   In cases where companies have the ability to avoid input price pressure by reducing the volume of the input they use (for example, by substituting on a significant scale to other inputs), we would consider this a 'partial pass' against this criterion.

Each criterion is scored as a pass or fail (or a partial pass in some cases for the second and third criterion). If criteria 2 and 3 are both passed and at least one of sub-criteria 1A or 1B is passed, then the cost item in question advances to Stage 1B of the RPEs assessment framework. If, however, any of the above criteria (1A and 1B, 2 or 3) are failed, then the cost item is not advanced to Stage 1B, and no RPE allowance is recommended for that cost item. If criterion 2 and/or 3 receives a 'partial pass' and all other criteria are passed, then Ofwat would need to investigate the cost item in more detail to determine the extent to which the input price is captured by CPIH and/or the scope for management control, and hence to reach a judgment on the strength of the case for an RPE allowance.

In cases where we do not recommend an RPE allowance for a cost item, by definition this means that we are recommending that the allowed input price should change neither faster nor slower than CPIH. This implies that the input price needs to be linked in some way to CPIH. Since wholesale controls are indexed to out-turn CPIH, the implication for wholesale controls is the CPIH indexation of revenues is sufficient to compensate companies for out-turn movements in the input price.

Stage 1B: What, if anything, should be done about these RPEs?

For those cost items deemed to have a material RPE outside management control in Stage 1A, we advance to the second stage of our framework to assess whether anything should be done to account for these RPEs.

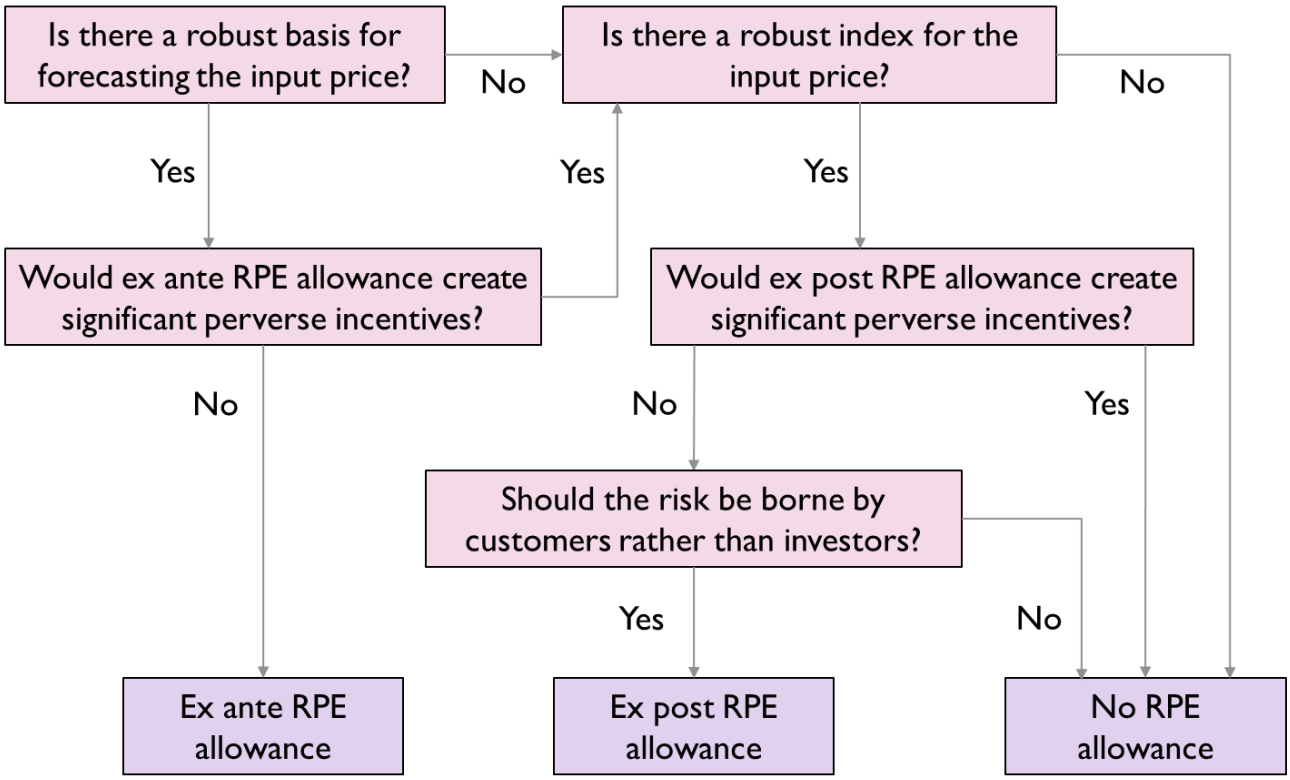
This second stage is an additional set of criteria used to determine what, if anything, should be done to account for the material RPEs identified in Stage 1A. This includes considering whether or not there is a sufficiently robust mechanism for taking account of the RPE and, if so, whether an ex ante or ex post allowance is appropriate. The criteria for Stage 1B are:

- Is there a robust basis for forecasting the input price? There could be a good basis for forecasting the RPE if: firstly, the input price trend (and wedge relative to CPIH) is relatively stable over time such that past changes in input prices are a good proxy for future price changes; or, secondly, if there are reliable forecasts of the input price (e.g. demonstrated by past forecasts which have performed well against actual outturns).
- Is there a robust and relevant index for the input price? This criterion assesses whether there is an existing published index that captures well changes in the price of a given input.

- Would an RPE mechanism for the cost area create any perverse incentives for companies? This criterion considers whether different tools for providing an RPE allowance would create perverse incentives for companies, such as reduced incentives to control input cost increases. This would include consideration of the extent to which relevant indices (which could form the basis for RPE allowances) are directly dependent on water companies' reported costs, as this could reduce incentives on companies to control costs as higher costs would increase the index value and RPE allowance.
- Should the risk be borne by customers rather than investors? There is a policy choice to be made as to whether the risk of input cost changes should be borne by the customers or the investors. With no ex post RPE allowance the risk is borne by investors, with any systematic component to this risk feeding into the cost of capital,[13] while with an ex post RPE allowance the risk is borne by consumers.

The flow diagram below shows how the answers to these questions are used to determine what action (no RPE allowance, an ex ante RPE allowance or an ex post RPE allowance) is most appropriate for a given cost item.

Figure 2.1: Stage 1B assessment map.



Source: Europe Economics' framework.

It should be noted that companies will still benefit from cost sharing under the PR19 cost sharing mechanism, even for cost items for which no RPE allowance is provided.

[13] In particular, any systematic component to this risk will be picked up in betas estimated from market data, provided that the market data used for beta estimation is from a period in which no such ex post RPE allowance existed or was expected to exist.

2.3.2 Stage 2: Check on overall RPEs 'package' implied by Stage 1 results

Having completed the assessment of RPE allowances for individual cost items in Stage 1, Stage 2 involves checking the overall RPEs 'package' implied by the results of Stage 1. This is done by comparing the outcome of the above assessment of RPEs on an individual cost item basis with the overall RPE implied by the relevant input PPI(s) for the water and wastewater sector. This allows us to consider whether, looking at totex as a whole, there is a strong case for including an RPE.

2.4 Stage 1: Assessment of RPEs in each cost area

In this section of the report, we assess each cost item in turn against the criteria of Stage 1A. In each case we set out the evidence that we use in assessing the cost item against the criterion, and conclude by stating whether the criterion is passed or failed.

2.4.1 Labour

Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?

To assess labour against this criterion, we consider evidence on the relationship between movements in labour costs and movements in CPIH.

Analysis of historical data (from 2002/3 to 2010/11) suggests that changes in water company labour costs have not been well correlated with changes in CPIH. We find a very weak correlation between June Returns data on 'employment costs' and CPIH (of +0.16), and also a very weak correlation for 'hired and contracted services' and CPIH (also +0.16). However, the very weak correlations may in part be due to the fact that changes in labour costs also reflect changes in the volume of labour (rather than just changes in the price of labour).

By looking at sector specific wage indices we can abstract from the effect of volume changes. There are two key wage indices reported by the ONS: the Index of Labour Cost per Hour (ILCH) and Average Weekly Earnings (AWE). These ONS wage indices are available for the electricity, gas and water supply sector as a whole. Further, the ONS also report the Annual Survey of Hours and Earnings (ASHE) dataset which separately identifies water supply and sewerage wages.

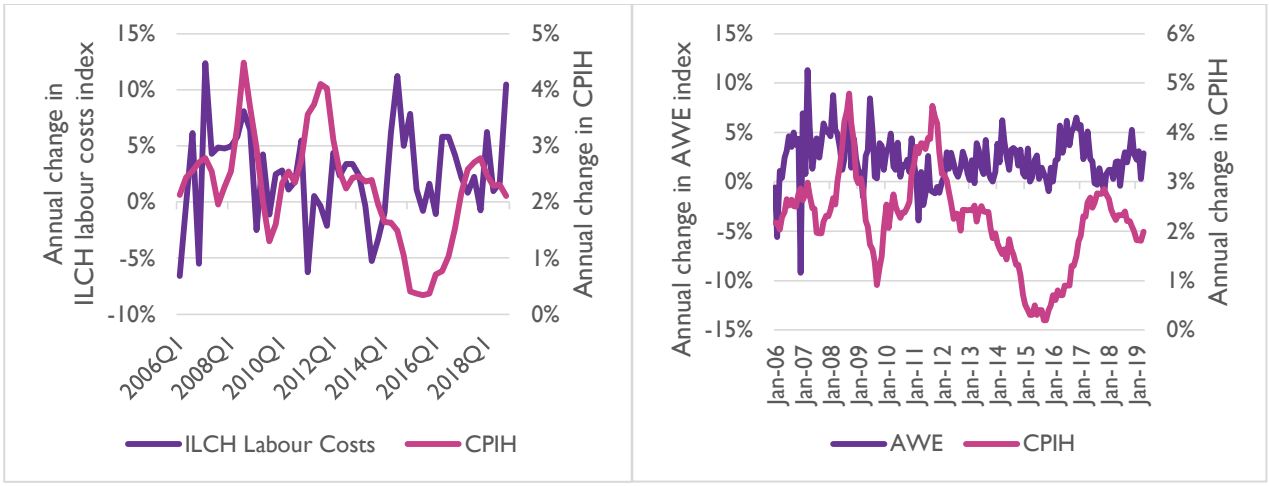
The OBR also produce economy-wide forecasts for average earnings growth (calculated as wages and salaries divided by number of employees), which can be compared with forecasts for CPIH. Sector specific wage forecasts are not available.

We do not find any strong evidence of correlation between ONS wage indices for the electricity, gas and water supply sector and CPIH. This lack of correlation is evident from the plots of wage indices against CPIH growth rates in Figure 2.2. It should be noted that the charts plot the quarterly change in the labour costs indices and the quarterly change in CPIH against two different vertical axes, and cannot therefore be used to examine the wedge between the two price indices.

With no lag, we estimate the correlation coefficient for the ILCH labour costs measure and CPIH to be -0.08, and the equivalent figure for the AWE measure to be -0.09 (based on data from 2006 to 2019). We also fail to find any material correlations when investigating one or two years lags in either direction. This implies that the change in CPIH in any given year is not a good predictor of the change in wage indices in the electricity, gas and water supply sector that year or in either of the subsequent two years, or vice versa.

Figure 2.2: Growth rates of wages indices and CPIH (2006 to 2019)

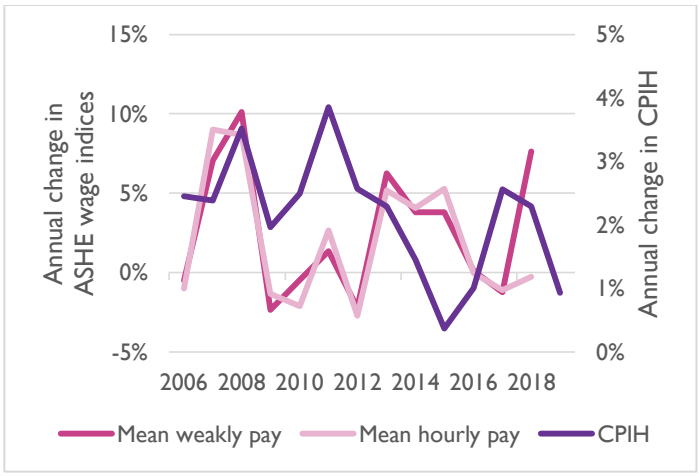
(a) ILCH labour costs index **(b) AWE index**



Note: Wage indices growth rates are presented on the primary (left-hand) axis, CPIH growth rates on the secondary (right-hand) axis.
Source: ONS data.

Furthermore, we do not find any strong evidence of correlation between the labour costs data for the water supply and sewerage sector and CPIH. This lack of correlation is evident from the plots of the ASHE wage indices for the water supply and sewerage sector and CPIH over the time period from 2006 to 2018 as shown in Figure 2.2. Chart (c) again has two different vertical axes where the ASHE labour cost indices are shown against the left-hand axis and CPIH against the right-hand axis, and therefore it cannot be used to examine the wedge between the two price indices.

Figure 2.3: Growth rate of the ASHE wage index and CPIH (2006 to 2018)



Note: Wage indices growth rates are presented on the primary (left-hand) axis, CPIH growth rates on the secondary (right-hand) axis.
Source: ONS data.

Is the expected value of the wedge between the input price and CPIH materially different from zero?

A number of approaches have been used by other consultancies on behalf of water companies to estimate the size of any real price effect. As mentioned in section 2.1, these can be broadly classified into three groups: approaches which examine the relationship between the input cost and economic fundamentals (such as general price inflation); approaches which extrapolate forward past trends in input prices; and approaches which use independent third party forecasts.

The first and second approaches are broadly comparable. The first approach estimates some 'wedge' between the input price and an economic fundamental and then adds that 'wedge' to future forecasted

values of the economic fundamental. The second approach instead takes historical input price growth and extrapolates that forward and then subtracts future forecasted values of the economic fundamental to estimate the 'wedge'. Given the comparability of the first and second approaches, our focus here is on deriving results using the first and third approaches.

First looking at historical data, we find an average 'wedge' of zero between changes in CPIH and changes in the electricity, gas and water supply sector wage indices (from 2006 to 2018 for the ILCH index, and from 2006 to 2019 for the AWE index). Moreover, looking at data so far available for the most recent price control period (April 2015 to present), we find that neither the ILCH – CPIH wedge nor the AWE – CPIH wedge are significantly different from zero in statistical terms.[14]

Looking specifically at historical data for the water supply and sewerage sector, we find an average 'wedge' of zero between changes in the ASHE index for the water supply and sewerage sector and CPIH from 2006 to 2018 (both for mean weekly pay and mean hourly pay). Moreover, looking at data for the most recent price control period (2015 to present), we find that neither index (mean weekly pay and mean hourly pay) are significantly different from zero in statistical terms.

NERA investigates the wedge using other specialised labour cost inflation measures. In particular, it considers the AWE index for construction as published by the ONS. We have also investigated the historical wedge between this index and CPIH and found that this is not significantly different from zero in statistical terms (analysing monthly data from 2006 to 2018).

In some cases, consultancies have developed water-company specific wage indices to reflect the composition of a water company's labour force in terms of the share of managers, technical staff, administrative staff etc.[15] This has then to be mapped to ONS wage indices[16] using Standard Occupational Classification (SOC) codes, such that a composite wage index and growth rates specific to the water company can be estimated. We have replicated this analysis using the average share of different employment categories across all water companies. Comparing the growth in this composite index with CPIH growth since 2011, we found that the wedge is not statistically different from zero. Therefore, the results of this composite wage analysis are consistent with our analysis using the electricity, gas and water supply sector and the water supply and sewerage sector wage indices published by the ONS.

We have also investigated the case for a real price effect based on relevant forecast data. NERA and Economic Insight make use of forecast data provided by the OBR. Consultancies also consider other forecasts not in the public domain, including forecasts from Oxford Economics analysed by Economic Insight. In what follows, we focus on the forecasts from the OBR as the official government body responsible for producing macroeconomic forecasts.

The OBR currently forecasts nominal average earnings growth and CPI growth out to 2023.[17] As OBR does not forecast CPIH directly, we take OBR's CPI forecasts as they move closely in line with CPIH. As shown in Table 2.5 below, the OBR forecasts that average nominal earnings will grow by 3.0 per cent in 2020, 3.1 per cent in 2021, 3.1 per cent in 2022 and 3.3 per cent in 2023. This implies an average wedge of 1.1 per cent.

[14] All of the statistical tests presented for this sub-criterion have been carried out at the 5 per cent significance level, using quarterly data in the case of the ILCH index and monthly data in the case of the AWE index.

[15] Though we consider the wedge implied by a composite wage index for the water and wastewater sector, it should be acknowledged that the composition of labour is to some extent controllable by companies and therefore that the composite wage index cannot be considered a completely exogenous input price.

[16] Wage data by employment category are available from the Annual Survey of Hours and Earnings (ASHE) published by ONS. Consistent data are available back to 2011. Data before then are not comparable due to a change in the categorisations.

[17] OBR (2019): "Economic and Fiscal Outlook, March 2019". Available at: https://cdn.obr.uk/March-2019_EFO_Web-Accessible.pdf.

Table 2.5: Percentage change in average earnings and productivity: OBR forecasts

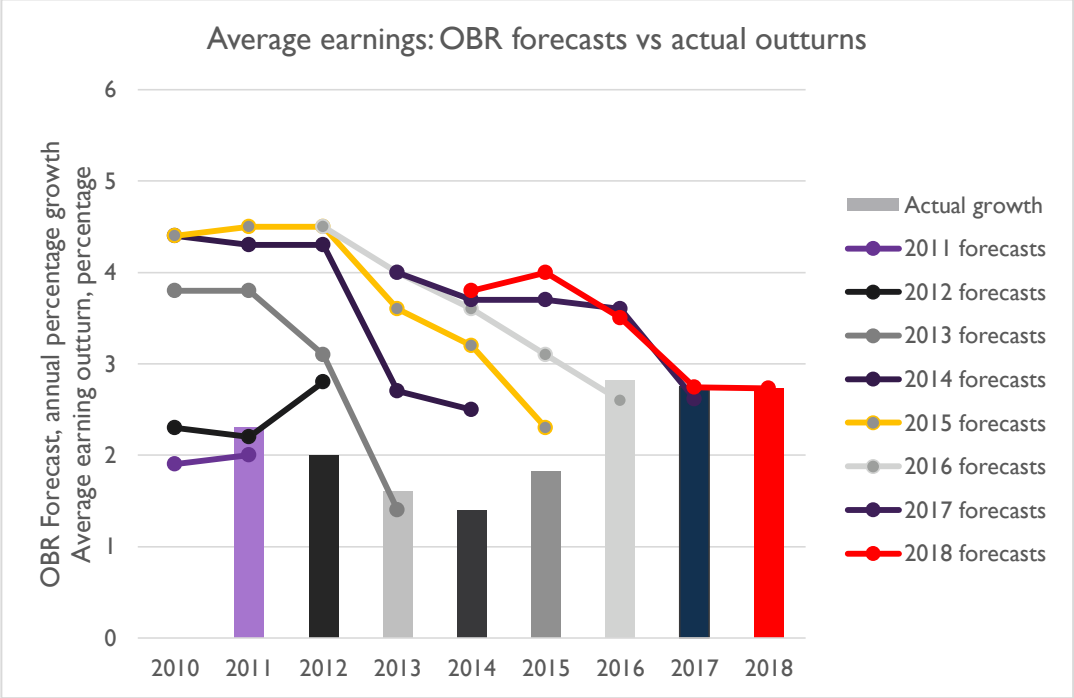
	Outturn	Forecast					
	2017	2018	2019	2020	2021	2022	2023
Average earnings	2.8	3.0	3.1	3.0	3.1	3.1	3.3
Output per hour	1.0	0.5	0.8	0.9	1.1	1.2	1.3

Source: OBR.

NERA also estimate the implied private sector earnings growth based on OBR forecasts for economy-wide and public sector wage growth, and assuming public sector employees account for 17 per cent of the workforce. We have replicated that analysis and found that the wedge between implied private sector earnings growth and the CPI is 0.7 per cent.

The OBR forecasts therefore do suggest a positive wedge in wage growth (both economy-wide and private sector specific) over CPIH growth. However, data published by the OBR itself comparing its previous forecasts with actual outturn data call into question the reliability of these forecasts. Figure 2.4 and Table 2.6 below compares actual outturn growth rates, with forecast growth rates. It can be seen from this that there is general tendency to overestimate average earnings growth. For example, in November 2010, the OBR forecast earnings growth in 2015 to be 4.4 per cent, whereas the outturn value was 1.8 per cent – a discrepancy of 2.6 percentage points. Overall, therefore, we find that the OBR has systematically overestimated average earnings growth and, as such, reliance on these forecasts could lead to an upward bias in any estimated RPE.

Figure 2.4: Average earnings: OBR forecasts vs actual outturns



Source: OBR.

Table 2.6: Average earnings: OBR forecasts vs actual outturns

		Forecasted year											
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	2010	1.9	2.3	3.8	4.4	4.4							
	2011	2	2.2	3.8	4.3	4.5							
	2012		2.8	3.1	4.3	4.5	4.5						
	2013			1.4	2.7	3.6	4	4					
Forecast date	2014				2.5	3.2	3.6	3.7	3.8				
	2015					2.3	3.1	3.7	4	4.4			
	2016						2.6	3.6	3.5	3.4	3.6		
	2017							2.6	2.7	3.0	3.4	3.6	
	2018								2.7	2.4	2.5	2.8	3.0
Actual		**2.3**	**2.0**	**1.6**	**1.4**	**1.8**	**2.8**	**2.7**	**2.7**				

Source: OBR.

Uncertainty around Brexit and its macroeconomic effects also add to uncertainty about the reliability of OBR forecasts.

Overall, we find that whether there is a strong basis on which to conclude that there is a material real price effect in expectation ultimately depends on whether reliance is placed on OBR forecasts.

Sub-criterion passed or failed depending on whether reliance is placed on OBR forecasts.

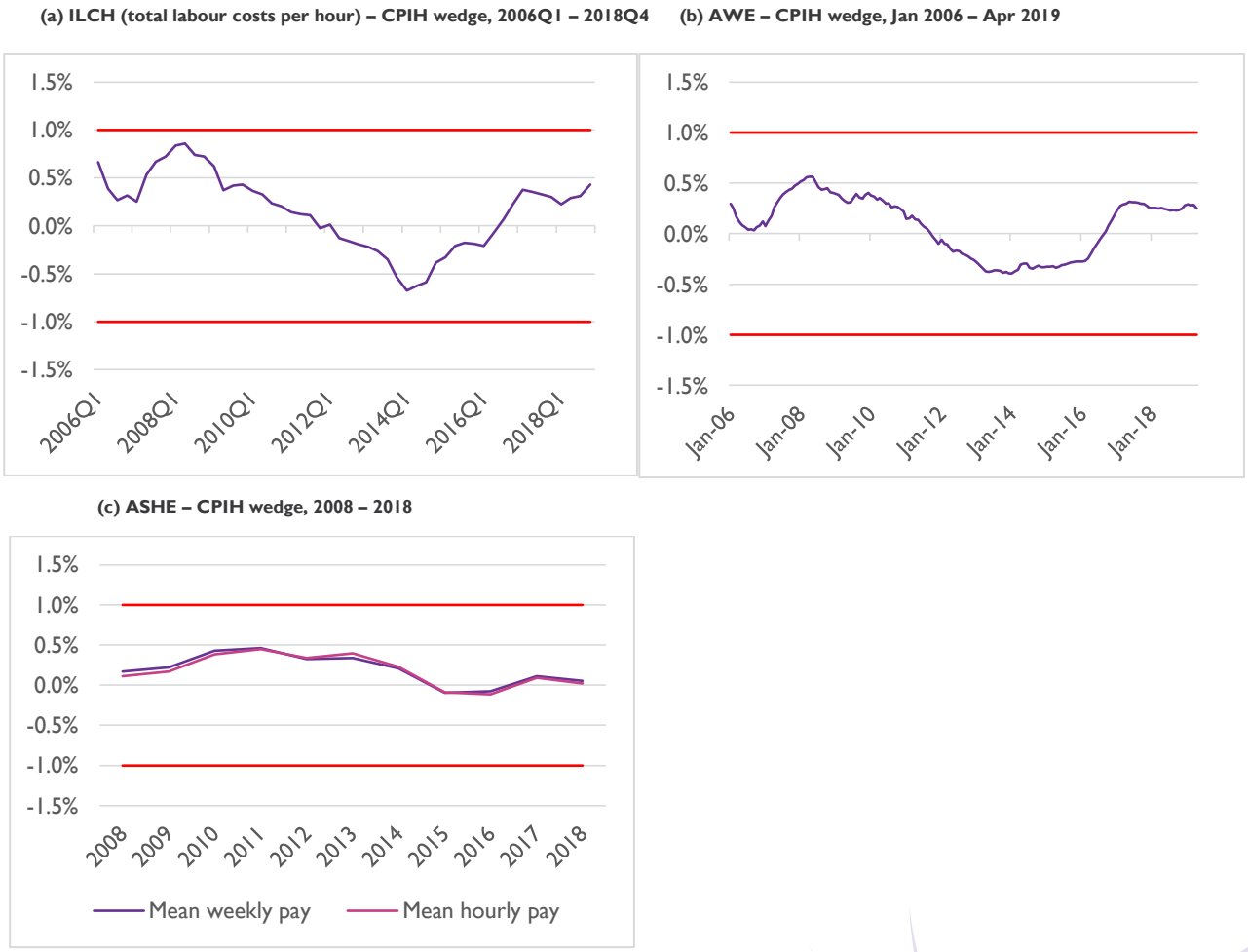
Does the wedge between the input price and CPIH exhibit high volatility over time?

In examining whether the input price may exhibit high volatility over time, we are interested specifically in its volatility over the course of a price control (i.e. over a five year period) rather than, say, its volatility on

a month-to-month basis. Consequently, we investigate the volatility of the five-year rolling average wedge between the wage indices and CPIH. We consider this in terms of its implications for the volatility of overall totex by adjusting for the share of the cost item in totex (which for labour is 33.3 per cent of wholesale totex[18]). The results of this exercise are shown in Figure 2.5 below.

It can be seen that neither wedge shows high volatility over time: in the case of the ILCH index, the wedge (as a proportion of totex) varies between approximately -0.7 and +0.9 per cent; in the case of the AWE index the variation is between approximately -0.4 and +0.6 per cent; and in the case of the ASHE index the variation is between approximately -0.1 and 0.5 per cent (for both mean weekly pay and mean hourly pay). Therefore, the five-year rolling average wedge for these wage indices at no point exceeds 1 per cent of totex.

Figure 2.5: Five-year rolling average of wage index – CPIH wedges as a share of totex, 2011 – 2019



Source: ONS.

Sub-criterion failed.

Are there compelling reasons to think that CPIH does not adequately capture the input price?

The CPIH basket is a weighted basket of goods and services that reflect the spending of the average consumer. There is no discrete item for labour in the CPIH basket. As such, we conclude CPIH does not

[18] This share has been calculated as an unweighted average across companies and across the years of the next price control period, based on data submitted by companies in App24. The same approach has been used to calculate cost shares later in this report for other cost areas.

capture changes in labour costs. (We acknowledge that wage rates will feed indirectly into the price of consumer goods that are in CPIH, but for the reasons discussed in more detail in appendix 3 we no longer look at input cost shares in other sectors when assessing cost areas against this criterion. The main reason for this is to take account of Earwaker's critique that there is an inconsistency in considering input price pressures in other sectors in our RPEs assessment when we do not net off productivity growth in other sectors in our assessment of frontier shift.)

Criterion passed.

Is the input price, and exposure to that input price, outside management control during the duration of the price control?

To assess labour against this criterion, we consider each of the three hypothetical ways in which companies might limit their exposure to increases in input prices.

A. The price of labour does, to a large degree, remain outside company control. If a water company is already paying efficient wages, then it has little scope to limit increases in wage rates if economy-wide wages are increasing. Failure to increases wages in such circumstances could see employees move to roles with similar skill requirements in other sectors, as well as creating difficulties in attracting new personnel. Some labour skills are more sector specific and, therefore, not as susceptible to these economy-wide pressures, although there may be competition for these employees between water companies. In our view, there is no evidence to suggest that water companies have market power in labour markets (and hence we do not consider that they can control the market price that has to be paid for labour).

   It is possible that companies could offer internal training schemes and apprenticeships, enabling them to hire people at lower skill levels and train them for specific roles in the company, rather than competing in the labour market for employees with more general skills (such as university graduates) where higher salaries may be required to attract new starters. However, if labour markets are competitive, once they have been trained staff would be expected to leave for higher paying jobs elsewhere if the company does not remunerate them for their new level of skill.

B. There are some mechanisms by which companies can protect themselves against wage volatility, even though they cannot avoid input price pressures on an expected value basis. For example, they could secure external staff from other companies under a long-term framework contract, with prices agreed over the regulatory control period. This could protect companies from the risk of unforeseen changes in wage rates, although contractors would be expected to build expected increases in wage rates into their bid prices.

C. Furthermore, there are some mechanisms by which companies can respond to increases in labour costs by reducing the volume of labour they use:

   - Substituting capital for labour – one response to increasing labour costs is to substitute labour with capital. This could help both to reduce the volume of labour required and/or change the composition of the workforce. This could take a number of forms in the context of the water sector, for example:

     - Promoting remote operation automation – the installation of telemetry and use of remote and automated operation reduces the need for staff to be physically present on site. New technologies and increases in digital capability have the potential to further increase remote operation automation. This can decrease the number of workers required and reduce the need for shifts at unsociable hours, both of which can reduce exposure to changes in labour prices.

- Reprofiling work – water companies can bring forward or delay work as necessary to reduce their exposure to expected changes in wage rates. This could reduce the volume of labour used at periods where wage rates are highest.

Overall, while in our view there is no evidence that water companies have market power in labour markets, there is some scope for companies (such as through the mechanisms outlined) to protect themselves against input price volatility and to respond to increases in labour costs by reducing the volume of labour they use.

Criterion partially passed (can protect against input price volatility and can reduce volume of input).

Summary of assessment

Table 2.7 below summarises our assessment of labour. Overall, since labour costs pass the second criterion, and partially pass the third criterion, our assessment of recommending an RPE allowance for labour depends upon the first criterion and the partial pass for the third criterion. The first criterion, whether the RPE will differ substantially from zero over the period of the price control, in turn depends upon whether reliance is placed on OBR forecasts. In relation to the third criterion, companies have some ability to protect against input price volatility and can reduce the volume of the input that they use in response to an increase in the input price.

Table 2.7: Summary of assessment of RPE allowance for labour

Assessment criteria	Decision
1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	
A. Is the expected value of the wedge between the input price and CPIH materially different from zero?	Depends on whether reliance is placed on OBR forecasts
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Pass
3. Is the input price and exposure to that input price outside management control during the duration of the price control?	Partial Pass
Overall	**Depends on whether reliance is placed on OBR forecasts**

Source: Europe Economics' analysis.

As labour costs could potentially pass Stage 1A of the assessment framework if reliance is placed on OBR forecasts, we advance it for consideration in Stage 1B of the framework.

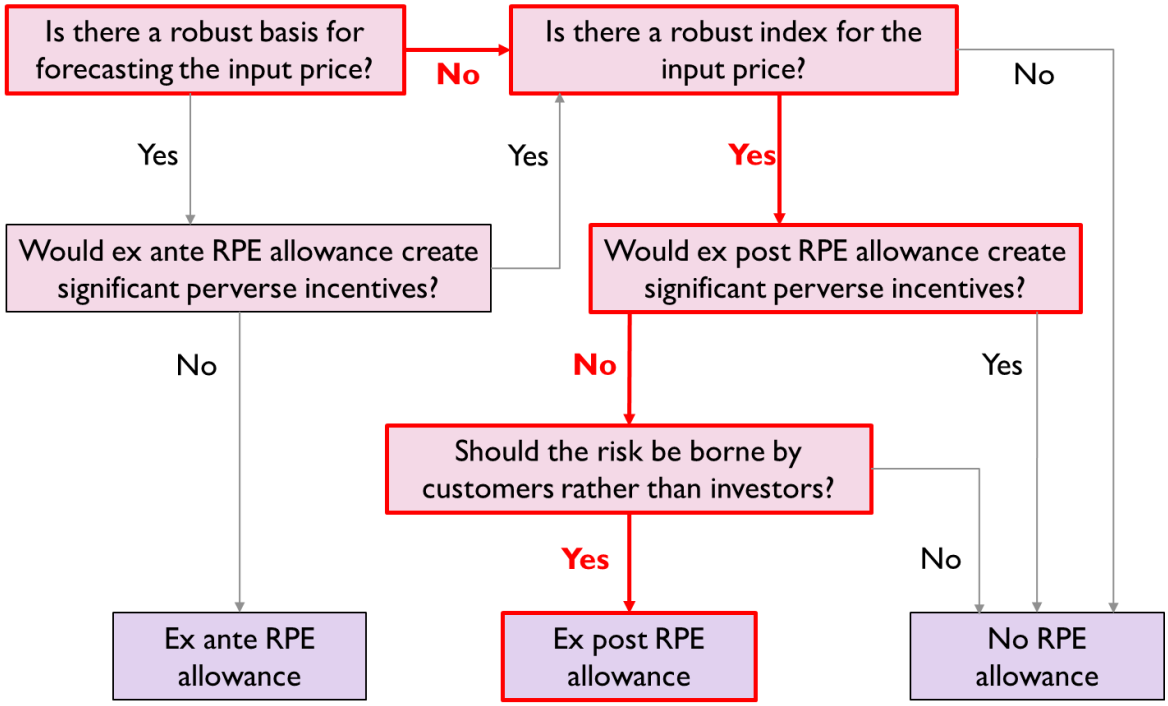
What, if anything, should be done about this RPE?

Working through the assessment map presented in Figure 2.6, we conclude the following with respect to labour costs:

1. Is there a robust basis for forecasting the input price? No – OBR forecasts have repeatedly failed to provide accurate forecasts of labour costs in the past.
2. Is there a robust index for the input price? Yes – as discussed in Appendix 1, either the ONS wage index for "All employees" or for "Manufacturing" would represent a robust index to use for indexation purposes.

3. Would an ex post RPE allowance create significant perverse incentives? No – the ONS wage indices for "All employees" and for "Manufacturing" are based on data from the wider economy and cannot therefore be influenced by the actions of water companies.
4. Should the risk be borne by customers rather than investors? Yes – the risk should be borne by customers as labour costs is a material cost item (representing 33.3 per cent of water company totex) which is not captured by CPIH.

Figure 2.6: Stage 1B assessment map for labour costs



Source: Europe Economics' analysis.

In the light of this analysis, we recommend an ex post indexation mechanism for labour costs. This will mean that if that if real wages increase, then the additional wage costs will automatically feed through into price limits. At the same time, if the latest OBR forecasts also turn out to be over-estimates, water customers will be protected from paying for forecast real wage increases which do not happen.

As regards the indexation mechanism that should be used for labour costs, we would recommend that Ofwat uses either the ONS "All employees" or the ONS "Manufacturing" wage index for reasons related to data quality and avoiding potential incentive problems. This recommendation is based on the multi-criteria assessment of three candidate wage indices included in Appendix 1.

2.4.2 Energy

Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?

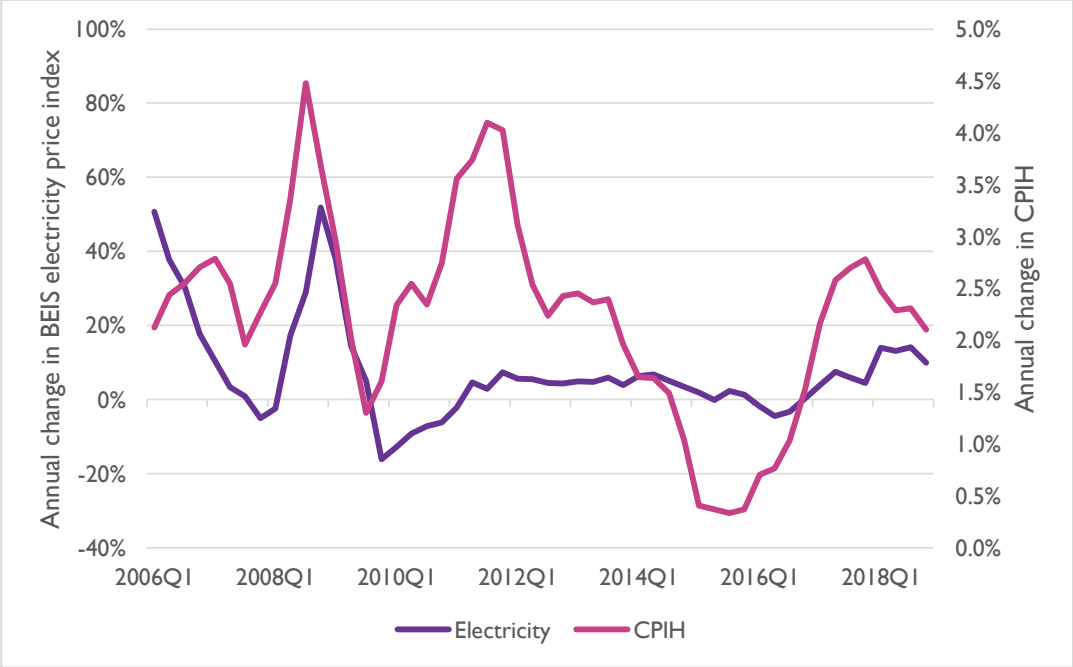
Historical water company cost data reports power costs, rather than overall energy costs. We find a moderate positive correlation between changes in water company power costs and changes in CPIH for the period from 2002/3 to 2010/11 (a correlation coefficient of +0.47 based on June Returns data). However, the Regulatory Accounts data for more recent years suggest that there is no material correlation between the two series (a correlation coefficient of +0.03 from 2012/13 to 2016/17). Again, as with labour costs, it must be acknowledged that some of the underlying changes in power costs will reflect changes in

volume rather than changes in prices, and this in turn will have affected the correlation coefficients that we have estimated.

To focus on the effects of price changes, we look at the evolution of the electricity price index for industrial customers published by the Department for Business, Energy and Industrial Strategy (BEIS).[19] This reflects the fact that electricity is the most important energy cost for water companies.

Figure 2.7 below shows the evolution of growth rates for this electricity price index as compared with CPIH. The industrial electricity price index appears to show similar movements to CPIH prior to 2010 but this relationship has broken down since then. The chart plots the annual percentage change in the BEIS electricity price index and the annual percentage change in CPIH against different axes, and cannot therefore be used to examine the wedge between the two price indices. Instead, the chart is intended to show in a visual way whether the two price series are correlated. We find the correlations between changes in these energy price indices and changes in CPIH (assuming no lag) to be moderately positive (+0.34).[20]

Figure 2.7: Growth rates of electricity price index and CPIH (2006 to 2018)



Note: Growth rates of industrial electricity prices (as reported by BEIS) are presented on the primary (left-hand) axis, CPIH growth rates on the secondary (right-hand) axis.
Source: BEIS and ONS data.

Is the expected value of the wedge between the input price and CPIH materially different from zero?

For some water companies, Economic Insight developed composite energy price indices to reflect the different types of energy used by the water companies in question. The wedge between this constructed index and relevant inflation indices was then assessed. Economic Insight's preferred measure of general price inflation is nominal GDP inflation rather than CPIH, because in its view the drivers of nominal GDP inflation and energy costs are more alike. Economic Insight also uses historical data for its constructed energy price indices to extrapolate forward energy costs over the next control period. Data limitations

[19] Data available at: https://www.gov.uk/government/collections/quarterly-energy-prices

[20] We also explored the strength of correlations with 1 and 2 years lags in both directions, but these correlations were found to be materially weaker. This is consistent with the patterns observed in Figure 2.7 above.

preclude the construction of a composite energy price index here, but we nevertheless investigate the historical wedge between the BEIS industrial electricity price index and general price inflation.

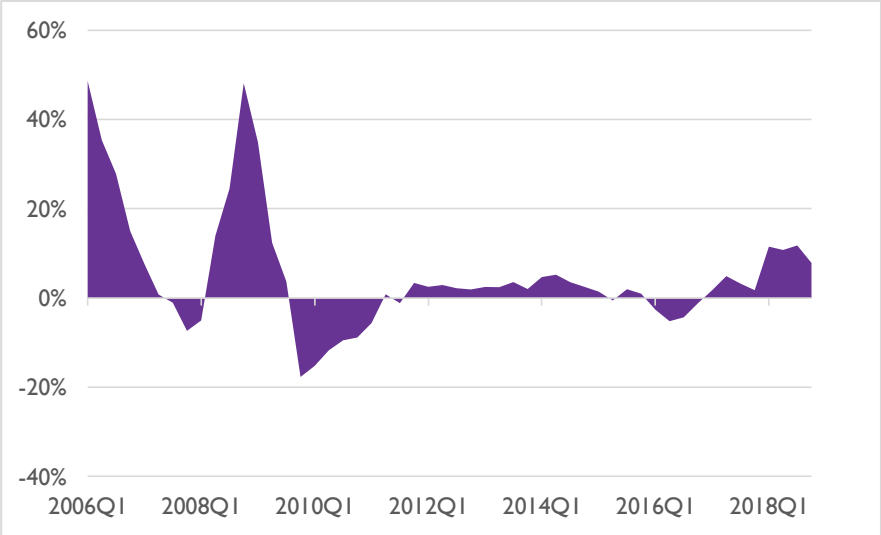
We find evidence of a significant positive wedge relative to changes in CPIH of +5.2 per cent. This statistically significant wedge is largely driven by very high positive wedges prior to 2010 (as shown in Figure 2.8).[21]

Focusing on data for the period from 2010 onwards (i.e. excluding the period of high volatility prior to 2010), we find the wedge between the BEIS industrial electricity price index and CPIH is not significantly different from zero in statistical terms. However, focusing on data from 2011 and 2012 onwards, we do find evidence of a statistically significant positive wedge of 2.7 and 2.8 per cent respectively.[22]

Overall, evidence of a real price effect based on historical wedge analysis is mixed, as it depends which period the analysis is done over.

The lack of compelling evidence is echoed by the submissions on energy RPEs in company business plans, with some companies proposing zero or negative RPEs while others propose positive RPEs.

Figure 2.8: Wedge between annual change in the electricity price index and CPIH, 2006Q1 - 2018Q4



Source: BEIS and ONS data, Europe Economics' analysis.

In many cases water companies and their consultants have assessed the size of any real price effect using independent third party forecasts. The most commonly used measure is the Updated Energy and Emissions Projections bulletin published by BEIS.[23] This includes forecasts of industrial retail electricity prices out to 2035 for a reference scenario, as well as for high and low price scenarios.

BEIS released its 2018 Updated Energy and Emissions Projections on 16 May 2019,[24] after companies had submitted their responses to Ofwat's Initial Assessment of Plans. The BEIS numbers for its low, reference, and high scenarios are shown in the table below.

[21] In particular, we find peak wedges of +48.6 per cent in 2006 Q1 and +48.1 per cent in 2008 Q4.

[22] All of the statistical tests presented for this sub-criterion have been carried out at the 5 per cent significance level, using quarterly data for the BEIS electricity price index.

[23] See "Updated energy and emissions projections: 2017 – Annex M: Growth assumptions and prices". Available at: https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017

[24] See "Updated energy and emissions projections: 2018 – Annex M: Growth assumptions and prices". Available at: https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2018

Table 2.8: BEIS electricity price projections for reference, high and low scenarios (2018 prices)

	Electricity price (p/kWh)			Percentage change		
Scenario	**Low**	**Reference**	**High**	**Low**	**Reference**	**High**
2019	11.4	12.4	13.5			
2020	11.5	12.4	13.9	0.6%	0.5%	3.0%
2021	11.6	12.5	13.8	0.8%	0.8%	-0.9%
2022	11.4	12.5	13.7	-1.4%	-0.2%	-0.8%
2023	11.5	12.5	13.6	0.6%	0.1%	-0.6%
2024	11.7	12.8	13.9	1.6%	2.4%	2.2%
2025	12.3	13.5	14.1	5.0%	5.1%	1.5%
Average percentage change (2020-2024)				**0.4%**	**0.7%**	**0.6%**
Average percentage change (2020-2025)[25]				**1.2%**	**1.4%**	**0.7%**

Source: BEIS data, Europe Economics' analysis.

Based on the latest BEIS reference scenario, electricity prices are expected to rise by an average 0.7 per cent per year in real terms between 2020 and 2024. The low and high price scenarios show average percentage changes of 0.4 per cent and 0.6 per cent.

Analysis of past BEIS electricity price forecasts shows significant differences compared with outturns, thus raising serious questions about the reliability of such forecasts. For example:

- The BEIS 2014 edition forecasted a rise in industrial electricity prices of 12 per cent in 2015 and 8 per cent in 2016, while in practice prices only rose by around 1 per cent in 2015 and fell by almost 3 per cent in 2016.
- In the 2015 edition, industrial electricity prices were forecast to rise by 9 per cent in 2016, but as mentioned above they actually fell by almost 3 per cent in that year.

Uncertainty around Brexit and its macroeconomic effects further add to the uncertainty about the reliability of BEIS forecasts.

Oxera investigates a different index published by National Grid on Future Energy Price Scenarios.[26] National Grid's wholesale gas price 'base case' forecasts show an average increase per year of 4.0 per cent in nominal terms. This implies a 2.0 per cent positive wedge over the period. We do not have earlier forecast data against which to assess the reliability of past forecasts against actual outturns.

What is clear from all of the evidence presented is that the future price of energy is quite uncertain, and that forecasts of energy prices have proven to be unreliable.

Nonetheless, the historical wedge analysis does find a statically significant wedge over some time periods, and the BEIS forecast does project a real terms increase in industrial electricity prices. Hence, we consider that whether energy passes this criterion ultimately depends on whether weight is placed on BEIS forecasts, and on the weight placed on pre-2010 data.

Sub-criterion depends on whether weight is placed on BEIS forecasts and on pre-2010 data.

[25] We have included 2025 in our analysis above, noting that only the first quarter of 2025 falls within Ofwat's next price control period. As the second last row of the table shows, excluding 2025 from the average implies lower average percentage changes in BEIS electricity price projections for all three scenarios for the 2020-24 period.

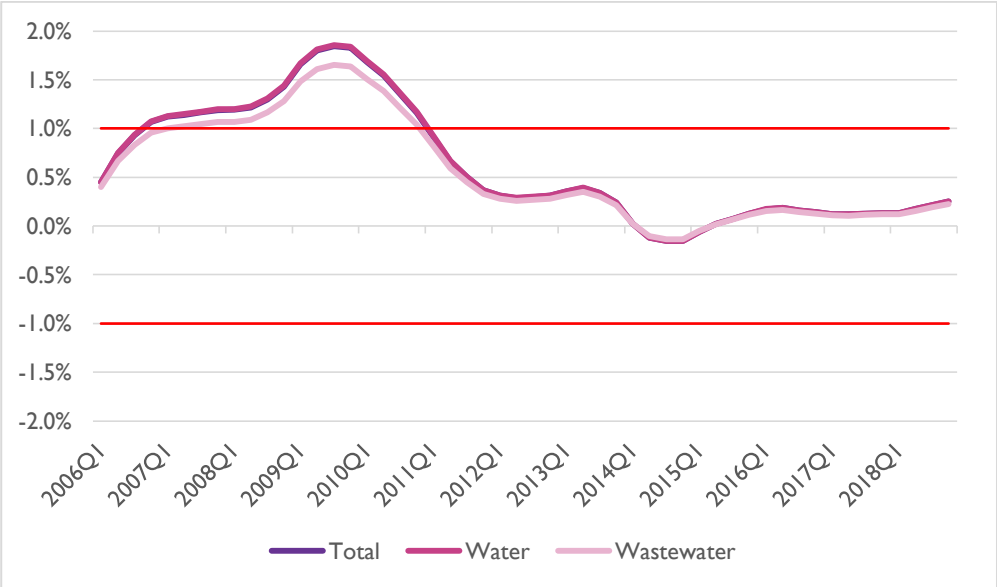
[26] National Grid (2018), "Future Energy Scenarios". See "Data Workbook" file, available at: http://fes.nationalgrid.com/fes-document/

Does the wedge between the input price and CPIH exhibit high volatility over time?

The historical wedge between the electricity price index and CPIH varies between -2 and 20 per cent (over the period from 2006Q1 to 2018Q4), although it appears to have been more stable in recent years. These wedges are clearly more volatile than the wedges for labour. However, it must be recognised that energy costs are a significantly smaller proportion of totex (9.3 per cent) than labour costs, which means that a 1 per cent variation in energy costs has a much smaller impact on totex than a 1 per cent variation in labour costs.

In order to formalise this analysis, we again assess volatility by looking at the five-year rolling average wedge as a share of totex. The results are shown in Figure 2.9 below. We present results for the industry in total and also separately for water and wastewater, given the lower exposure to electricity prices that results from electricity generation by the bioresources part of wastewater businesses. Prior to 2011 there is a material impact on totex from the wedge between industrial electricity prices and CPIH, although after 2011 the wedge (as a proportion of totex)[27] fluctuates within the bounds set by our materiality threshold.

Figure 2.9: Five-year rolling average of wedge between electricity price index and CPIH as a share of totex



Source: BEIS data; industrial sector data, including Climate Change Levy.

Whether sub-criterion is passed depends on weight placed on pre-2011 data.

Are there compelling reasons to think that CPIH does not adequately capture the input price?

The share of electricity in the CPIH basket is 1.3 per cent, and the total share of energy (i.e. including other fuels) is 5.2 per cent (based on 2018 weights). The figure of 5.2 per cent has been calculated as the sum of 2.7 per cent for the category of 'Electricity, gas and other fuels' and 2.5 per cent for the category of 'Fuels and lubricants'.

There is some evidence of a long-run relationship between oil, gas and electricity prices, although the relationship may not always hold over short time periods.[28] The relationship between these prices is likely

[27] In assessing volatility as a share of totex, we have netted off the energy cost savings from energy generation in wastewater bioresources.

[28] See, for example: Frydenberg, Stein & Onochie, Joseph & Westgaard, Sjur & Midtsund, Nora & Ueland, Hanna (2014), "Long-term relationships between electricity and oil, gas and coal future prices—evidence from Nordic countries, Continental Europe and the United Kingdom." OPEC Energy Review. 38. 10.1111/opec.12025

to reflect the fact that some long-term gas contracts on the Continent are indexed to oil prices, and arbitrage across the UK-Continent interconnector in turn links UK wholesale gas prices to continental gas prices. Further, the important role played by gas-fired generation in the UK means that wholesale electricity prices will be influenced by wholesale gas prices. To the extent that consumer energy prices in CPIH move together, the total share of energy of 5.2 per cent could be seen as providing indexation for water companies' power costs.

The share of 5.2 per cent is less than the estimated share of energy costs in water company wholesale totex of 9.4 per cent. The breakdown of this figure of 9.4 per cent between electricity and other energy costs is not available from the business plan tables, although we understand that electricity represents the most significant energy cost faced by water companies.

Overall, the available evidence suggests that CPIH does not fully capture the impact of energy costs, although it does so on a partial basis.

Criterion partially passed.

Is the input price and exposure to that input price outside management control during the duration of the price control?

As for the case of labour costs above, we consider each of the three hypothetical ways in which companies might limit their exposure to increases in input prices for energy.

A. In our view, there is no evidence to suggest that water companies have market power in energy markets (and hence we do not consider that they can control the market price that has to be paid for energy).
B. There are some actions companies can take to reduce exposure to unexpected short-term (e.g. within year) fluctuations. In particular, water companies can make use of fixed energy tariffs to minimise exposure to energy price fluctuations, which typically fix prices for one to two years, after which a new deal would need to be made subject to market conditions. This mechanism, however, will not allow them to avoid the expected value of any increase in energy prices, since this will be built into the prices that energy suppliers offer water companies when fixed prices are agreed. Further, this mechanism may not allow them to reduce exposure to fluctuations over the whole price control, given that energy contracts are typically agreed on an annual or biennial basis.
C. There are other mechanisms by which water companies might be able to reduce net consumption of energy in response to price increases, although there are limitations to what they will be able to achieve. These mechanisms include:
    - Timing of energy use – with data on energy consumption and smart management analytics increasingly available, companies can reduce their bills by carefully managing the times at which they use energy. Companies may also be able to lower energy prices by reducing usage at peak times ('Triads'), though ongoing scope for this may be limited.[29]

and Bencivenga C., Sargenti G., D'Ecclesia R.L. (2010) "Energy markets: crucial relationship between prices." In: Corazza M., Pizzi C. (eds) Mathematical and Statistical Methods for Actuarial Sciences and Finance. Springer, Milano

[29] The Triads refer to three half-hour periods with highest system demand from November to February each year, and are used as part of a charging mechanism by National Grid to smooth demand for electricity during peak periods. Energy prices for each company are set according to how much energy each uses during these periods, incentivising companies to reduce usage at times when demand is likely to be high. By reducing their energy usage at peak times water companies can reduce their overall energy costs. The Triad charging system has been in place since the 1990s, and companies have already implemented measures to reduce usage during the peak periods, so opportunities to deliver further savings may be limited.

- Improve energy efficiency – energy efficiency improvements can be made by upgrading old technologies, as well as through making changes to the configuration or operating regime of assets to achieve additional savings (e.g. use of power factor correction to reduce inefficiencies in the way electrical equipment consumes electricity).
- Increase energy generation – water companies can reduce the impact of energy price rises by generating their own energy. Options for generation include energy recovery from sludge,[30] as well as renewable energy generation through solar PV, wind turbines and hydropower. However, the potential to exploit renewable energies will depend on factors to some extent outside company control; for example, the benefits of hydropower will depend on the local topography, while the ability to utilise available land for new wind turbine installations will depend on planning policy for onshore wind installations.[31] Evidence from revised company business plan submissions shows that the value of energy generation is forecast to constitute on average 18 per cent of wholesale wastewater bioresources totex. This represents 1 per cent of total wholesale totex (reducing energy costs as a proportion of wholesale totex from 9.7 to 8.7 per cent).

In terms of timing of energy use, there is reason to believe that much of the scope for cost saving has already been captured and therefore that there is limited scope for further saving. While increasing energy efficiency and energy generation can clearly reduce exposure to energy price movements, this typically takes time to implement and involves significant capital investment. As such, it is difficult to conceive of these as measures that can reduce exposure to unexpected energy price changes within a single price control (although companies could reduce exposure to foreseen price increases by including energy efficiency initiatives in their business plans).

Overall, therefore, we find that while the above mechanisms would allow companies to take some action to protect themselves against any increase in energy prices, there are limitations to what it will be possible for them to do. Hence we conclude that there is *some* scope for management control, though a material element remains outside management control over the period of a price control.

Criterion partially passed (can reduce volume of input).

Summary of assessment

Table 2.9 below summarises our assessment of energy.

[30] Energy recovery from sludge is widely used by water companies to offset energy costs. Over the last 20 years a large number of combined heat and power (CHP) engines have been installed by companies to generate power and heat for use in treatment processes. Companies may have the option to increase energy recovery by replacing some of the older, less efficient, generating plant (such as older CHP engines reaching the end of their useful lives). It is also possible for companies to convert the biogas from sludge to biomethane (with properties equivalent to natural gas), which can then be sold back to the grid, generating new income streams from gas sales as well as renewable energy incentive payments. Several UK water utilities are trialling advanced conversion technologies (pyrolysis and gasification) which have been used in other sectors (e.g. waste) but have not yet achieved widespread acceptance in the wastewater sludge sector. If these trials are successful and cost-effective and the technology is adopted, it has the potential to significantly increase the amount of energy it is possible to extract from sludge.

[31] Website: https://www.southwestwater.co.uk/environment/efficient-energy-management/investment-in-wind-power/ accessed 05/09/2018

Table 2.9: Summary of assessment of RPE allowance for energy

Assessment criteria	Decision
1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	
A. Is the expected value of the wedge between the input price and CPIH materially different from zero?	Depends on whether reliance is placed on BEIS forecasts and on weight placed on pre-2010
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Depends on weight placed on pre-2011 data
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Partial Pass
3. Is the input price and exposure to that input price outside management control during the duration of the price control?	Partial Pass
Overall	**Depends on whether reliance is placed on BEIS forecasts, and on weight placed on pre-2010 data[32]**

Source: Europe Economics' analysis.

As energy costs could potentially pass Stage 1A of the RPE assessment framework if reliance is placed on BEIS forecasts and if some weight is placed on pre-2010 data, we advance energy for consideration in Stage 1B of the framework.

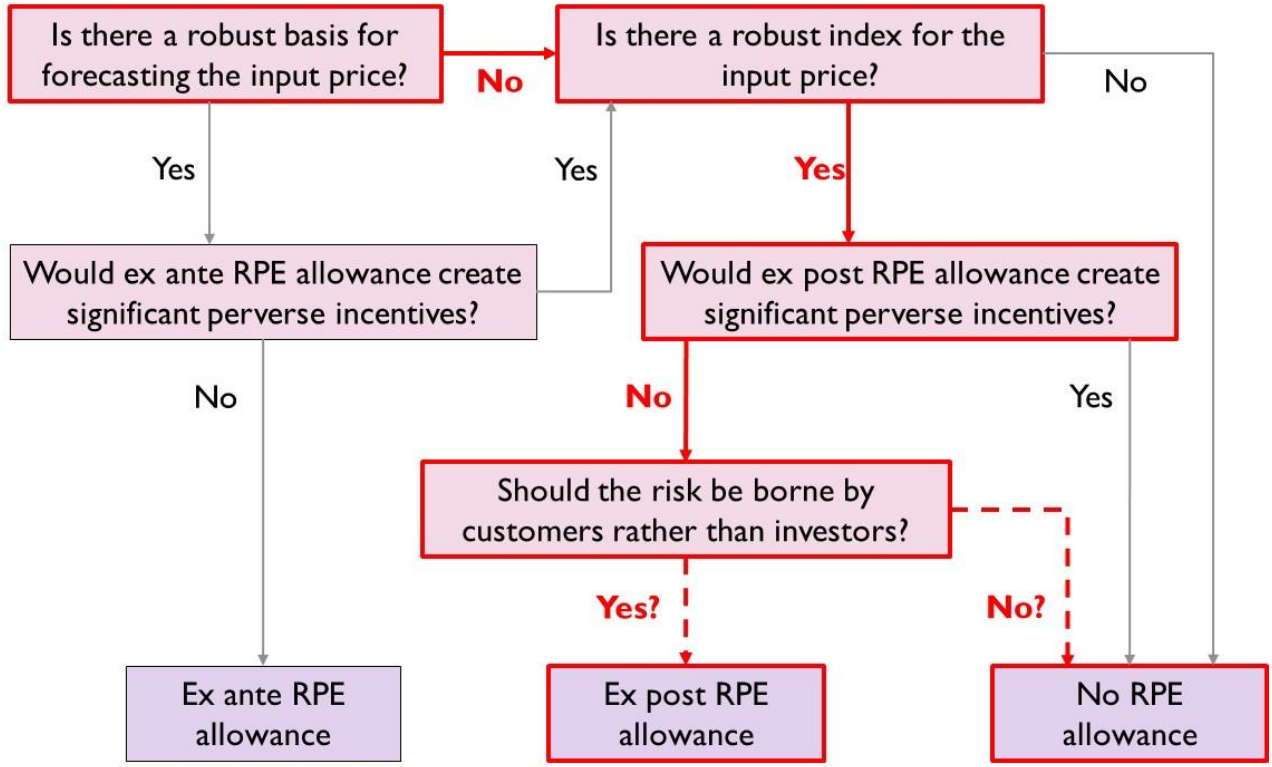
What, if anything, should be done about this RPE?

Working through the assessment map presented in Figure 2.10, we conclude the following with respect to labour costs:

1. Is there a robust basis for forecasting the input price? No – BEIS forecasts have repeatedly failed to provide accurate forecasts of labour costs in the past.
2. Is there a robust index for the input price? Yes – BEIS publish an electricity price index for industrial customers.
3. Would an ex post RPE allowance create significant perverse incentives? No – the BEIS industry electricity price index is based on data from across different sectors and therefore cannot be influenced to any significant degree by water companies.
4. Should the risk be borne by customers rather than investors? Depends – Ofwat will need to make a policy judgment on whether the risk should be borne by customers or companies, bearing in mind the fact that energy costs represent a lower proportion of totex than labour costs (9.4 per cent) and are already partially captured by CPIH.

[32] Furthermore, we note from criteria 2 and 3 that energy costs are partially captured in CPIH and are partially under management control.

Figure 2.10: Stage 1B assessment map for energy costs



Source: Europe Economics' analysis.

Overall, our conclusion is that whether energy qualifies for an RPE mechanism depends on whether reliance is placed on BEIS forecasts for industrial electricity prices and on the weight that Ofwat attaches to the high wedge between growth in industrial electricity prices and CPIH prior to 2010. An ex post indexation mechanism could be considered for energy, although it should be noted that energy is partially captured by CPIH and energy costs represent a lower share (9.4 per cent) of water company totex than labour costs (33.3. per cent).

2.4.3 Chemicals

Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?

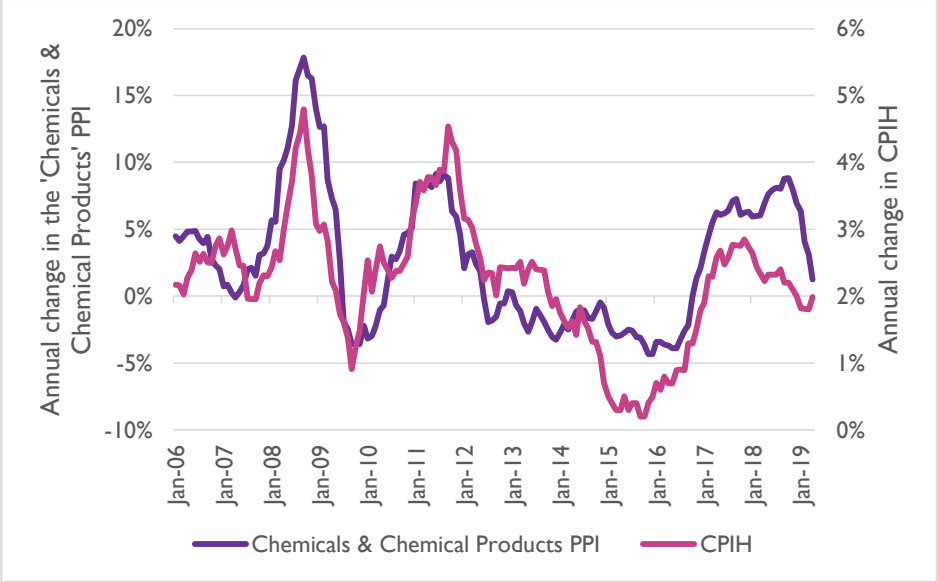
As water companies do not specifically report chemicals costs, we look at 'materials and consumables' as the closest available proxy for chemicals. For the period for which June Returns data and CPIH data are both available (2006/07 to 2010/11), we find only a very weak correlation between changes in water companies' 'materials and consumables' costs and changes in CPIH (a correlation coefficient of 0.13). However, the underlying correlation between the price of chemical inputs and the CPIH may be masked by changes in the volume of chemicals used by water companies, as well as the factor that 'materials and consumables' will include other costs.

We therefore look at relevant price indices that capture changes in the price of chemicals. The ONS report an output PPI for 'chemicals and chemical products'. This exhibits a strong correlation with CPIH, with a correlation coefficient of +0.76 (based on monthly data from January 2006 to April 2019, and with no lag).[33]

[33] We also analysed the correlation assuming either positive or negative 1 or 2 year lags, but the correlations in all these cases were found to be much weaker (i.e. correlation coefficients close to zero).

This strong correlation is evident from below which plots growth rates in the chemicals and chemical products PPI alongside growth rates in CPIH. The chart below plots monthly changes in the 'chemicals and chemical products' output PPI index and the monthly changes in CPIH against two different vertical axis and therefore cannot be used to examine the wedge between the two indices.

Figure 2.11: Growth rates of 'Chemicals & Chemical Products' PPI and CPIH (2006 to 2019)



Note: Growth rates of chemicals prices are presented on the primary (left-hand) axis, CPIH growth rates on the secondary (right-hand) axis.
Source: ONS data.

Is the expected value of the wedge between the input price and CPIH materially different from zero?

A commonly adopted approach in company business plans is to look at the 'Chemicals and Chemical Products' PPI produced by the ONS. NERA and Oxera both investigate this index, the former through an econometric approach and the latter by undertaking historical wedge analysis. As with labour and energy costs, Economic Insight have constructed company-specific chemicals cost indices. It has done so by matching historical data on water company chemicals purchases with relevant US Producer Price Indices published by the Bureau of Labour Statistics (which provide a more granular breakdown of chemicals prices from which to construct a composite index than the ONS data).

Our focus is on a historical wedge analysis between changes in the 'chemicals and chemical products' index and changes in the CPIH (as undertaken by Oxera). Based on data from 2006 to present, we find the wedge not to be significantly different from zero in statistical terms. Moreover, using just data available so far for the most recent price control period (i.e. April 2015 to the present), the wedge has again not been statistically different from zero.[34] Historical wedge analysis therefore does not suggest a material real price effect.

Business plan submissions acknowledge the lack of independent third party forecasts on chemicals (relative to labour and energy prices). That said, Economic Insight did investigate forecast price data for some chemicals published by the World Bank, though primarily as a benchmark rather than as a formal estimate. We have analysed the latest World Bank Commodities Price Forecast published in April 2018, which provides yearly forecasts out to 2025, as well as a forecast for 2030.[35] These data show average nominal price increases for different chemicals over the period 2020 to 2025 ranging from -0.7 to 0.9 per cent.[36] Given forecast CPIH of 2 per cent per year over this period, this implies negative wedges ranging from 1.1 to 2.7 per cent. However, given that these are global estimates by the World Bank and only available for a few specific types of chemicals, we place less weight on these forecasts than the historical wedge analysis.

Overall, placing most weight on the historical wedge analysis, we believe that the evidence suggests that there is no material real price effect in expectation for chemicals. Our findings are consistent with those reported in company business plans, analysis of which has shown an average wedge for chemicals of 0.1 per cent, with estimates of the wedge ranging between -1.2 and +1.2 per cent.

Sub-criterion failed.

Does the wedge between the input price and CPIH exhibit high volatility over time?

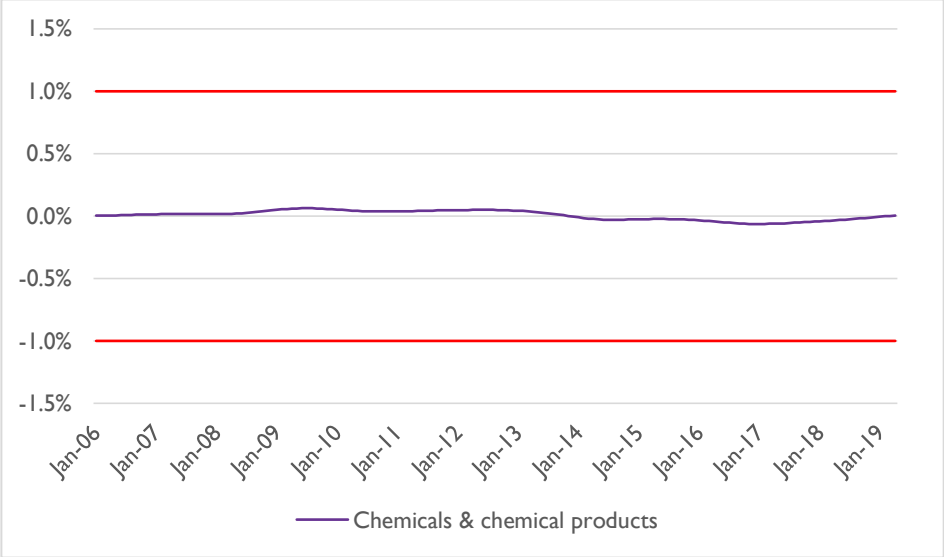
Figure 2.12 below shows a five-year rolling average of annual changes in the 'chemicals and chemical products' PPI – CPIH wedge as a share of wholesale totex. Since chemicals is such a small proportion of wholesale totex (circa 2 per cent), it is clear that the implied volatility on totex is very small (ranging from -0.06 per cent to +0.06 per cent). Therefore, for the period from January 2006 to April 2019, at no point (when evaluating over a five-year horizon) does the wedge exceed 1 per cent of wholesale totex.

[34] All of the statistical tests presented for this sub-criterion have been carried out at the 5 per cent significance level, using monthly data.

[35] World Bank Commodities Price Forecast (nominal US dollars), April 23, 2019. Available at: http://pubdocs.worldbank.org/en/598821555973008624/CMO-April-2019-Forecasts.pdf

[36] Average nominal growth rates from 2020 to 2025 inclusive: DAP at 0.1 per cent; TSP at -0.7 per cent; phosphate rock at -0.2 per cent; urea at -0.1 per cent; and potassium chloride at 0.9 per cent.

Figure 2.12: Five-year rolling average of Chemicals PPI – CPIH wedge as a share of totex



Source: ONS data.

Sub-criterion failed.

Are there compelling reasons to think that CPIH does not adequately capture the input price?

There is no explicit category for chemicals in the CPIH basket. The closest categories we can identify in the CPIH basket are 'cleaning equipment' which constitutes 0.18 per cent of the basket, and 'cleaning and maintenance products' which represent a further 0.38 per cent. Together these items account for 0.56 per cent of the CPIH basket.[37] This is less than the share of chemicals in wholesale totex, which is around 2 per cent. Further, we acknowledge that these CPIH categories will include equipment as well as chemicals, and in any case bear limited resemblance to the industrial chemicals that would be purchased by water companies.

Overall, we conclude that changes in chemicals costs are not well captured by changes in CPIH.

Criterion passed.

Is the input price and exposure to that input price outside management control during the duration of the price control?

We again consider each of the three hypothetical ways in which companies might limit their exposure to increases in input prices in the case of chemical costs.

A. In our view, there is no evidence to suggest that water companies have market power in chemicals markets (and hence we do not consider that they can control the market price that has to be paid for chemicals).

B. As regards companies' ability to protect themselves against volatility in chemicals prices, they typically agree two to three year contracts with chemical suppliers, with prices fixed over that period. This means that during a given price control period, contracts with chemical suppliers will typically be renegotiated at least once. At this point, companies would be exposed to changes in market conditions that have occurred since signing the previous contract.

[37] We recognise that imports constitute a material proportion of CPIH. However, these imports will themselves be affected by chemicals costs in other countries.

C. In terms of the mechanisms by which companies can respond to significant increases in chemical prices (e.g. due to restricted availability), it may become cost efficient for companies to switch to an alternative chemical or process (and thus reduce the volume of the input used). An example in the water industry is the transition from Alum to Ferric coagulants, driven in part by the relative costs of these two chemicals and uncertainty over the long term sustainability of supply. However, while substitution between chemical products may be possible, substitution away from chemicals altogether may be difficult as they form a key part of the treatment process both for water and wastewater. As such, if chemical prices increase across the board, then it may be more difficult for water companies to limit their exposure to these prices increases.

Overall, given that contracts typically only last two to three years and given the difficulty of substituting away from chemicals in the treatment process, we believe that exposure to this input price is largely outside management control during a five-year price control period.

Criterion passed.

Summary of assessment

Table 2.10 below summarises our assessment of chemicals. Overall, due to its failure of the first criterion (significant likelihood that the value of the RPE will differ substantially from zero over the period of the price control), we do not recommend an RPE allowance for chemicals.

Table 2.10: Summary of assessment of RPE allowance for chemicals

Assessment criteria	Decision
1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	
A. Is the expected value of the wedge between the input price and CPIH materially different from zero?	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Pass
3. Is the input price and exposure to that input price outside management control during the duration of the price control?	Pass
Overall	**Fail**

Source: Europe Economics' analysis.

2.4.4 Materials, plant and equipment

Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?

There are no cost items reported by companies in June Returns or Regulatory Accounts data that correspond directly to 'materials, plant and equipment' costs. The closest proxy available is to look at capital costs. The correlation between capital costs and CPIH is not found to be consistent over time. Based on June Returns data from 2006/07 to 2010/11, we find a weak negative correlation between changes in water company capital costs and changes in CPIH (a correlation coefficient of -0.25). However, for the Regulatory Accounts data from 2012/13 to 2016/17, we find a moderate positive correlation (with a coefficient of +0.63).

For previous cost items, we have sought to focus on changes in the underlying input price (and abstract from volume changes) by identifying a suitable index which captures such changes: wage indices for labour costs; an industrial electricity price index for energy costs; and a chemicals and chemical products index for chemical costs. However, there is no one single index that captures well the changes in prices of 'materials, plant and equipment'. Instead, we have considered a range of indices which may reflect the price of individual components and therefore help determine whether there is a case for an RPE substantially different from zero.

Water company consultants have looked at a range of indices in this respect. Economic Insight considered the 'Resource Cost Index of Building Non-housing (NOCOS)' and the 'Resource Cost Index of Maintenance of Building Non-Housing (NOMACOS)', both of which are produced by the Building Cost Information Service (BCIS) of the Royal Institute of Chartered Surveyors (RICS). It also analysed evidence from the 'Construction Output Price Inflation (COPI)' index published by the ONS. Oxera investigated the 'Machinery and equipment' price index produced by the ONS, as did NERA. NERA also considered 'Plant and Road Vehicles' PAFI index from BCIS, and the ONS PPI for 'Inputs for Water Collection, Treatment and Supply' and 'Other Pumps and Compressors'. We consider all of these indices below in coming to our assessment of whether there is a material real price effect in expectation, with the exception of the 'Plant and Road Vehicles' PAFI index which does not appear to be publicly available, and the ONS PPI for 'Inputs for Water Collection, Treatment and Supply' as we believe this is more broadly defined to cover all water sector inputs – not just materials, plant and equipment. (We consider the latter index in Stage 2 of our framework in Section 2.5 below.)

In addition to the above indices proposed by water companies, we also consider a Government-published 'Construction Material Price Index' which could proxy for material costs.

Is the expected value of the wedge between the input price and CPIH materially different from zero?

We have carried out historical wedge analysis against CPIH for the indices described above and found the following:[38]

- For the NOCOS index, we find a statistically significant positive wedge of 1.4 per cent between 2006Q1 and 2012Q1.[39]
- For the NOMACOS index, we find a statistically significant positive wedge of 1.3 per cent between 2006Q1 and 2012Q1.
- For the COPI index, we do not find a statistically significant wedge for the full period of data available from January 2014 to March 2019.
- For the 'Machinery and equipment n.e.c.'[40] output PPI, we do not find a statistically significant wedge for the period January 2006 to April 2019.
- For the 'Other pumps and compressors' output PPI, we do not find a statistically significant wedge for the period January 2006 to April 2019.
- For the 'Construction Material Price Index', we find a statistically significant positive wedge of 1.1 per cent for the period January 2007 to April 2019.[41]

The evidence presents a mixed picture. For some indices, we find evidence of a positive RPE (in the order of 1.1 to 1.4 per cent). In other cases, we find no evidence of a statistically significant wedge. We also find that some companies propose a zero or negative wedge for this cost item.

[38] All of the statistical tests presented for this sub-criterion have been carried out at the 5 per cent significance level.
[39] The start date is determined by the first period for which CPIH growth data are available, while the end date is the last period in which the NOCOS index was published by BIS. The same applies for the NOMACOS index.
[40] The acronym n.e.c. stands for 'not elsewhere classified'.
[41] Data before January 2007 are not available.

Looking at ONS data for various input PPI indices, we have identified four further input PPIs that are likely to be used as inputs in the water sector and that show a decline in real prices over the period from 2011 to 2018. These input PPIs include 'Computer, electronic and optical products' (with a decline of -8.8[42]), 'Electrical equipment' (with a decline of -0.7 per cent), 'Motor vehicles, trailers and semi-trailers' (with a decline of -4.7 per cent) and 'Other manufactured goods' (with a decline of -0.8 per cent).

On balance, given this mixed evidence, we do not believe there is a robust case for a material real price effect in expectation.

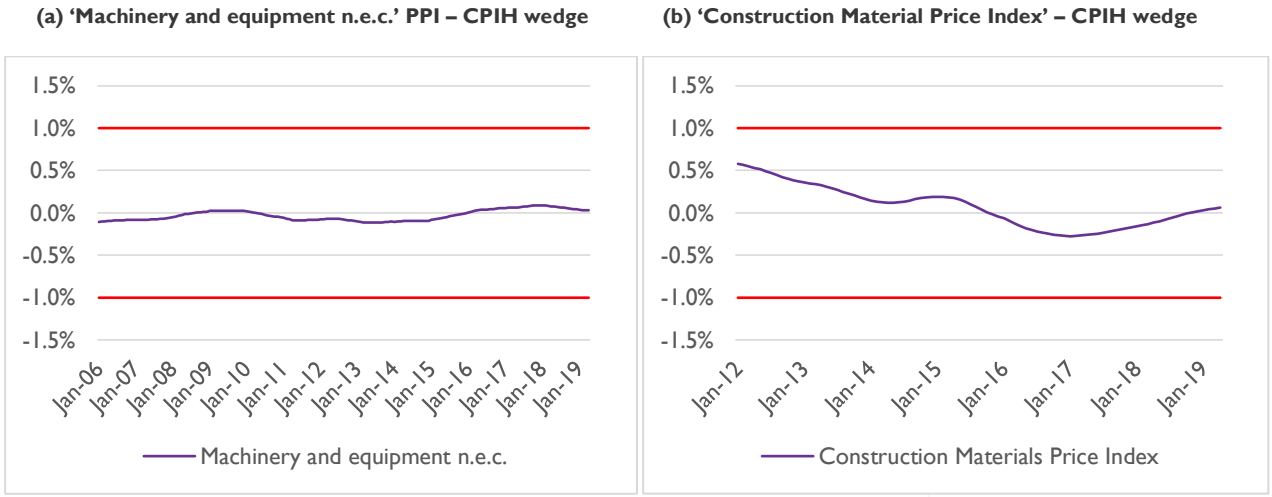
Sub-criterion failed.

Does the wedge between the input price and CPIH exhibit high volatility over time?

In investigating the volatility of the wedge between the input price and CPIH over time, we focus specifically on the 'Construction Material Price Index' and the 'Machinery and equipment n.e.c.' PPI. These both provide a suitably long timeframe over which to assess volatility on a rolling five-year average basis. The NOCOS and NOMACOS indices are more out of date, while the COPI index has only been published since 2014 so there is insufficient time series to construct a five-year rolling average.

Figure 2.13 below shows the five-year rolling averages for the 'Machinery and equipment n.e.c.' output PPI – CPIH wedge and 'Construction Material Price Index' – CPIH wedge, both as a share of totex.[43] The five-year rolling average of the 'Machinery and equipment n.e.c.' PPI – CPIH wedge varies between -0.1 and 0.1 per cent, while for the 'Construction Material Price Index' – CPIH wedge the variation is between -0.3 and +0.6 per cent. Thus, as a share of totex, these indices at no point exceeds the 1 per cent threshold that is required to pass this criterion.

Figure 2.13: Five-year rolling average of annual changes in price index – CPIH wedge as a share of totex



Source: ONS data in (a), gov.uk in (b), Europe Economics' analysis.

Sub-criterion failed.

Are there compelling reasons to think that CPIH does not adequately capture the input price?

There is no direct read across from 'materials, plant and equipment' to items in the CPIH basket. The closest parallel that can be drawn is with the housing and DIY equipment costs that feed into CPIH, as well as the purchase of vehicles, relevant spare parts and the maintenance and repair of those vehicles. Collectively these items have a weight of 15.5 per cent in the CPIH basket., However, we acknowledge that

[42] All figures quoted in this paragraph refer to declines in real prices.

[43] Based on the finding from company business plan submissions that materials, plant and equipment costs represent on average 20.2 per cent of wholesale totex.

the read across from materials, plant and equipment costs faced by water companies to these items in the CPIH basket may be weak.[44,45]

Overall, given the above evidence, we believe that CPIH does not fully capture the input price for 'materials, plant and equipment' costs, although it may do so on a partial basis.

Criterion partially passed.

Is the input price and exposure to that input price outside management control during the duration of the price control?

As for other cost items, we consider each of the three hypothetical ways in which companies might limit their exposure to increases in input prices in the case of chemical costs.

A. In our view, there is no evidence to suggest that water companies have market power in any of the materials, plant and equipment markets (and hence we do not consider that they can control the market price that has to be paid for materials, plants and equipment).

B. In terms of companies' abilities to protect themselves against volatility in input prices, in the case of capital maintenance activities, companies typically enter long term frameworks with suppliers, covering the duration of the regulatory control period, and in some cases, multiple AMPs. These frameworks can include price agreements for delivering certain asset types, and can therefore protect companies from volatility in the price of materials, labour and plant hire. However, the expected value of increases in these input prices are likely to be built into the prices that suppliers offer when bidding for such contracts.

C. With regard to any potential actions companies may take to respond to an increase in the price of plant, material and equipment costs, there may be scope for them to substitute between different materials and equipment if their relative prices change, although the evidence we have in this area is limited.

Overall, we believe that given the typical practice of signing long-term contracts that can cover multiple AMPs, water companies can insulate themselves from volatility in the prices for materials, plant and equipment within a given price control period.

Criterion partially passed (can protect against volatility).

Summary of assessment

Table 2.11 below summarises our assessment of materials, plant and equipment. Overall, we do not propose an RPE for 'materials, plant and equipment' due to its failure of the first and third criterion.

[44] The 15.5 per cent comprises: actual rentals for housing (8.6 per cent); regular maintenance and repair of the dwelling (0.3 per cent); tools and equipment for house and garden (0.5 per cent); purchase of vehicles (3.8 per cent); spare parts and accessories (0.4 per cent); and maintenance and repairs (1.9 per cent).

[45] This assessment is based on the assumption that 'materials, plant and equipment' incorporates the costs of leasing and purchasing buildings.

Table 2.11: Summary of assessment of RPE allowance for materials, plant and equipment

Assessment criteria	Decision
1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	
A. Is the expected value of the wedge between the input price and CPIH materially different from zero?	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Partial Pass
3. Is the input price and exposure to that input price outside management control during the duration of the price control?	Partial Pass
Overall	**Fail**

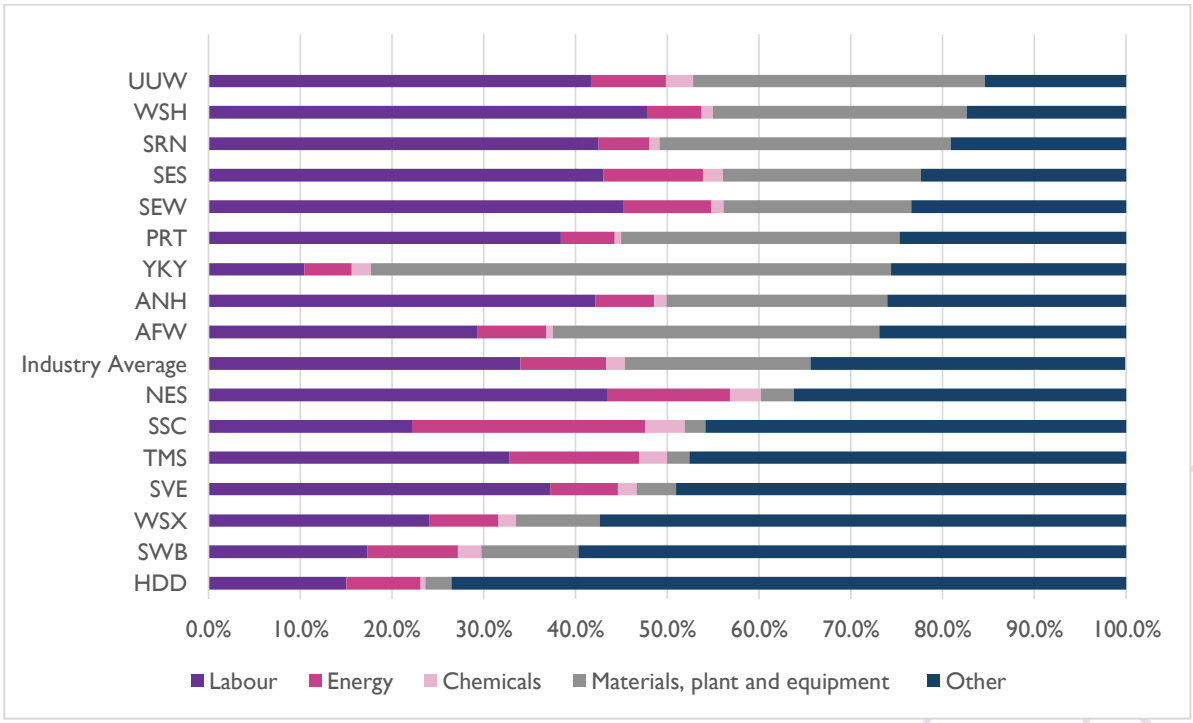
Source: Europe Economics' analysis.

2.4.5 'Other' cost items

In addition to the four cost items (labour, energy, chemicals, and materials plant and equipment) analysed above against our framework for assessing RPEs, we have also considered the 'other' input price category.

The 'other' cost category accounts for 34.3 per cent of totex for the industry as a whole.[46] However, as shown in Figure 2.14 below, the size of this "other" category varies substantially between companies, ranging from 15 per cent to 73 per cent. This may reflect differences between companies in the degree of outsourcing and/or differences in how costs are being categorised.

Figure 2.14: Differences in cost breakdown across companies



[46] This is calculated as a simple, unweighted average across companies.

Source: Ofwat, Europe Economics' analysis.

Clearly, the "other" category does not lend itself easily to RPEs analysis, since it is not clear what these costs are comprised of and hence what input prices may be relevant for this category. The fact that the industry as a whole has allocated a significant proportion of costs to this category therefore limits the percentage of overall totex that can be covered by RPEs analysis for individual cost areas.

Nonetheless, subsequently to our original report we have analysed two cost items which fall within the "other" category — namely, business rates and abstraction charges. Based on data company business plan submissions[47], we find an average share for business rates in wholesale totex to be 6.2 per cent over the next price control period. Similarly, we find an average share for abstraction charges in wholesale totex to be 1.7 per cent. Traffic Management Act costs account for around a further 0.4 per cent of totex.

Business rates are now indexed to CPI which moves closely in line with CPIH, implying that no RPE is needed for business rates. Nonetheless, Ofwat may wish to consider its approach to uncertainty surrounding future business rates (for example, associated with the period reviews of commercial property values) in other parts of the price control.

Data from company business plans shows that most companies are not anticipating any real terms increase in the abstraction charges that they pay.

This analysis of the "other" category does not suggest that any additional RPEs need to be considered.

2.4.6 Summary of assessment for all cost items

The results of our assessment are shown in Table 2.12. This assessment has been updated to take account of responses from companies and their consultants to our earlier work. In particular:

- We have removed the materiality criterion that we used in our previous report.
- For criterion 1A, we acknowledge that the answer for labour depends on whether reliance is placed on OBR forecasts, and that the answer for energy depends on whether reliance is placed on BEIS forecasts and on the weight that is placed on pre-2010 data.
- For criterion 1B, we have extended the volatility analysis back to 2006, and acknowledge that the assessment for energy depends on the weight that is placed on pre-2011 data.
- For criterion 2, we now only consider comparable items in CPIH — such as domestic energy prices in the case of companies' energy costs — and not input costs in other sectors.
- We have applied a more systematic framework for assessing whether input prices and exposure to those input prices are outside management control, with the answer for materials, plant and equipment changing from "Fail" to "Partial pass".

The table shows that whether labour qualifies for an RPE mechanism depends crucially on whether reliance is placed on OBR forecasts of real wage growth. Historically, OBR forecasts of real wages have proved to be inaccurate and biased upwards, and hence we do not recommend an ex ante RPE allowance for labour costs. We do, however, recommend that Ofwat considers an ex post indexation mechanism for labour, using all employees or manufacturing sector wages as a comparator, so that if there is real wage growth, the additional wage costs will automatically feed through into price limits.

Whether energy qualifies for an RPE mechanism depends on whether reliance is placed on BEIS forecasts for industrial electricity prices and on the weight that Ofwat attaches to the high wedge between growth in industrial electricity prices and CPIH prior to 2010. An ex post indexation mechanism could also be considered for energy, but the case is weaker than for wages since:

[47] Table App24.

- There is not the same theoretical reason for expecting a positive wedge (see discussion in Appendix 3 under "Consistency of assumptions on real wage growth and productivity");
- Energy is partially captured by CPIH and energy costs represent a lower share (9.4 per cent) of water company totex than labour costs (33.3. per cent).

For the other two cost items (chemicals and materials, plant and equipment), our framework unambiguously suggests that Ofwat should not make any RPE allowance.

Table 2.12: Summary of RPEs assessment

Cost Item		Labour	Energy	Chemicals	Materials, plant and equipment
1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	A. Is the expected value of the wedge between the input price and CPIH materially different from zero?	Depends on whether reliance is placed on OBR forecasts	Depends on whether reliance is placed on BEIS forecasts and on weight placed on pre-2010 data	Fail	Fail
	B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Depends on weight placed on pre-2011 data	Fail	Fail
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?		Pass	Partial Pass	Pass	Partial Pass
3. Is the input price and exposure to that input price outside management control during the duration of the price control?		Partial Pass	Partial Pass	Pass	Partial Pass
Overall		**Depends on whether reliance is placed on OBR forecasts**	**Depends on whether reliance is placed on BEIS forecasts and on weight placed on pre-2010 data**	**Fail**	**Fail**

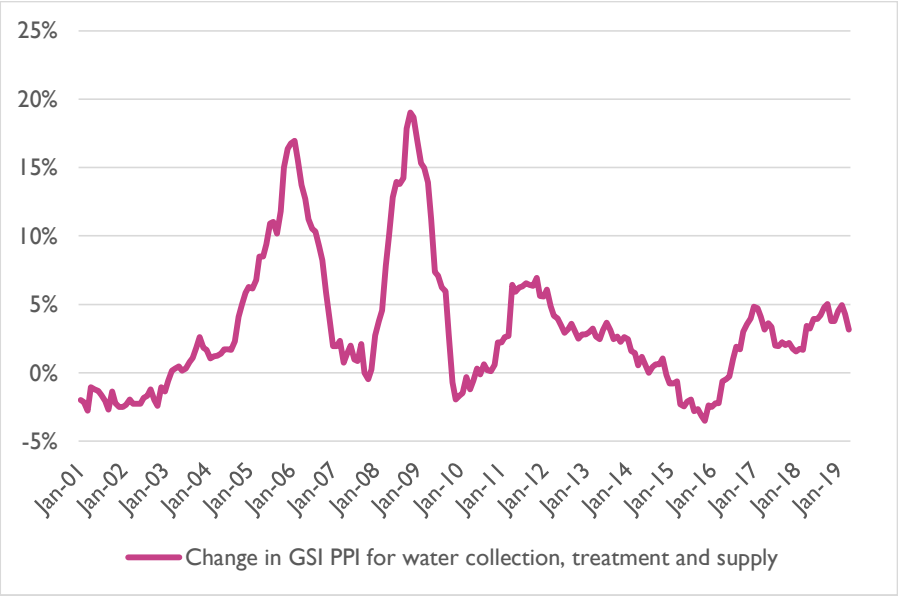
Source: Europe Economics' analysis.

2.5 Stage 2: Check on overall package implied by Stage 1 results

In this section, we compare the results of Stage 1, which assessed individual cost items, with an assessment which looks at whether there is a case for an RPE allowance when analysing all cost items in aggregate. We investigate this using the "GSI groups input PPI for water collection, treatment and supply" which looks at changes in the price of all water sector inputs.

Figure 2.15 below shows the evolution of the GSI input PPI from January 2001 to April 2019.

Figure 2.15: Change in GSI PPI for water collection, treatment and supply



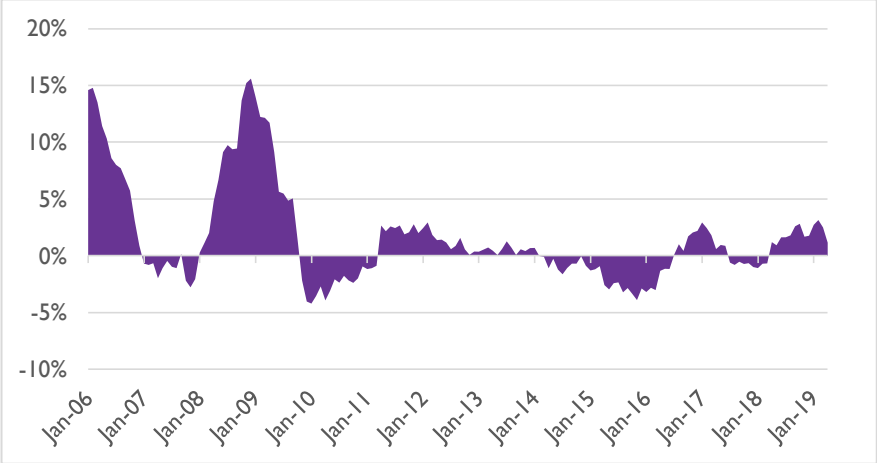
Source: ONS data, Europe Economics' analysis.

Data show that this input PPI is significantly more volatile than the CPIH. This suggests that the CPIH does not capture well the variability of input PPIs in the water sector. We found a moderate positive correlation between the input PPI and CPIH (a correlation coefficient of 0.56).[48]

Figure 2.16 below shows the evolution of the wedge between the input PPI and CPIH. It shows that, despite more marked volatility earlier in the series, since 2010 the wedge has been fairly stable and close to zero. Indeed, statistical tests show that for the period from 2010 onwards the wedge has not been significantly different from zero.

[48] We also evaluated positive and negative 1 and 2 year lags, but found much weaker correlations in all cases.

Figure 2.16: Input PPI and CPIH (Input PPI-CPIH) wedge



Source: ONS data, Europe Economics' analysis.

The evidence therefore suggests no compelling case for an overall RPE for wholesale totex, based on analysis of the wedge between "GSI groups input PPI for water collection, treatment and supply" and CPIH.

2.6 Conclusions on RPE allowances

Overall, both Stages 1 and 2 of our analysis identify that there is not a robust case for the inclusion of ex ante RPE allowances for wholesale totex.

Whether labour costs qualify for an RPE mechanism depends crucially on whether reliance is placed on OBR forecasts of real wage growth. Given OBR's tendency to systematically overestimate average earnings growth compared to actual outturns, we do not recommend an ex ante RPE allowance for labour costs. Instead, we recommend an ex post indexation mechanism so that if there is any real wage growth it will automatically feed into price limits.

Our assessment is that the case for allowing an energy RPE depends on whether reliance is placed on BEIS forecasts and on the weight placed on pre-2010 data. Analysis of past BEIS electricity price forecasts against outturns show significant differences and hence we do not recommend an ex ante RPE allowance for energy costs. If Ofwat considers that energy costs are material enough to warrant it, it may wish to consider an ex post indexation mechanism for power costs t.

For chemical and 'materials, plant and equipment' costs, our framework unambiguously suggests no compelling case for including an RPE.

Stage 2 analysed wholesale totex by looking at a relevant input PPI for the water sector as a whole, and did not find sufficiently strong evidence for an RPE.

3 Frontier Shift

The purpose of this chapter is to provide Ofwat with estimates of the regulated water companies' scope for frontier shift over the next control period, AMP7. Frontier shift relates to the ability of even the most efficient firms in the sector (i.e. those on the "efficiency frontier") to become more efficient over time. In the current context, the aim is to derive a frontier shift estimate which reflects the pressures to become more efficient that firms face in competitive sectors, so that price regulation mimics competition. Productivity growth is regularly used as an approximation of the frontier shift in regulatory literature.

In arriving to a figure for the frontier shift in the water industry, we conducted a Total Factor Productivity (TFP) analysis. While partial measures of productivity can be defined — such as labour productivity and LEMS (labour, energy, material and services) productivity — we consider that a TFP measure is more appropriate for botex, since it takes into account all measurable factors of production.

TFP growth captures the change in output that is not explained by changes in inputs. It is calculated as the residual of the growth in outputs less the weighted average growth in different inputs – labour, capital and intermediate inputs (e.g. materials).

In this chapter of the report we first set out what companies have proposed in their business plans with regard to frontier shift, as well as the methodologies underpinning these estimates. We then set out our preferred approach for estimating frontier shift in the water and wastewater sector, by looking at TFP growth in suitable comparator sectors. Specifically, we use a TFP growth analysis based on the growth accounting calculations performed by EU KLEMS. This approach is commonly adopted by regulators and regulated companies, and the EU KLEMS data are widely regarded as a credible source of TFP estimates.

3.1 Frontier shift estimates proposed by water companies

This section presents water companies' estimates for, and approaches to calculating, frontier shift. First we summarise the figures put forward by water companies, and then we describe the various methods companies have used in generating these estimates.

Frontier shift estimates

Table 3.1 below summarises the frontier shift figures that water companies have proposed in their business plan submissions for the wholesale segment. Frontier shift figures are sometimes provided separately for each price control area (water resources, water network plus, wastewater network plus and wastewater bioresources), and are also typically provided separately for opex and capex. In some cases, figures for other aggregates such as botex are also provided. Where multiple companies have submitted the same forecasts, this is noted in the second column. We also report whether the numbers were produced by an external consultancy, and if so whom, or produced in-house.

Table 3.1: Summary of company frontier shift proposals

Frontier shift estimates (per year)	Water companies	External consultancy or in-house?
Opex water resources: 0.53% as central estimate with -0.04% and 0.94% as lower and upper bounds Opex other wholesale areas: 0.67% as central estimate with 0.05% and 1.05% as lower and upper bounds Capex: 0.28% as central estimate with -0.31% and 0.56% as lower and upper bounds	Northumbrian Water, Wessex Water and Yorkshire Water	Economic Insight
0.6% for opex and 0.7% for capex	Bristol Water	NERA
Water resources opex: 0.7% Network plus opex: 0.4% or 0.8% All capex: 0.7% Botex: 0.6% or 0.7%	South East Water	Oxera
Water resources opex: 0.7% Network plus opex (water and waste): 0.4% or 0.8% Bioresources opex: 0.9% All capex: 0.7% Botex (water): 0.6% or 0.8% Botex (waste): 0.7% or 0.8%	Southern Water	Oxera
-0.2% as central estimate for dynamic efficiency relative to CPIH with -0.6% and 0.2% as lower and upper bounds	United Utilities Water	In-house
1% for opex and capex	Anglian Water	In-house
1%	Severn Dee and Severn Trent Water	In-house
No frontier shift estimates reported (see 'Efficiencies' section)	Affinity Water, South West Water, Portsmouth Water, Sutton and East Surrey Water, South Staffordshire Water, Thames Water and Welsh Water	-

Source: Company business plans.

Efficiency estimates

Seven water companies (South Staffordshire Water, Thames Water, Welsh Water, Sutton and East Surrey Water, South West Water, Portsmouth Water and Affinity Water) focused on their projected cost efficiencies instead of producing frontier shift numbers. Among these, Affinity Water did not provide a discussion of its submitted efficiency numbers. Companies' estimates, and the bases for these estimates, are summarised in Table 3.2 below. Although in some cases not entirely clear, the total efficiency estimates proposed by companies generally includes both frontier shift and catch-up. Therefore the figures based on projected efficiencies below are not directly comparable to the frontier shift estimates for the wholesale segment presented above.

Table 3.2: Summary of company efficiency proposals for wholesale segment

Efficiency estimates (per year)	Water companies	Basis for efficiency estimates
1.6% for opex 1.1% for capex	South Staffordshire Water	Comparing base costs for 2019-2020 to projection for price review period
13.6% for total opex over next price review period	Thames Water	Comparing actual and forecast costs based on properties served
Between 0.79% and 4.9% for opex Between -2.79% and 2.18% for capex	Welsh Water	Cost savings due to efficiency programmes implemented by company
2% from 2021-22, amounting to a total of 8% by 2024-25	Sutton and East Surrey Water	Based on company's internal transformation programme
1% per annum compounded for opex (5% efficiency embedded within capital programme)	South West Water	Company efficiency targets
0.5% for both opex and capex (water resources and water network plus)	Portsmouth Water	Company assumption

Source: Company business plans.

3.2 Approaches used in producing frontier shift estimates

In general, water companies, or economic consultancies on behalf of water companies, have applied two approaches to estimate frontier shift or efficiency figures for the next price control period:

- Estimating frontier shift numbers based on total factor productivity (TFP) figures.
- Providing forecast efficiency improvements based on projected costs.

Table 3.3: Summary of frontier shift estimation approaches by water companies

Commissioned TFP analysis	Adjust externally estimated TFP figures (i.e. adjusted third-party figures)	Report frontier shift numbers, but no evidence of supporting calculations	No frontier shift estimates, only forecast efficiency improvements
No catch-up included	*No catch-up included*	*No catch-up included*	*Catch-up generally included*
Northumbrian Water, Wessex Water, Yorkshire Water, Bristol Water, South East Water and Southern Water	Anglian Water and United Utilities Water	Severn Dee and Severn Trent Water	Affinity Water, South West Water, Portsmouth Water, Sutton and East Surrey Water, South Staffordshire Water, Thames Water and Welsh Water

Source: Europe Economics analysis of company business plans.

The approach of estimating frontier shift by TFP has been followed primarily by companies who commissioned economic consultancies to produce frontier shift estimates for them, or by those who relied on third-party reports on TFP estimates and adjusted these to reflect the company's view regarding appropriate comparators. In some cases, water companies have provided frontier shift estimates directly, but with no clear supporting evidence.

Other water companies focused on projected efficiencies, for which figures have been based on: companies' assumptions or targets; forecast cost savings; or internal planned or ongoing future efficiency programmes and improvements.

In the remainder of this section, we focus on the specific approaches used when estimating frontier shift using TFP estimates, in particular looking at:

- The choice of comparator sectors.
- The choice of time period.
- The choice of gross output TFP or gross value added TFP.
- The approach to deriving a final TFP estimate based on TFP estimates for comparator sectors.

3.2.1 Choice of comparator sectors

Economic consultancies on behalf of water companies have used two main approaches to select what they consider to be suitable comparators. Economic Insight[49] and Oxera[50] have examined the similarities between the activities water companies undertake and the activities undertaken in other sectors, selecting those with the most comparable activities. NERA[51] has adapted/extended the list of comparator sectors used in previous work undertaken by other regulators.

Similarities between activities undertaken by water companies and comparators

Economic consultancies on behalf of water companies have generally developed a list of comparators by mapping other sectors onto different parts of the water value chain based on the similarity of activities undertaken. Economic Insight's selection process relies on a comparison of some measure of capital intensity in the sectors, through the use of external datasets such as the Annual Business Survey from the ONS. In the case of Oxera, the justification provided for its proposed comparators is more qualitative, e.g. a discussion of some of the activities undertaken by the proposed comparator and how these relate to water companies' operations. The list of comparators used by consultancies on behalf of water companies based on this approach is summarised in Table 3.4.

Table 3.4: Comparators based on similarities in activities

Comparator sectors
Total industries (whole UK)
Agriculture, forestry and fishing
Wholesale trade, except of motor vehicles and motorcycles
Real estate activities
Total manufacturing
Chemicals and chemical products
Other manufacturing; repair and installation of machinery and equipment
Construction

Source: consultancies (Economic Insight, NERA and Oxera) on behalf of water companies.

Consultancies also express diverging views about the suitability of TFP estimates from the 'Electricity, gas and water supply' (EGW) sector. NERA argues that the inclusion of EGW may not be valid, citing problems such as endogeneity (i.e. that companies' past performances would influence the future benchmark). Oxera, on the other hand, did include EGW as a cross-check, noting that including EGW reduces the estimated TFP figures.

[49] Economic Insight on behalf of Northumbrian Water, Wessex Water and Yorkshire Water. Future references to the work done by Economic Insight always refers to the work it did on behalf of these water companies.

[50] Oxera on behalf of South East Water and Southern Water. Future references to the work done by Oxera always refers to the work it did on behalf of these water companies.

[51] Future references to the work done by NERA always refers to the work it carried out on behalf of Bristol Water.

Comparators used in previous regulatory decisions

NERA has drawn upon the comparators used for other regulated industries and adapted these as necessary to reflect water companies' activities more closely. In some cases, Oxera also noted whether the comparator in question has been used in a previous regulatory decision. The list of comparators used by consultancies on behalf of water companies based on this approach is summarised in Table 3.5.

Table 3.5: Comparators based on those used in previous regulatory decisions

Comparator sectors
Manufacture of chemicals and chemical products
Manufacture of electrical and optical equipment
Manufacture of transport equipment
Construction
Sale, maintenance and repair of motor vehicles; retail sale of fuel
Transport and storage
Financial intermediation
Other manufacturing and recycling
Manufacture of rubber and plastics

Source: consultancies (Economic Insight, NERA and Oxera) on behalf of water companies.

3.2.2 Choice of time period

Consultancies on behalf of water companies have considered the impact of economic cycles on TFP growth estimates, but expressed diverging views over which time period TFP growth should be estimated. Overall, three main approaches have been applied in generating TFP estimates:

- Estimation using the full time series of 1970 and 2007 for which EU KLEMS NACE 1 data are available. This timeframe was used by NERA for estimating TFP figures.
- Oxera used a complete business cycle between 1996 and 2014, where the start year is partly influenced by data limitations (with no comparable data available before 1996). Furthermore, it also considered a shorter business cycle between 2002 and 2010 (where the start and end years have been identified as small deviations from the trend in TFP growth) as a sensitivity check.
- Economic Insight used data between 1999 and 2015 as a central case, on the basis that this balances the pre-crisis years characterised by high productivity growth and the 8-year post-crisis period where productivity growth is lower. At the same time it also estimates a high case based on data between 1999 and 2008 (representing the pre-crisis period), and a low case based on eight years of data between 2007 and 2015 (representing the post-crisis period).

3.2.3 Choice of gross output TFP or gross value added TFP

All consultancies that estimate TFP growth figures on behalf of water companies make use of the EU KLEMS datasets. NERA primarily draws on the gross output (GO) TFP measure using the NACE 1 dataset, stating that this productivity measure would fit the purposes of UK regulators. Nonetheless, the value added (VA) measure and the NACE 2 dataset have also been explored by NERA. Oxera states that both GO and VA based measures of TFP growth are valid, but uses the VA measure noting that this is the one published in the most recent EU KLEMS dataset. Economic Insight does not explicitly discuss the choice between VA and GO measures.

3.2.4 Deriving a final TFP estimate based on TFP estimates for comparator sectors

In general, consultancies on behalf of water companies have used either weighted or unweighted averages to generate the final TFP estimates.

The use of unweighted averages usually implies that a simple arithmetic average of the TFP numbers generated for the comparator sectors is calculated (i.e. effectively each comparator enters the final TFP estimate with the same weight). Oxera and NERA use unweighted averages to produce their final (preferred) TFP estimates and cite reasons such as avoiding putting too much weight on sectors where the dynamics could be different than those experienced by water companies.

In some cases, consultancies applied weights for the selected comparators. Economic Insight chose to apply greater weight to industry averages than specific industries, while Oxera (for its set of weighted average estimates) determined the weights by matching comparator sectors to different activities and then applying a weight which reflects the cost share of that activity in total water company costs.

3.3 Points made by water companies and their consultants in IAP responses

Below we briefly summarise the points made by companies in response to our first report in relation to our frontier shift analysis.

Water companies and their consultants raised points regarding our choice of comparator sectors, our choice of time period, and the addition made by Ofwat for the impact of totex and outcomes framework.

In relation to our choice of comparator sectors, John Earwaker, Oxera on behalf of South East Water and Southern Water, and NERA on behalf of Bristol Water have all commented that the upper bound of the TFP estimate range provided by Europe Economics focused on stronger performing sectors rather than being calculated as an average. Oxera on behalf of South East Water and Southern Water also argued that our analysis failed to consider the representativeness of the comparator sectors.

With regard to the choice of time period, NERA on behalf of Bristol Water stated that Europe Economics did not consider full business cycles and both John Earwaker and Economic Insight on behalf of Yorkshire Water argued that we did not attach sufficient weight to the recent productivity slowdown that the UK has experienced.

Economic Insight on behalf of Yorkshire Water and NERA on behalf of Bristol Water further stated that Ofwat's decision to attach weight to the gross value added (GVA) measure was incorrect.

Economic Insight on behalf of Wessex Water and Yorkshire Water stated that the addition made by Ofwat for the impact of the totex and outcomes framework double counted the impact that the totex and outcomes framework has on efficiency. NERA on behalf of Bristol Water claimed that Ofwat included a capital substitution effect alongside the impact of the totex and outcomes framework, which Europe Economics advised against doing in its report.

Further details on the points made by companies and their consultants and our response to these comments is available in Appendix 3.

3.4 Decomposing TFP

While in a tradition going back to Solow (1956), TFP growth used to be referred to as frontier shift (or technical change, using a different terminology), more recent research has highlighted that only in special circumstances will TFP growth reflect just frontier shift. Indeed, it is possible to show from first principles that TFP growth can be decomposed into the following components:

- Frontier shift — where the maximum output that can be achieved from given inputs increases through time. As discussed later in section 3.6.2, only disembodied technical shift (i.e. technical shift that is additional to better quality labour or capital inputs) is captured.
- A technical efficiency change component — where firms move closer to or further away from the maximum level of output that can be produced for a given set of inputs.
- A scale component — where unit costs rise or fall depending on whether volume is increasing and decreasing in the sector and whether there are increasing or decreasing returns to scale. (There will by definition be no scale component in sectors with constant returns to scale.)
- An allocative efficiency component — where output increases (or decreases) due to firms adopting a more efficient (or less efficient) mix of inputs (i.e. capital, labour and intermediate goods).

This means that positive TFP growth can represent any one, or more, of the following:

- Positive frontier shift.
- A decrease in technical or allocative inefficiencies through catch-up to the frontier.
- Increasing returns to scale and input growth, or decreasing returns to scale and negative input growth.

This means that, at least from a theoretical point of view, TFP growth is a good proxy for frontier shift when:

- Inefficiency is absent or relatively invariant over time; and
- Scale effects are not important, i.e. when returns to scale are approximately constant or there is no input growth.

We consider the implications of these two additional components of TFP in turn.

Catch-up

Some TFP growth can reflect catch-up as firms get closer to the efficiency frontier over time, irrespective of any movement in the frontier itself. Consequently, failure to account for catch-up would be likely to result in overestimation of frontier shift.

There are two sources of catch-up:

- Improvements in technical efficiency, as firms may use of their existing inputs more efficiently for a given level of available technology.
- Improvements in allocative efficiency, as firms improve optimise their mix of inputs (labour and capital) to maximise efficiency.

In order to limit the effect of catch-up on TFP estimates, an established approach is look at TFP growth in comparator sectors which are competitive. There are two possible rationales for this approach:

- In a reasonably competitive industry, inefficient firms will not survive in the long run, meaning that surviving firms may only have small efficiency differentials.
- Alternatively, in a reasonably competitive industry, efficiency levels of individual producers might vary a lot but, on average, they might tend to cancel out.

By way of contrast, in industries where competitive forces are not present (e.g. due to natural monopolistic features or public ownership), TFP growth may arise to a greater extent from improvements in technical or allocative efficiency (i.e. catch-up). This could be especially true following episodes of privatisation, or when some form of competition for the market is introduced, such that productivity gains can be easily achieved by cutting slack.

Scale effects

Returns to scale are another component of TFP. With increasing returns to scale, and input growth, the marginal cost per unit is falling and this is reflected in a higher TFP figure, as proportionally more output is

produced for a given increase in inputs. Similar logic applies with decreasing returns to scale and a decline in inputs.

There are two key sources of returns to scale that we should be aware of:

- Growth of an industry as a whole, which could allow all firms to exploit further returns to scale.
- Changes in the market structure of an industry, for example through mergers and acquisitions, with the formation of larger companies allowing greater exploitation of returns to scale.

The scope for scale effects in the water and wastewater sector may be less than in other sectors. In particular, growth of the water and wastewater sector as a whole may be more limited, as it is an established utility providing a basic good and therefore large future increases in demand do not seem plausible. Indeed, since 1995, ONS data show that output in water collection, treatment and supply has fallen by on average 0.9 per cent per annum.[52] In theory, therefore, TFP estimates that more accurately reflect the frontier shift that is achievable in water and wastewater could be attained by looking at sectors where the scope for scale effects is more limited. This is because the TFP estimates for these sectors will be a more accurate reflection of pure frontier shift, rather than also incorporating the impacts of scale economies or diseconomies. The scope for scale economies would be more limited in industries that have experienced no significant output growth or changes in market structure over time. In practice, however, identifying industries that have behaved like this is difficult.

Whether or not TFP estimates for comparator sectors will provide an over- or underestimate of the underlying frontier shift will depend on whether there are decreasing, constant or increasing returns to scale in that sector, as well as whether input growth has been positive, stable or negative over time. There is empirical evidence that some manufacturing industries exhibit approximately constant returns to scale, in which case a scale effect will not be relevant.[53] While some other manufacturing industries may have a positive scale effect, there could be other manufacturing industries in which the scale effect may be negative (i.e. meaning that frontier shift is potentially higher than the TFP estimate).

We have investigated the magnitude of the scale effects within our data and find that, on average, there is no scale effect associated with our choice of comparator sectors (which we set out in Section 3.77). As such, no adjustment to TFP estimates for a scale effect is required in our analysis. Details of the estimates that support this conclusion can be found in Appendix 2.

3.5 Capital substitution effect

TFP is a measure of productivity which takes all inputs (capital, labour and intermediate goods) into account. TFP estimates are therefore most directly relevant to an assessment of frontier shift for totex.[54]

If TFP estimates were to be used to inform frontier shift for opex, then there is a theoretical basis for adjusting the TFP estimates by including a capital substitution effect. This is because opex will to a large extent reflect labour costs, and labour productivity typically increases through time faster than overall TFP due to capital inputs increasing faster than labour inputs, which increases the amount of capital employed

[52] See ONS: IOP: 36: Water Collection Treatment and Supply: CVMSA. Available at: https://www.ons.gov.uk/economy/economicoutputandproductivity/output/timeseries/k24d

[53] For example, Wen-Jen Hsieh (1995) tested for scale elasticities in 20 US manufacturing industries, and found that many of them showed constant returns to scale, although there were some that displayed increasing or decreasing returns to scale.

[54] Even in the case of totex, it should be noted that the inputs considered in TFP analysis are not identical to totex. In particular, the capital inputs considered in TFP analysis are the flow of capital services from the total stock of capital in the sector, whereas the capex included within totex represents additions to the capital stock in the sector. Nonetheless, TFP is typically considered a good proxy for the frontier shift that can be applied to totex.

per unit of labour. This can be illustrated by thinking of the greater labour productivity which will result when a firm invests capital in IT or machinery that allows more processes to be automated.

Some past consultancy studies have estimated the magnitude of the capital substitution effect that is relevant when applying TFP estimates to opex. For example, a 2012 CEPA report[55] for the ORR presents estimates of the capital substitution effect in selected sectors that range from 0.2 to 1.4 per cent depending on the sector and the time period considered. CEPA's base case estimate of the capital substitution effect for the economy as a whole was 0.4.

Our study seeks to produce a frontier shift estimate for both wholesale totex and wholesale botex. For wholesale totex, no adjustment for the capital substitution effect is necessary. However, an adjustment can appropriately be applied to the frontier shift estimate for wholesale botex.

Since botex includes some capital (i.e. capital maintenance), it would be incorrect to include the full capital substitution effect that would be relevant if TFP estimates were being applied to opex. At the same time, botex does not include all capital, since it excludes capital enhancement. This means that there is some residual scope for companies to make further savings in botex (over and above the figure implied by TFP estimates) due to the substitution of capital enhancement for botex over time. This implies that including no capital substitution effect understates the potential for efficiency gains in botex, whereas including a full capital substitution effect would overstate potential gains. Therefore, we believe a partial capital substitution effect is appropriate, which adjusts the full capital substitution effect by the share of capital enhancement in total capital expenditure. By doing so, we in effect consider substitution between capital enhancements and botex only (but not between capital maintenance and opex).

When reaching a judgement on the scale of this partial capital substitution effect, it should be noted that the introduction of totex incentives at PR14 may lead to a period of time in which the water sector re-optimises the balance of capex and opex towards the latter, as historical regulatory incentives which biased firms towards capex are removed. This may lead to a temporary period of time in which firms substitute opex for capex until they achieve the optimal balance – although over the longer term the trend of capital-labour substitution (which applies across the economy) is likely to continue. This could depress the size of the capital substation effect in the short term.

We present our findings on the scale of the partial capital substitution effect in Section 3.10.4.

3.6 Quality adjustments to TFP

In order to fully capture the extent of frontier shift in TFP figures, changes in the quality of both inputs and outputs must be appropriately taken into account:

- Changes in the quality of output need to be included in the analysis, as a superior quality of output (not just a greater volume of output) can be a reflection of inputs being used more efficiently.
- Changes in the quality of inputs need to be excluded from measures of input growth, in order to estimate a genuine frontier shift. Failure to do so would understate the extent to which water companies can achieve efficiency savings, as improvements in the quality of inputs (labour, capital or intermediate inputs) would not be captured in TFP estimates, despite providing efficiency savings.

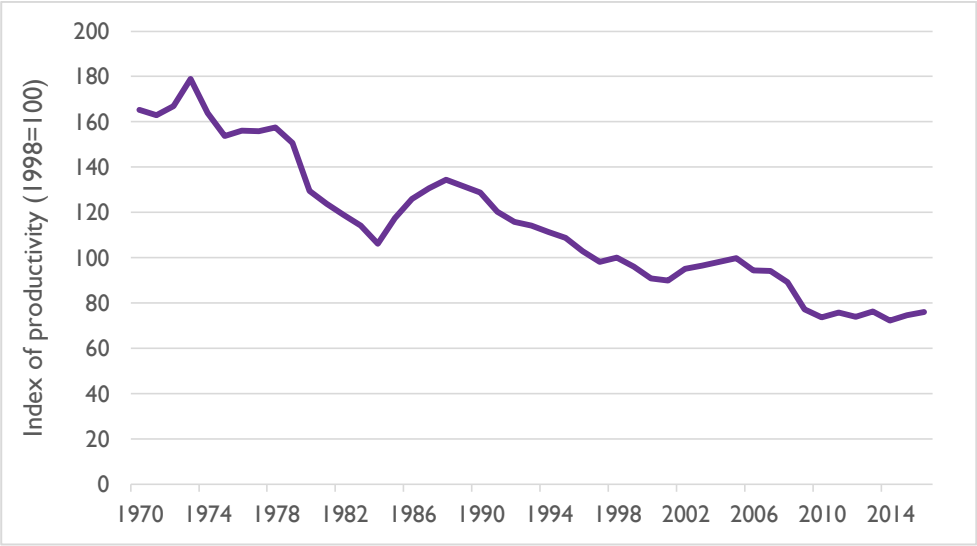
We consider each in more detail in turn.

[55] CEPA, "Scope for improvement in the efficiency of Network Rail's expenditure on support and operations: supplementary analysis of productivity and unit cost change", March 2012

3.6.1 Changes in quality of output and evidence from water sector TFP

TFP estimates for the water sector itself exemplify the problem of using TFP growth as a measure of frontier shift if improvements in the quality of output are not taken into account. Figure 3.1 below shows the ONS's index of productivity measure for the water supply, sewerage, waste management and remediation activities from 1970 to 2016. The data show a significant decline in the TFP of the water sector, by more than half for the period as a whole. This equates to an (arithmetic) average fall in TFP of 1.6 per cent per annum. Moreover, for the water, electricity and gas sector as a whole, EUKLEMS data show consistently negative TFP growth since 2000. Such consistent falls in TFP for the UK water sector are not credible.

Figure 3.1: Index of productivity for water supply, sewerage, waste management & remediation activities



Source: ONS data.

One of the key reasons behind this material fall in published TFP data is likely to be the fact that the output measures used for the water sector do not account for changes in the quality of output (e.g. improved customer services, or reduced water leakages and bursts), or for greater environmental benefits. This is a significant omission, given the amount that water companies have invested to improve the quality of water, reduce environmental impact etc.

We were informed by the ONS that the output measure it uses is the volume of delivered water. In other words, the ONS output measure does not take into account benefits of higher water quality, a better environment and so on. As a result, if companies spend money on tackling such issues, then inputs necessarily go up but the measured output variable would be unchanged, so measured productivity would by definition fall. Even more starkly, for water companies investing in demand management programmes, inputs would again go up while measured output would in this case decline. A similar issue is present in EU KLEMS data (though they only report data for the electricity, gas and water supply sector combined), as it is our understanding from speaking with EU KLEMS that its own output measures come from Eurostat which in turn gets them from national statistics agencies, i.e. the ONS in the case of the UK.

Adjusting for quality of outputs is therefore important to achieving a more robust measure of frontier shift, and particularly so in industries where quality improvements may not be well captured by key measures of output (as in the water and wastewater sector). Failure to do so is likely to lead to an underestimate of the true frontier shift, insofar as quality-adjusted TFP growth is larger than the non-quality-adjusted TFP growth when there has been quality improvement over the period under analysis.

The importance of taking into account output quality changes in productivity growth analysis have also been highlighted in a recent study by Maziotis et al (2017) for the English and Welsh water and wastewater undertakers observed over the 2001-2008 period. The authors show that failing to control for quality (proxied by the number of written complaints, the number of more than 12 and 24 hours of unplanned service interruptions and the number of properties below the reference level) leads to significant underestimation of productivity growth over the sample period.[56] Specifically, they looked at the performance of water companies over the period 2001 to 2008, finding that when failing to control for quality of service productivity declined during all years of the sample. However, when quality of service was accounted for, they found that productivity improved by 4.13 per cent from 2000 to 2004, before declining in the remaining years of the sample. This evidence shows the marked effect that accounting for changes in quality can have on the estimated productivity figures.

A 2017 report commissioned by UK Water also investigates the impact of including quality-adjustments to TFP growth estimates in the water sector and finds that these are materially positive.[57] Specifically, it finds that when adjustments are made, on a conservative basis, for output quality, the average productivity growth is 2.1 per cent per year from 1994 to 2017 (compared to only 1.0 per cent per year with no quality adjustment). The report makes use of compliance-based measures of quality for water (meeting higher standards of drinking water quality), and output measures for wastewater (improvements in river water quality), in order to adjust the output index used for estimating TFP growth. Table 3.6 below is reproduced from the Water UK report, and shows average TFP growth for different time periods both with and without quality adjustment. It shows that, by accounting for changes in quality, estimates of average TFP growth rates in any given control period increase materially.

Table 3.6: Annual TFP growth estimate over price control periods from Water UK Report

Time 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 for Water UK, "Productivity Improvement In The Water And Sewerage Industry In England Since Privatisation", 29.07.2017.

Given concerns that TFP estimates from EU KLEMS for the category which includes the water sector fail to account for improvements in the quality of outputs, it is important to consider TFP estimates for other sectors in which this concern is less material.

[56] Maziotis et al (2017) computed a Malmqvist-Luenberger productivity indicator using DEA techniques.

[57] Frontier Economics for Water UK, "Productivity Improvement In The Water And Sewerage Industry In England Since Privatisation", 29.07.2017.

3.6.2 Changes in quality of inputs

Changes in the quality of inputs over time can also contribute to frontier shift by allowing firms to make cost savings.

Traditional productivity analysis (using TFP) does not account for the frontier shift associated with improvements in the quality of inputs, since TFP is computed as the residual change in output after taking account of changes in both the quantity and the quality of inputs. The quality of inputs is typically already accounted for: through the use of quality adjusted price deflators in the case of capital; and through the use of a composition term in the case of labour (which captures, for example, changes in education levels of the workforce). Given these adjustments, traditional productivity analysis is only accounting for what is known as 'disembodied' technical change, which reflects changes in the way a given set of inputs of a given quality are used to produce the output.

However, technical change is also 'embodied' in the quality of inputs to the sector. This is especially true of capital goods but also for intermediate inputs, as successive vintages of capital goods and intermediate inputs might incorporate new technologies and therefore be more productive than past ones. Somewhat similarly, the quality of labour inputs might improve through an increase in the share of highly educated employees, i.e. through human capital accumulation.

For regulatory purposes, it is important to ensure the cost saving effects of both embodied and disembodied technical change are taken into account. Failure to account for the technical change 'embodied' in intermediate inputs, capital and labour would omit key sources of cost savings, and could therefore lead to overly generous cost allowances. A regulator forecasting a reduction in the price of ICT capital, for example, might allow for a lower increase of ICT capex, but the firm might exploit the new technology embodied in this new ICT capital to further reduce other (capital or non-capital) costs. In other words, even if the regulator correctly forecasts that some capex can be delivered at lower costs, the firm can exploit the newly installed machines to further cut costs because of the embodied technical change they incorporate.

EU KLEMS uses quality-adjusted inputs. In the case of capital, changes in quality are taken into account through the use of quality adjusted price deflators. The EU KLEMS documentation (Jager, 2018)[58] specifically states, for example, that ICT investment (the type of capital goods where quality changes are likely to have been more important) reflect quality adjusted price declines. In the case of labour, changes in quality are taken into account through a labour composition term. Specifically, the EU KLEMS dataset makes use of the European Labour Force Survey (EULFS) to get information on changes in the composition of the labour force, in terms of age, gender and education levels.

Because these input quality improvements over time are taken into account, the TFP growth estimates contained in the EU KLEMS database will tend to capture only disembodied technical change and not the benefit of embodied technical change (although it is possible that some embodied technical change that is not fully captured through the input quality correction will be captured).[59]

Using TFP estimates that reflect only disembodied technical change (like those from EU KLEMS) will therefore introduce a downward bias compared with true frontier shift, and thus underestimate the overall scope for cost reductions.

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[58] Jager (2018), "EU KLEMS Growth and Productivity Accounts: 2017 Release, Statistical Module". Available at: http://euklems.net/TCB/2018/Methology_EUKLEMS_2017_revised.pdf

[59] Jorgenson and Griliches (1967) note that quality changes are not always fully captured and that such errors contribute between 0 and 28 per cent per year to the initial measured rate of growth of total factor productivity. See: Jorgenson and Griliches (1967), "The Explanation of Productivity Change".

We have therefore reviewed selected academic papers to understand the potential scale of embodied technical change (that is not captured by TFP estimates), relative to disembodied technical change (that is captured in TFP estimates). Below we summarise the key findings of this, and the implications for our assessment of frontier shift.

Uri (1983)[60] examines the relative magnitude of disembodied and embodied technical progress in the US for the period 1947 to 1980, finding that disembodied technical progress has been around 3 per cent per year, while embodied technical progress in the capital stock has been 3 to 4 per cent per year. This implies that embodied technical change in the capital stock is of the same order of magnitude as disembodied technical change. Uri also notes that 'educational attainment significantly enhances labour productivity'.

Hulten (1992)[61] estimated what he calls "investment-specific technological change", which is a result of new equipment becoming less expensive or better than old equipment. The paper concludes that quality change (embodied technical change) has accounted for approximately 20 per cent of the residual output growth not attributed to inputs on average. In other words, 20 per cent of estimated TFP figures actually represent embodied technical change due to a failure to adjust accurately for changes in the quality of inputs.

Greenwood et al. (1997) find that embodied technological change explains close to 60 percent of the growth in output per hours worked.[62] This paper employs a similar approach to Hulten (1992), but claims to build upon it by accounting for the endogeneity issues between output and technical change. It must be noted however that this analysis relates to labour productivity, not TFP, and therefore will also capture the capital substitution effect.

Overall, the evidence on the scale of embodied technical change is rather limited. Nevertheless, we can make use of the evidence presented by Uri (1983) and Hulten (1992) to provide a rough indication of the potential scale of embodied technical change. First, Uri (1983) reports that disembodied and embodied technical change are of similar orders of magnitude. Second, Hulten (1992) finds that approximately 20 per cent of estimated TFP growth actually represents embodied technical change – implying that disembodied technical change accounts for the remaining 80 per cent of estimated TFP growth. Using Hulten's data as the starting point, and with the aim of equalising the magnitude of embodied and disembodied technical change (as claimed by Uri), we can deduce that embodied technical change not captured by TFP growth estimates is a further 60 per cent on top of the existing TFP growth estimates. The rationale for this is set out in Table 3.7 below.

Table 3.7: Estimation of embodied technical change excluded from TFP estimate

	Disembodied technical change	Embodied technical change	Source
Included in TFP estimate	80%	20%	Hulten (1992)
Excluded from TFP estimate	-	**60%**	-
Total	80%	80%	Consistent with Uri (1983)

Source: Europe Economics' analysis, using Uri (1983) and Hulten (1992).

[60] Uri (1983), "Embodied and disembodied technical change and the constant elasticity of substitution production function". Journal of Applied Mathematical Modelling, Vol. 7(6), pp. 399-404.

[61] Hulten (1992), "Growth Accounting When Technical Change is Embodied in Capital", The American Economic Review, Vol. 82, No. 4 (Sep., 1992), pp. 964-980.

[62] Greenwood, Hercowitz, Krusell (1997) "Long-Run Implications of Investment-Specific Technological Change". The American Economic Review, Vol. 87, No. 3 (Jun 1997), pp. 342-362.

The evidence base is limited on the issue of embodied technical change and, therefore, the evidence and analysis presented above should be seen only as illustrative of the potential magnitude of efficiency gains from embodied technical change that are excluded from traditional TFP estimates. If we interpret the evidence from Uri (1983) and Hulten (1992) as set out above, then this would imply that a traditional TFP estimate would need to be uplifted by a further 60 per cent to account for embodied technical change.

3.7 Selection of comparator sectors

Based on earlier discussions, there are three important issues that reduce the credibility of water sector TFP estimates as a measure of frontier shift:

- Given that water is a price regulated sector, TFP figures in this sector will incorporate catch-up to the frontier.
- Water sector TFP figures may not reflect the frontier shift expected of a competitive sector given that the sector has historically been organised on a regional monopoly basis.
- Water sector TFP figures do not appear to capture improvements in quality of output (e.g. improved environmental outcomes).

We therefore look at TFP growth in comparator sectors as a more robust measure of the potential for future frontier shift in the water sector. The use of comparators also provides an external challenge to the water sector, based on the productivity performance of other relevant sectors of the economy.

3.7.1 Our criteria for selecting comparator sectors

The key first question is therefore which comparator sectors should be used. As we are using TFP data from the EU KLEMS database, we are restricted to the sectors contained in this dataset. Our choice of sectors from those available in the EU KLEMS database is guided by two principal criteria:

- whether the sector is competitive (i.e. a predominantly private non-price regulated sector); and
- whether the sector is similar to the water sector in terms of the nature of activities undertaken.

We have also checked how our comparator selection compares with the sectors that other consulting firms have used.

The sector is competitive

The reason for limiting comparators to competitive sectors is that, in a competitive environment, TFP growth is primarily driven by frontier shift, as firms behind the frontier would be driven out the market. Therefore, by focusing on competitive sectors we reduce the materiality of the catch-up component of TFP estimates, such that TFP estimates are a more accurate reflection of underlying frontier shift. (This does not however correct for the issues of returns to scale or capital substitution.)

Sectors in the EU KLEMS dataset that are predominantly public in nature such as: "Public Administration and Defence; Compulsory Social Security"; "Education"; "Community, social and personal services"; "Health and social work"; "Activities of extraterritorial organizations and bodies"; and "Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use", are therefore not suitable as comparators.

The sector is similar in nature to the water and wastewater sector

In assessing whether sectors are similar in nature to the water sector, the focus was on identifying sectors with predominantly comparable activities to water wholesale, including: the extraction and processing of some primary resource; the operation and maintenance of some network for delivering a product; and/or manufacturing processes likely to involve large scale plant and equipment. We also considered data on the

capital intensity of each sector and how comparable that is to the water sector, although this was not treated as an over-riding consideration where there were other reasons for including a comparator.[63]

3.7.2 Comparing our selection of comparator sectors to those of other consultancies

The tables below report the sectors chosen by other consultancies in generating frontier shift estimates for water companies to inform their business plan submissions, alongside our own choice of comparators sectors. Table 3.8 presents the list of wholesale comparators. We have looked at reports by Economic Insight, Oxera and NERA. In each case, we provide our reasons for excluding comparator sectors proposed by other consultancies that we did not include in our own selection.

Table 3.8: Comparator sectors used by other consultancies

Industry	Economic Insight[64]	NERA[65]	Oxera[66]	Our chosen comparators
Total industries	✓			
Total manufacturing	✓		✓	✓
Wholesale trade, except of motor vehicles and motorcycles	✓			
Construction	✓	✓	✓	✓
Financial intermediation		✓		
Agriculture, forestry and fishing	✓			
Real estate activities	✓			
Chemicals and chemical products		✓	✓	✓
Other manufacturing; repair and installation of machinery and equipment			✓	✓
Transport and storage	✓		✓	✓
Manufacture of electrical and optical equipment		✓		
Manufacture of transport equipment		✓		
Sale, maintenance and repair of motor vehicles; retail sale of fuel		✓		
Manufacturing nec; recycling		✓		
Manufacture of rubber and plastics		✓		
Machinery and equipment n.e.c				✓

[63] We calculated the level of capital intensity for all available sectors by dividing the nominal capital stock by the nominal gross output for the latest available year in the EU KLEMS dataset (2014). We compared the capital intensities of other sectors with the figure for "Electricity, gas and water supply". In some cases, these data helped to guide our choice of comparators, by allowing us to exclude sectors with capital intensities significantly above or below that of the wholesale water industry.

[64] Economic Insight reports prepared for Yorkshire Water, Affinity Water, Bristol Water, Northumbrian Water, South West Water and Wessex Water.

[65] NERA report prepared for Bristol Water.

[66] Oxera reports prepared for South East Water and Southern Water.

Industry	Economic Insight[64]	NERA[65]	Oxera[66]	Our chosen comparators
Electricity, gas and water supply[67]			✓	

Source: company business plans and Europe Economics' own comparator selection.

Our chosen comparators (as indicated in the final column of Table 3.8) are primarily competitive sectors and similar to the wholesale water and wastewater sector in terms of the nature of activity undertaken. More specifically:

- "Total manufacturing" – this broad category includes many elements which will be similar in nature to the activities undertaken in the water sector, which would include building and maintaining plant, equipment and machinery, processing an end product, and storing and distributing that product.
- "Construction" – this sector is reflective of the activities undertaken in the water and wastewater sectors as it includes the construction and maintenance of new infrastructure, such as new water and wastewater treatment works, new dams or new pipeline network.
- "Chemicals and chemical products" – this category includes activities related to the processing of chemicals and chemical products, which will be similar in nature the process of treating water after abstraction and processing wastewater before its release into the environment.
- "Other manufacturing; repair and installation of machinery and equipment" – like "Total manufacturing", this category captures a variety of activities which share similarities with the wholesale water sector. It includes activities which will be reflective of those typically undertaken by water and wastewater companies, such as the repair and installation of machinery and equipment.
- "Transport and storage" – other transport networks can be seen as having some similarities to the building and operation of networks for transporting water and wastewater. We acknowledge that the scope of activities in the transport and storage sector may be more diverse than similar activities undertaken in the water sector; nonetheless we consider that these will still be sufficiently reflective of the activities undertaken in the water sector.
- "Machinery and equipment n.e.c" – by the same logic as for "total manufacturing" and "other manufacturing; repair and installation of machinery and equipment", this category captures many elements which share similarities with the wholesale water sector.

Below we list the reasons why we have excluded some of the comparator sectors chosen by other consultancies from our list of wholesale comparators:

- "Total Industries" – this is excluded from our selection, as we instead select "Total manufacturing" which more closely reflects wholesale water activities. "Total Industries" includes a significant services element which is not a suitable comparator for wholesale water activities.
- "Agriculture, forestry and fishing", "Sale, maintenance and repair of motor vehicles; retail sale of fuel" and "Wholesale trade, except of motor vehicles and motorcycles" – we do not consider these to be good comparators to the water sector in terms of the nature of activities performed.
- "Financial intermediation" – this is excluded because the impacts of the global financial crisis on this sector and the effects on productivity thereafter make it an unsuitable comparator. Moreover, relative to wholesale water and wastewater activities, it is very different in terms of the actual activities undertaken.
- "Manufacture of electrical and optical equipment", "Manufacture of transport equipment", "Manufacturing nec; recycling", and "Manufacture of rubber and plastics" – we instead include the more general "Machinery and equipment n.e.c" and "Other manufacturing; repair and installation of machinery and equipment" which we consider better reflect water company capital enhancement and maintenance activities.

[67] Used as a sensitivity check only.

- "Real estate activities" – we exclude this as a comparator because the capital intensity of this sector is found to be significantly higher than that of other wholesale sectors, including the electricity, gas and water supply sector. Moreover, this comparator covers estate agency and real estate management activities that are not reflective of wholesale water activity.

3.7.3 Final choice of comparator sectors in NACE 1 and NACE 2 classifications

Our final selection of sectors in the NACE 2 classification can be found in the table below. We also report the closest sector definition based on NACE 1 classification (if any). This is because in producing our TFP growth estimates, we make extensive use of both NACE 1 and NACE 2 versions of the EU KLEMS database.

Table 3.9: Comparator sectors for wholesale

Comparator sectors in NACE 2	NACE 1 closest equivalent
Construction	Construction
Transport and storage	Transport and storage
Chemicals and chemical products	Chemicals and chemical products
Professional, scientific, technical, administrative and support service activities	*(No NACE 1 equivalent)*
Machinery and equipment n.e.c.	Machinery, n.e.c.
Other manufacturing; repair and installation of machinery and equipment	*(No NACE 1 equivalent)*
Total manufacturing	Total manufacturing

Source: Europe Economics' comparator selection from EU KLEMS dataset.

3.8 Choice of time period

Economic literature suggests that productivity, as measured by TFP, is procyclical. Some explanations for this cited in the literature are: that GDP growth and productivity growth tend to move together as they are both driven by technology shocks; that unobserved employee effort falls in downturns and rises in upturns, such that measures of productivity that do not account for employee effort varying over time are necessarily procyclical; and that the production process generally exhibits economies of scale, such that productivity rises in upturns when scale increases, and falls in downturns.[68] Given the procyclicality of productivity, the choice of time period could have a significant effect on TFP estimates.

3.8.1 Time periods used by other consultancies and regulators

In Table 3.10 below, we summarise the time periods used by other consultancies in their TFP analysis undertaken on behalf of water companies.

[68] See: BIS (2011), "Productivity and the economic cycle". BIS Economic Paper No. 12, March 2011.

Table 3.10 Time periods used by other consultancies in frontier shift on behalf of water companies

Report	Time period used
Oxera	1996 to 2014
Economic Insight	1999 to 2015; 1999 to 2008; 2007 to 2015
NERA	1970 to 2007

Source: Europe Economics' analysis of company business plan submissions.

Oxera focus on a longer business cycle for 1996 to 2014, including what they term "the 'irregular' period during the financial crisis". Inclusion of these 'irregular' TFP growth rates in 2008 and 2009 may materially depress averages across whole period analysed. Economic Insight look at three different periods, and in particular it is interesting to note how their 'high case' scenario (1999 to 2008) and 'low case' scenario (2007 to 2015) both include TFP growth data for 2008 when the global financial crisis had a significant downward impact on TFP growth. Its high case scenario may therefore be biased downwards by the inclusion of 2008. NERA rely on the longest time series possible in estimating TFP growth, as a means of limiting certain theoretical and data measurement issues.

We have also reviewed regulatory literature to see what time periods have been used in analysing frontier shift in other regulated sectors. In Table 3.11 below, we present examples of what other consultancies have used as time periods in the past for other regulators.

Table 3.11 Time periods used by other consultancies in frontier shift analysis of regulated industries

Report	Main time period used	Sensitivity checks
CEPA (2018) review of Ofgem's approach to RIIO1	1970 to 2007; 1970 to 2015; 2007 to 2015; 2010 to 2015	-
CEPA (2013) for the CAA	1997 to 2006	1972 to 2006 (including all available business cycles)
CEPA (2012) for the ORR	1997 to 2006	1986 to 2006; 1978 to 2006; 1972 to 2006
Reckon (2011) for the ORR	1970 to 2007; 1981 to 2007	-
Oxera (2008) for the ORR	1981 to 2004	1970 to 2004; 1990 to 2002

Source: consultancy reports.

There are broadly two approaches to choosing the time period: using the entire time series; or, dividing the available data into business cycles and examining the TFP growth across full cycles.

Using the entire time series provides the benefit of more data points, which can help to reduce the impacts on final estimates of atypical TFP growth over a single business cycle due, for example, to an industry-only shock. On the other hand, examining TFP growth over an entire business cycle captures the cyclical nature of TFP growth, and thus reduces the likelihood that we under- or overestimate TFP figures by looking at a predominantly strong or weak growth period in the past. Another advantage of analysing TFP over full business cycles is that does not require a judgement to be made about what part of the business cycle the UK economy will be in over the next control period.

3.8.2 Impact of the global financial crisis on historical figures and future predictors of productivity

According to the latest version of the EU KLEMS dataset, for the two crisis years only (2008 and 2009), total economy TFP growth was on average around -1 per cent per annum. Since then TFP growth has continued to be markedly weaker than its pre-crisis trend — in the four years from 2010 to 2014, annual TFP growth in the total economy has been close to zero. Two important questions arise from this:

- Do we expect economy-wide productivity to rise to its pre-crisis levels over the course of the next control period, do we expect it to stay at the new lower post-crisis levels, or do we expect it to be somewhere in between? In other words, which past is a better predictor for the future over the period of AMP7?
- Have comparator sectors of most relevance to the water and wastewater sector seen the same reduction in TFP growth that has been observed for the economy as a whole?

In relation to the first question, in its November 2017 Economic and Fiscal Report the OBR revised down further its forecasts for future productivity growth, although it still expects productivity growth to pick up from its current level. The OBR looks specifically at labour productivity, rather than TFP. The OBR assumes that trend hourly labour productivity growth will rise slowly to 1.2 per cent in 2022 and that productivity growth will rise by 0.1 percentage points a year from 2023-24 until it reaches 2.0 per cent in 2030-31. Averaging over the next control period, this means that future economy-wide productivity growth as predicted by the OBR is significantly lower than the 1972 to 2007 average productivity growth of 2.1 per cent. Furthermore, uncertainty around Brexit and its macroeconomic effects also increase uncertainty surrounding OBR forecasts of productivity growth.

An OBR report also claims that productivity growth has been 1.5 percentage points lower on average since the crisis than in the pre-crisis period.[69] The report explains that three quarters of that fall is attributable to the manufacturing and financial sectors, with smaller negative contributions from ICT and professional services. According to the OBR's report, these four sectors have been responsible for the entire productivity slowdown, despite representing only around one third of total output.

Our figures for comparator sectors reflect these sectoral differences to some extent – the post-crisis average for our wholesale comparators (from the NACE 2 dataset) are not far off the pre-crisis figure from the last cycle in the NACE 1 dataset; however certain sectors, such as "Total Manufacturing" and "Chemicals and chemical products" see a marked decrease in TFP growth. Other sectors, such as "Professional, scientific, technical, administrative and support service activities" see a recovery in TFP growth. This differences between the OBR report and the EU KLEMS data could be due to a different sectoral definition, differences in the precise time period analysed and/or differences in the measure of productivity. Nonetheless, the important conclusion is that although total economy productivity growth has been lagging behind pre-crisis averages, productivity growth in certain sectors has recovered.

In the light of this uncertainty, we take a cautious approach and do not limit our analysis to only one period (be it post-crisis or pre-crisis). Instead, we look at data over various periods and take account of the above considerations in interpreting the data.

3.8.3 Our choice of time period

The time periods that can be used are restricted by the years available in the NACE 1 and NACE 2 datasets. In particular:

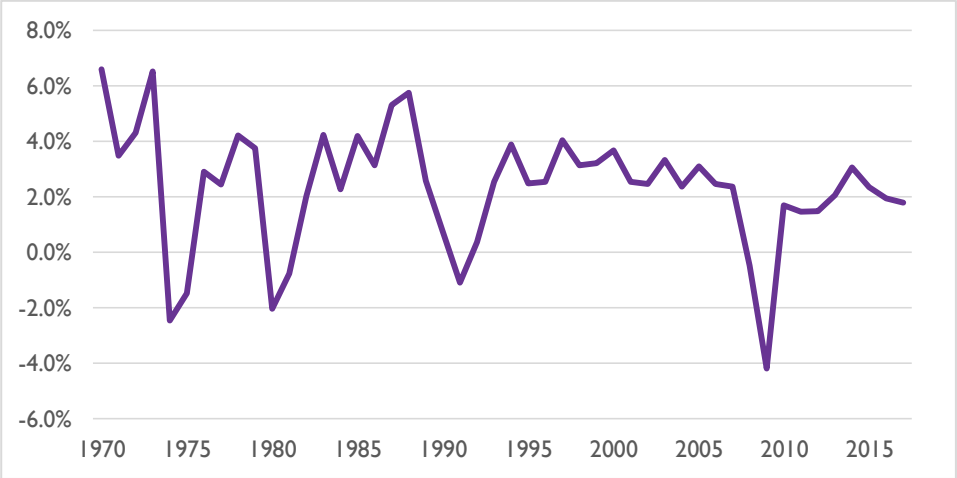
[69] Fiscal sustainability report July 2018, Office of Budget Responsibility.

- For NACE 1, the full available time series for TFP indices runs from 1970-2007, allowing us to calculate TFP growth for the years 1971 until 2007.
- For NACE 2, the full available time series for TFP indices is from 1998-2015, allowing us to calculate TFP growth for the years 1999 until 2015.[70]

We have chosen to look at both datasets. This is because both datasets have limitations and therefore there is value in looking at the results of both. The more recent NACE 2 data is beneficial as it allows us to explore TFP growth in the post-crisis period, which is not possible using the NACE 1 data as it is only available up to 2007. To the extent that future productivity growth may be in line with the most recent past productivity growth, then it is important to have examined post-crisis productivity data. However, a key disadvantage of the NACE 2 dataset is that the short period for which data are available preclude the possibility of examining TFP growth over full business cycles. The short time series of data available (particularly post-crisis) also make TFP estimates more volatile as they are more sensitive to the TFP growth figure in any single year. The NACE 1 dataset does, on the other hand, allow us to analyse TFP growth over full business cycles as data are available back to 1970.

With the NACE 1 dataset we consider it most appropriate to assess TFP growth over full economic cycles. We base our choice of economic cycles on a trough-to-trough basis, using UK GDP growth data. As seen in Figure 3.2, our data contains three full economic cycles: 1974 – 1979, 1980 – 1989 and 1990 – 2007. We note that the years 1974 to 1979 are atypical due to the significant impact of the 1970s oil crises, and so we exclude this business cycle from our analysis. We note in contrast that NERA (on behalf of Bristol Water) chose to include these years, by using the full NACE 1 time series from 1970 to 2007.

Figure 3.2: GDP growth (1970-2017)



Source: World Bank.

With the NACE 2 dataset, we assess TFP growth over three time periods: over the full period from 1999 to 2014; a pre-crisis period from 1999 to 2007; and a post-crisis period from 2010 to 2014. Though we report all three, our preferred measures are the pre-crisis and post-crisis measures which exclude the two years of data most heavily affected by the global financial crisis (2008 and 2009). We consider these years atypical and believe their inclusion would introduce a downward bias in any estimation of potential TFP growth over the forthcoming control period, especially given that the years covered by the dataset do not include a full upswing in the economic cycle either before or after the crisis. We note in contrast that Economic Insight, NERA and Oxera choose to include these years in their TFP analysis. (In the case of

[70] It should be noted that, though TFP in value added terms is available in the EU KLEMS dataset up to 2015, this dataset does not report data for gross output for 2015, thus limiting the time range in our calculations for TFP growth in gross output terms to 1999-2014. See the discussion of converting to gross output TFP in Section 3.9.

Economic Insight, these years were included in its "post-crisis" estimates, which we believe to be inappropriate since these two years do not reflect the performance of the economy in the years after the crisis.)

Our choice of time periods and datasets is therefore as shown in the table below.[71]

Table 3.12: Summary of datasets and time periods analysed

Dataset	Time periods analysed
EU KLEMS November 2009 release (March 2011 revision) **(NACE 1 dataset)**	• 1971-2007 – the entire period. • 1990-2007 – the most recent full business cycle. • 1980-1989 – the previous full business cycle. • 1980-2007 – the last two full business cycles.
EU KLEMS September 2017 release (July 2018 revision) **(NACE 2 dataset)**	• 1999-2014 – the entire period. • 1999-2007 – pre-crisis period. • 2010-2014 – post-crisis period.

Source: Europe Economics' selection of time periods for analysis.

We undertake TFP growth analysis for all of these time periods and use data in the round to derive our recommended range for the frontier shift, with our lower bound informed particularly by the data for the post-crisis period (i.e. 2010-2014).

3.9 Adjustment from gross value added to gross output TFP

Growth in TFP can be expressed in two ways, as value added TFP growth or alternatively as gross output TFP growth. The two measures are closely linked to each other, but are conceptually different. Gross output captures all inputs that go into production in a sector, including those intermediate inputs purchased from other sectors. TFP in gross output terms represents the residual growth in output once growth in capital, labour and intermediate inputs have been taken into account. Value-added TFP on the other hand considers only capital and labour as inputs, thus omitting the effect of intermediate inputs. The differences between the two measures can be quite significant, with the value added measure systematically higher in magnitude than the gross output measure.

In terms of the consultancy reports produced on behalf of water companies (as summarised in Section 3.2.3):

- NERA primarily drew on the gross output TFP measure, seeing this as the most appropriate productivity measure given Ofwat's intended use of it at PR19, i.e. applying the productivity improvement to companies' total factor inputs, rather than just labour and capital costs. That said, it also explored the value added TFP measure.
- Oxera stated that both measures are theoretically valid ways of measuring productivity. It noted that the main advantage of the gross output measure is that it is the appropriate concept at the company level, as it takes into account spending on intermediate inputs. Oxera argued that the key advantage of the value added measure is its immunity to changes in the vertical structure of firms. Overall, Oxera said that while ideally both measures would be calculated, it uses the value added TFP measure as this is the only one published in the EU KLEMS dataset.

[71] We also use the EU KLEMS October 2012 release which contains TFP in value added terms for a longer time series in NACE 2. This however does not contain data for gross output, which prevents us converting the figures to TFP in gross output terms. See Section 3.2.3 for a discussion of gross output and value added measures of TFP growth.

- Economic Insight did not explicitly discuss or make a choice between the value added and gross output measures.

An earlier report by First Economics (on behalf of South East Water for PR14) made use of value added TFP estimates on the grounds that the latest releases of EU KLEMS data that were available at the time only included value added TFP data.[72] First Economics noted the possibility of using an older EU KLEMS dataset which contains both gross output and value added data, but was uncomfortable in doing so as significant revisions in the later release suggested that earlier figures were no longer valid. First Economics also raised concerns about basic errors in the gross output data (though it provided no elucidation of what these may be) and about the consistency of the gross output data over periods in which industries undergo vertical integration or separation. First Economics believed that these drawbacks carried sufficient weight to preclude the use of gross output data.

In our view, the most appropriate measure of TFP growth for the regulatory purpose of estimating frontier shift is TFP growth in gross output terms. This is because Ofwat intend to apply the frontier shift estimates to totex or botex, both of which include expenditure on intermediate inputs.[73] A gross output measure of TFP is also less sensitive to changes in the degree of outsourcing over time.[74] Therefore, for sectors in which outsourcing is important, the gross output TFP measure is typically preferable.

Some TFP data in EU KLEMS are only reported in value added terms, and this has in the past been used as a rationale for focusing on the value added measure of TFP. However, we can apply a simple formula to convert the TFP in value added terms into TFP in gross output terms:

$$TFPG_{VA} = \frac{TFPG_{GO}}{\frac{VA}{GO}}.$$

This formula states that TFP growth in value added terms is equal to TFP growth in gross output terms divided by the share of value added in gross output. As value added (VA) is a subset of gross output (GO), TFP growth in gross output terms is always lower in magnitude than TFP growth in value added terms. We apply this formula by sector and by year to obtain TFP growth estimates in gross output terms.

While (based on our reasoning above) the gross output TFP measure is generally preferred, we acknowledge that it cannot be assumed in *all* cases to be the superior measure. Rather, it is simply that for the value added TFP measure to reflect technical progress, a more stringent set of criteria must be met.[75]

In conclusion, TFP growth in gross output terms is our favoured measure, but we suggest that some lesser weight be placed on the figures for TFP growth in value added terms as well.

3.10 TFP estimates for the chosen comparator sectors

In this section, we present our TFP growth estimates for each of our comparator sectors for the selected time periods. TFP growth estimates are calculated as arithmetic averages of annual TFP growth values over the time period in question.

[72] First Economics (2013), "Water Industry Input Price Inflation and Frontier Productivity Growth". A report prepared for South East Water, August 2013. Available at: https://corporate.southeastwater.co.uk/media/1494/app18tps_firsteconomics.pdf

[73] This is consistent with reasoning set out by both NERA and Oxera, summarised above.

[74] This observation for *TFP measures*, should not be confused with the fact that the exact opposite is true for *labour productivity measures*, i.e. it is gross output measures of labour productivity which are more sensitive to the degree of outsourcing than value added measures of labour productivity. These issues are discussed in more detail in: OECD (2001), "Measuring Productivity".

[75] The value added TFP measure represents frontier shift only when the production function is such that capital and labour are separable from intermediate inputs and technical progress favours capital and labour only, which might be considered a rather implausible assumption.

3.10.1 TFP growth in gross output terms

In Table 3.13, we present the TFP growth values in gross output terms using the shorter, more recent EU KLEMS database which uses NACE 2 sector definitions. The table first presents the data for our comparator sectors, including an unweighted average across those sectors. The last row shows the corresponding figures for "Market economy", to show the difference between productivity growth in our comparators sectors and in the overall market economy.

Table 3.13: TFP growth in gross output (NACE 2)

Industry Comparators	Average (1999-2014)	Average Pre-crisis (1999-2007)	Average Post-crisis (2010-2014)
Chemicals and chemical products	0.8%	1.3%	-0.7%
Construction	-0.1%	0.2%	0.7%
Machinery and equipment n.e.c.	0.9%	1.2%	1.0%
Other manufacturing; repair and installation of machinery and equipment	1.0%	1.2%	1.3%
Professional, scientific, technical, administrative and support service activities	0.9%	1.1%	1.5%
Total manufacturing	0.6%	0.9%	0.3%
Transport and storage	0.0%	0.2%	0.5%
Average for comparators	**0.6%**	**0.9%**	**0.6%**
Market economy (for purpose of comparison)	0.2%	0.7%	0.0%

Source: Europe Economics' analysis of EU KLEMS data. NB. All figures are rounded to 1 decimal place. Averages are calculated using exact values for individual sectors, then rounded to 1 decimal place.

In Table 3.14, we present the TFP growth values in gross output terms using the longer EU KLEMS database which uses NACE 1 sector definitions. For this NACE 1 dataset, 'Total industries' has been included instead of 'Market economy'.

Table 3.14: TFP growth in gross output (NACE 1)

Industry Comparators	Average (1971 - 2007)	Average cycle 1 (1980-1989)	Average cycle 2 (1990-2007)	Average 2 cycles (1980-2007)
Chemicals and chemical products	1.3%	1.6%	1.2%	1.3%
Construction	0.3%	0.8%	0.3%	0.5%
Machinery, nec	0.5%	0.5%	0.8%	0.7%
Total manufacturing	0.6%	1.0%	0.6%	0.8%
Transport and storage	1.0%	1.3%	0.7%	0.9%
Average for comparators	**0.7%**	**1.0%**	**0.7%**	**0.8%**
Total industries (for purpose of comparison)	0.2%	0.3%	0.3%	0.3%

Source: Europe Economics' analysis of EU KLEMS data.

3.10.2 TFP growth in value added terms

As explained above, we believe that in most cases the most appropriate measure of frontier shift is TFP growth in gross output terms, but that some weight should also be placed on value added figures. Table 3.15 shows TFP growth estimates for our comparator sectors in value added terms using the NACE 2

database; Table 3.16 reports TFP growth estimates based on a longer time series in NACE 2;[76] and Table 3.17 presents TFP growth estimates using the NACE 1 database.

Table 3.15: TFP growth in value added (NACE 2)

Industry Comparators	Average (1999-2014)	Average Pre-crisis (1999-2007)	Average Post-crisis (2010-2014)
Chemicals and chemical products	2.0%	3.3%	-2.1%
Construction	-0.2%	0.4%	1.6%
Machinery and equipment n.e.c.	2.2%	3.2%	2.4%
Other manufacturing; repair and installation of machinery and equipment	2.1%	2.8%	2.7%
Professional, scientific, technical, administrative and support service activities	1.5%	1.9%	2.6%
Total manufacturing	1.7%	2.4%	1.0%
Transport and storage	0.0%	0.5%	1.1%
Average for comparators	**1.3%**	**2.1%**	**1.3%**
Market economy (for purpose of comparison)	0.5%	1.5%	-0.1%

Source: Europe Economics' analysis of EU KLEMS data.

Table 3.16: TFP growth in value added (NACE 2)

Industry Comparators	Average (1973 - 2009)	Average cycle 2 (1980-1989)	Average cycle 3 (1990-2007)	Average 2 cycles (1980-2007)
Chemicals and chemical products	4.2%	5.0%	4.1%	4.4%
Construction	0.5%	2.1%	0.9%	1.3%
Machinery and equipment n.e.c.	1.1%	1.2%	2.0%	1.7%
Other manufacturing; repair and installation of machinery and equipment	-1.6%	-2.8%	-0.4%	-1.2%
Professional, scientific, technical, administrative and support service activities	-0.5%	-0.2%	0.8%	0.4%
Total manufacturing	1.6%	2.8%	1.9%	2.2%
Transport and storage	1.1%	2.4%	1.0%	1.5%
Average for comparators	**0.9%**	**1.5%**	**1.5%**	**1.5%**
Total industries (for purpose of comparison)	0.3%	0.5%	0.9%	0.7%

Source: Europe Economics' analysis of EU KLEMS data.

[76] This dataset does not include data on gross output, which prevents us from performing the adjustment into TFP growth in gross output terms. Hence no longer time series in NACE 2 is available for TFP growth in gross output terms.

Table 3.17: TFP growth in value added (NACE 1)

Industry Comparators	Average (1971 - 2007)	Average cycle 2 (1980-1989)	Average cycle 3 (1990-2007)	Average 2 cycles 1980-2007
Chemicals and chemical products	3.8%	4.6%	3.5%	3.9%
Construction	0.7%	2.0%	0.7%	1.2%
Machinery, nec	1.2%	1.1%	2.1%	1.8%
Total manufacturing	1.8%	2.8%	1.8%	2.2%
Transport and storage	2.1%	2.4%	1.7%	1.9%
Average for comparators	**1.9%**	**2.6%**	**2.0%**	**2.2%**
Total industries (for purpose of comparison)	0.4%	0.5%	0.6%	0.6%

Source: Europe Economics' analysis of EU KLEMS data.

3.10.3 Interpreting TFP growth estimates

We first of all derive a frontier shift range for wholesale water businesses without including any capital substitution effect. This is the range that is relevant if our frontier shift estimate is applied to totex (rather than botex). The effect of including a partial capital substitution effect — which becomes relevant if our frontier shift estimate is applied to botex — is discussed separately in the next section.

In determining a range for our TFP growth estimates for wholesale activities, we consider which values can be interpreted as a lower bound and which can be interpreted as an upper bound. The lower and upper bound are both based on GO TFP data.

Lower bound

Our recommended lower bound for wholesale is 0.6 per cent. This is based on the post-crisis period (NACE 2 data for 2010-2014) during which the economy as a whole has been characterised by low productivity growth relative to pre-crisis years (see discussion in section 3.8.2). Looking ahead to the forthcoming price control period, we believe that this represents a lower bound for productivity growth, as the economy may recover, or at least start to recover, to the pre-crisis long-run average over the course of the control period. Therefore, we take the average TFP growth of our chosen comparator sectors for the post-crisis period as our lower bound. As can be seen in the final column of Table 3.13, this is 0.6 per cent.

Upper bound

Our recommendation for the upper bound for wholesale is 1.2 per cent. In determining an upper bound, we take note of Ofwat's approach of setting stretching performance targets for the water companies.[77] As such, we focus on the TFP growth performance of the stronger performing comparator sectors (rather than taking an average across all comparator sectors as we do for determining the lower bound). In particular, therefore, our choice of upper bound is based on the following pieces of evidence:

- Based on pre- crisis performance in stronger performing sectors, the more recent NACE 2 data (in Table 3.13) point to an upper estimate of around 1.2 per cent. This is driven directly by the estimates for "Machinery and equipment nec" and "Other manufacturing; repair and installation of machinery and equipment", as well as the estimates for "Chemicals and chemical products" and "Professional, scientific, technical, administrative and support service activities", which are close by (1.3 per cent and 1.1 per cent respectively). As such, four of our seven comparator sectors, saw TFP growth at a rate of, or very close to, 1.2 per cent. TFP growth for "Total manufacturing" was not far behind at 0.9 per cent.

[77] See Ofwat (2017), "Delivering Water 2020: Our final methodology for the 2019 price review".

We also note that even in the post-crisis figures, there are three comparator sectors clustered close to our upper bound ("Machinery and equipment n.e.c.", "Other manufacturing; repair and installation of machinery and equipment" and "Professional, scientific, technical, administrative and support service activities", with TFP growth rates of, respectively, 1.0, 1.3 and 1.5 per cent).

- We also consider the longer time series NACE 1 data in Table 3.14, which provide a longer term view of TFP growth performance. On this basis, the implied upper bound is again in the order of 1.2 per cent, driven by the "Chemicals and chemical products" sector when looking at the latest full economic cycle (1990-2007) and also supported by the "Transport and storage" sector when looking at the previous full cycle (1980-89).

We also note that consultancies working for the water companies have also presented several sectors in their analyses with annual TFP growth rates exceeding 1.2 per cent. For example:

- NERA on behalf of Bristol Water presented data showing that TFP growth in two of its selected comparator sectors exceeded 1.2 per cent in gross output terms, when looking at data between 1970 and 2007. In particular, NERA found the annual average TFP growth rate to be 1.3 per cent for 'manufacture of chemicals and chemical products' and 1.6 per cent for 'manufacture of electrical and optical equipment'. While NERA derived its final recommended frontier shift figure of 0.6 per cent for opex and 0.7 per cent for capex as an unweighted average of its selected comparators, we think it is worth noting that these figures that it presents for individual comparator sectors would support an upper limit of 1.2 or more.
- Furthermore, Oxera on behalf of both South East Water and Southern Water found that the average annual growth rate from 1996 to 2014 for 'chemicals and chemical products' was 1.4 per cent and for 'other manufacturing; repair and installation of machinery and equipment' was 1.3 per cent, in value added terms. Oxera then calculated both weighted and unweighted averages of its selected comparator sectors to derive the recommended figure of 0.7 per cent for water resources opex, 0.4 per cent or 0.8 per cent for network plus opex and 0.7 per cent for all capex for both companies.[78] Again, we think it is worth noting that the figures that Oxera presents for individual comparator sectors would support an upper limit of 1.2 or more, although in Oxera's case the figures are on a value-added basis rather than our preferred gross output basis.

Thus, overall, our proposed range for wholesale totex is **0.6 to 1.2 per cent**.

Later, in Section 3.11, we consider the implications of the TFP growth estimates in value added terms for the choice of a point estimate from within this range.

3.10.4 Estimating the partial capital substitution effect for wholesale botex

As explained in Section 3.5, a partial capital substitution effect should be added to our TFP estimates for frontier shift if applied to wholesale botex. (For wholesale totex, no capital substitution effect is necessary – hence, the analysis below applies exclusively to wholesale botex.)

Table 3.18 and Table 3.19 below present estimates of the scale of the partial capital substitution effect for our comparator sectors using both our NACE 1 and NACE 2 datasets, analysed over the various time periods described.[79] The data presented below are the size of the adjustments required to TFP growth in gross output terms.

[78] Further details on the frontier shift estimates proposed by Oxera on behalf of South East Water and Southern Water can be found in Table 3.1.

[79] The size of the partial capital substitution effect is estimated using the following formula:

$$S_e . S_k . (g(K) - (L))$$

Table 3.18: Partial capital substitution effect for NACE 1 comparator sectors

	Average (1971 - 2007)	Average cycle 1 (1980-1989)	Average cycle 2 (1990-2007)	Average 2 cycles 1980-2007
Chemicals and chemical products	0.2%	0.2%	0.3%	0.3%
Construction	0.1%	0.0%	0.1%	0.1%
Machinery, nec	0.1%	0.1%	0.1%	0.1%
Total manufacturing	0.2%	0.2%	0.2%	0.2%
Transport and storage	0.0%	-0.3%	0.1%	0.0%
Average for comparators	**0.1%**	**0.0%**	**0.2%**	**0.1%**
Total industries (for purpose of comparison)	0.3%	0.3%	0.2%	0.3%

Source: Europe Economics' analysis of EU KLEMS data.

Table 3.19: Partial capital substitution effect for NACE 2 comparator sectors

	Average (1999-2014)	Average pre-crisis (1999-2007)	Average post-crisis (2010-2014)
Chemicals and chemical products	0.4%	0.6%	0.0%
Construction	0.0%	0.0%	0.0%
Machinery and equipment n.e.c.	0.0%	0.1%	0.0%
Other manufacturing; repair and installation of machinery and equipment	0.1%	0.2%	-0.1%
Professional, scientific, technical, administrative and support service activities	-0.1%	0.0%	-0.2%
Total manufacturing	0.1%	0.2%	-0.1%
Transport and storage	0.1%	0.2%	0.0%
Average for comparators	**0.1%**	**0.2%**	**-0.1%**
Market economy (for purpose of comparison)	0.1%	0.2%	0.0%

Source: Europe Economics' analysis of EU KLEMS data.

We use the evidence above to determine what, if any, adjustment is required to our existing range for wholesale totex (0.6 to 1.2 per cent) to obtain a suitable range for wholesale botex. Firstly, looking at the post-crisis performance of our comparator sectors in NACE 2 (the final column of Table 3.19), it can be seen that the average size of the partial capital substitution effect is -0.1 per cent. As such, we propose no increase in the lower bound of our range for wholesale botex.

For the upper bound of the range, we again consider the average pre-crisis performance of our chosen comparator sectors in NACE 2, as well as the average for the last full business cycles for our comparator sectors in NACE 1. In both cases this points to an increase of our upper bound by 0.2 per cent.

Our recommended frontier shift range for wholesale botex is therefore **0.6 to 1.4 per cent.**

Where:

S_e is the share of capital enhancement in total capital expenditure;
S_k is the share of capital in the total output; and
$g(K) - g(L)$ is the difference in the growth rates of capital and labour.

3.11 Our recommended frontier shift ranges

Table 3.20 below summarises our proposed frontier shift ranges, for: wholesale totex; and wholesale botex.

Table 3.20: Proposed frontier shift ranges

Cost base	Frontier shift range
Wholesale totex	**0.6% - 1.2%**
Wholesale botex	**0.6% - 1.4%**

Source: Europe Economics' analysis.

The ranges above do not need to be adjusted for any scale effect, as we estimate the average size of the scale effect across our chosen comparator sectors to be zero (as discussed in Section 3.4 and Appendix 2). It should also be noted that the wholesale botex figures include an addition for a partial capital substitution effect, estimated to lie in the range of 0.0 to 0.2 per cent (as explained in Section 3.10.4).

Our recommendation is to select a number towards the upper end of our range. The reasons for selecting a number towards the upper end of the range are twofold:

- Some weight should be placed on TFP growth in value added terms. We explained in Section 3.9 that, in our view, TFP growth measured in gross output terms is a more appropriate measure of frontier shift if applied to botex or totex (which include spending on intermediate inputs), but nevertheless that some lesser weight should also be placed on TFP growth in value added terms. Since TFP growth estimates in value added terms are always higher in magnitude, by placing some weight on this we move towards the higher end of the range for TFP growth in gross output terms.
- Our TFP estimates exclude embodied technical change. As explained in Section 3.6.2, a true measure of frontier shift should take into account quality improvements 'embodied' in the inputs used by the sector – labour, capital and intermediate inputs. However, since input growth measures used by EU KLEMS are already adjusted (to the extent possible) for changes in their quality over time, the TFP estimates using EU KLEMS data primarily reflect 'disembodied' technical change, and not 'embodied' technical change. Though we have recognised that research on this issue is limited, we have found some evidence that allows us to provide an illustrative estimate of the potential magnitude of technical change embodied in capital inputs that is not captured in traditional TFP growth estimates. This evidence suggests that TFP growth estimates would need to be uplifted by 60 per cent to account for technical change embodied in capital inputs. While we do not wish to place emphasis on this single piece of quantitative evidence (which should be seen as illustrative only), it does suggest that, in order to account for the effects of embodied technical change, a number towards the upper end of each range should be chosen.

We also note that consultancies working for water companies have also presented several sectors in their analyses with annual TFP growth rates exceeding 1.2 per cent. For example:

- NERA on behalf of Bristol Water presented data showing that TFP growth in two of its selected comparator sectors exceeded 1.2 per cent in gross output terms, when looking at data between 1970 and 2007. In particular, NERA found the annual average TFP growth rate to be 1.3 per cent for 'manufacture of chemicals and chemical products' and 1.6 per cent for 'manufacture of electrical and optical equipment'. While NERA derived its final recommended frontier shift figure of 0.6 per cent for opex and 0.7 per cent for capex as an unweighted average of its selected comparators, we think it is

worth noting that these figures that it presents for individual comparator sectors would support an upper limit of 1.2 or more.

- Furthermore, Oxera on behalf of both South East Water and Southern Water found that the average annual growth rate from 1996 to 2014 for 'chemicals and chemical products' was 1.4 per cent and for 'other manufacturing; repair and installation of machinery and equipment' was 1.3 per cent, in value added terms. Oxera then calculated both weighted and unweighted averages of its selected comparator sectors to derive the recommended figure of 0.7 per cent for water resources opex, 0.4 per cent or 0.8 per cent for network plus opex and 0.7 per cent for all capex for both companies.[80] Again, we think it is worth that the figures that Oxera presents for individual comparator sectors would support an upper limit of 1.2 or more, although in Oxera's case the figures are on a value-added basis rather than our preferred gross output basis.

[80] Further details on the frontier shift estimates proposed by Oxera on behalf of South East Water and Southern Water can be found in Table 3.1.

4 Conclusions

This report has set out to assess the ongoing cost reductions that the water and wastewater sector should be expected to achieve over the forthcoming price control period from April 2020 to March 2025. In particular, it assessed the scope for ongoing cost reductions by analysing, for the forthcoming control period:

- Whether there is a robust case for any real price effects (RPEs).
- The scale of frontier shift the sector can be expected to achieve.

We present the results for each stage of the assessment in turn, for wholesale controls.

4.1 Real price effects

We developed a framework to assess the case for RPEs in a robust and transparent manner. Given the existing risk-sharing mechanisms that companies benefit from and the informational advantages they possess, the framework was designed so that an RPE allowance would only be recommended if there were a clear and robust case for including such an allowance.

The first stage of this framework used a set of criteria to assess the case for RPEs on an individual cost item basis, specifically with respect to:

- Labour costs,
- Energy costs,
- Chemical costs, and
- Materials, plant and equipment costs.

As shown in Table 4.1 below, whether labour qualifies for an RPE mechanism depends crucially on whether reliance is placed on OBR forecasts of real wage growth. Historically, OBR forecasts of real wages have proved to be inaccurate and biased upwards, and hence we do not recommend an ex ante RPE allowance for labour costs. We do, however, recommend that Ofwat considers an ex post indexation mechanism for labour using all employees or manufacturing sector wages as a comparator, so that if there is real wage growth, the additional wage costs will automatically feed through into price limits.

Whether energy qualifies for an RPE mechanism depends on whether reliance is placed on BEIS forecasts for industrial electricity prices and on the weight that Ofwat attaches to the high wedge between growth in industrial electricity prices and CPIH prior to 2010. An ex post indexation mechanism could also be considered for energy, but the case is weaker than for wages since:

- There is not the same theoretical reason for expecting a positive wedge (see discussion in Appendix 3 under "Consistency of assumptions on real wage growth and productivity");
- Energy is partially captured by CPIH and energy costs represent a lower share (9.4 per cent) of water company totex than labour costs (33.3. per cent).

For the other two cost items (chemicals and materials, plant and equipment costs), our framework unambiguously suggests that Ofwat should not make any RPE allowance.

Table 4.1: Summary of RPEs assessment

Cost Item		Labour	Energy	Chemicals	Materials, plant and equipment
1. Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	A. Is the expected value of the wedge between the input price and CPIH materially different from zero?	Depends on whether reliance is placed on OBR forecasts	Depends on whether reliance is placed on BEIS forecasts and on weight placed on pre-2010 data	Fail	Fail
	B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Depends on weight placed on pre-2011 data	Fail	Fail
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?		Pass	Partial Pass	Pass	Partial Pass
3. Is the input price and exposure to that input price outside management control during the duration of the price control?		Partial Pass	Partial Pass	Pass	Partial Pass
Overall		**Depends on whether reliance is placed on OBR forecasts**	**Depends on whether reliance is placed on BEIS forecasts and on weight placed on pre-2010 data**	**Fail**	**Fail**

Source: Europe Economics' analysis.

Final recommendations:

- For wholesale labour costs, given the uncertainty that surrounds future real wage growth, an ex post wage indexation mechanism could be used by Ofwat so that if real wages across the economy or manufacturing industry grow faster than assumed, this would automatically feed into price limits.
- For wholesale energy costs, given the uncertainty that surrounds the growth of future energy costs, an ex post indexation mechanism could also be considered by Ofwat, although the decision is more finely balanced given that energy costs account for a smaller share of totex and are partially captured in CPIH.
- For wholesale chemicals and 'materials, plant and equipment' costs, we conclude that CPIH indexation is sufficient to capture changes in the input costs over the next price control.

4.2 Frontier shift

Our assessment of frontier shift used an approach based on TFP analysis in comparator sectors. Based on that analysis we have derived our proposed frontier shift ranges for the water industry, as shown in Table 4.2 below.

Table 4.2: Proposed range of frontier shift in the water industry

Part of water sector	Frontier shift range
Wholesale totex	**0.6% - 1.2%**
Wholesale botex*	**0.6% - 1.4%**

Source: Europe Economics' analysis. *Includes adjustment for partial capital substitution effect.

The wholesale botex range includes an addition for a partial capital substitution effect (i.e. the extra productivity gains associated with capital enhancement expenditure substituting for botex expenditure). This is estimated to lie in the range of 0 to 0.2 per cent (as explained in Section 3.10.4).

All ranges above are implicitly adjusted for scale effects, as we estimate the average size of the scale effect across our chosen comparator sectors to be zero.

Our recommendation is to select a number towards the upper end of our range. The reasons for selecting a number towards the upper end of the range are twofold:

- Some weight should be placed on TFP growth in value added terms. We explained in detail in Section 3.9 that we believe TFP growth measured in gross output terms is a more accurate measure of frontier shift if applied to botex or totex (which includes spending on intermediate inputs), but nevertheless that some lesser weight should also be placed on TFP growth in value added terms. Since TFP growth estimates in value added terms are by definition higher in magnitude than the corresponding TFP gross output measure, by placing some weight on the former we move towards the upper end of the range for TFP growth in gross output terms.
- Our TFP estimates exclude embodied technical change. As explained in Section 3.6.2, a true measure of frontier shift should take into account quality improvements 'embodied' in the inputs used by the sector – labour, capital and intermediate inputs. However, the TFP estimates using EU KLEMS data reflect primarily 'disembodied' technical change. Though research on this issue is limited, we have found some illustrative evidence to suggest that TFP growth estimates would need to be uplifted by 60 per cent to account for technical change embodied in capital inputs. While we do not wish to place too much reliance on this single piece of quantitative evidence, it does suggest that, in order to account for the effects of technical change embodied in capital inputs, a number towards the upper end of each range should be chosen.

We also note that consultancies working for water companies have also presented several sectors in their analyses with annual TFP growth rates exceeding 1.2 per cent. For example:

- NERA on behalf of Bristol Water presented data showing that TFP growth in two of its selected comparator sectors exceeded 1.2 per cent in gross output terms, when looking at data between 1970 and 2007. In particular, NERA found the annual average TFP growth rate to be 1.3 per cent for 'manufacture of chemicals and chemical products' and 1.6 per cent for 'manufacture of electrical and optical equipment'. While NERA derived its final recommended frontier shift figure of 0.6 per cent for opex and 0.7 per cent for capex as an unweighted average of its selected comparators, we think it is worth noting that these figures that it presents for individual comparator sectors would support an upper limit of 1.2 or more.

- Furthermore, Oxera on behalf of both South East Water and Southern Water found that the average annual growth rate from 1996 to 2014 for 'chemicals and chemical products' was 1.4 per cent and for 'other manufacturing; repair and installation of machinery and equipment' was 1.3 per cent, in value added terms. Oxera then calculated both weighted and unweighted averages of its selected comparator sectors to derive the recommended figure of 0.7 per cent for water resources opex, 0.4 per cent or 0.8 per cent for network plus opex and 0.7 per cent for all capex for both companies.[81] Again, we think it is worth that the figures that Oxera presents for individual comparator sectors would support an upper limit of 1.2 or more, although in Oxera's case the figures are on a value-added basis rather than our preferred gross output basis.

The frontier shift efficiency ranges presented above are in addition to any efficiency gains expected from the move to totex and outcomes-based regulation.[82]

[81] Further details on the frontier shift estimates proposed by Oxera on behalf of South East Water and Southern Water can be found in Table 3.1.

[82] A caveat to this is that if an estimate of the efficiency gains from the totex and outcomes framework is added to our frontier shift numbers, then the capital substitution effect should be excluded from our figures. This is because the efficiency gains from the totex framework arise from the removal of the capital bias that existed historically, leading to a temporary period in which capex solutions are replaced with opex solutions where this is efficient. By contrast, the capital substitution effect arises from the longer-term economy-wide tendency for capital to be substituted for labour over time. Clearly, it would be inconsistent to include efficiency gains from both sources at the same time, since they involve substitution between capital and labour/opex that go in opposite directions.

Appendices

Europe Economics

Appendix 1: What Wage Index Should Be Used for an Indexation Mechanism?

The recommendation of an ex post indexation mechanism for real wage increases raises the question as to what wage index should be used for this purpose. In this appendix we set out and apply our framework for assessing different wage indices for an ex post indexation mechanism for wages.

The criteria for this assessment are:

1. Quality of data: An important attribute of any wage index used for indexation purposes within a price control is that the data should be of high quality, such that any movements in the index represent genuine movements in underlying wages and not just random variation due to a small sample.
2. Similarity in the nature of work to water sector: In assessing whether sectors are similar in nature to the water sector, we focus on identifying sectors with predominantly comparable activities to water wholesale, such as: the extraction and processing of some primary resource; the operation and maintenance of some network for delivering a product; and/or manufacturing processes likely to involve large scale plant and equipment.
3. Correlation with water sector wages: This criterion considers the correlation of each of the candidate indices with water sector wages to examine how closely they move in line with changes in wage rates in the water and sewerage sector.
4. Does not give rise to incentive problem: This criterion considers whether the proposed indexation mechanism would potentially cause incentive problems. For example, this might arise if an increase in water company wage rates has an appreciable effect on the index and thus on their allowed revenues under the indexation mechanism, as this would reduce companies' incentives to control wage rates.

Each criterion is scored on a five-point qualitative scale (very good, good, sufficient, bad, very bad) and an overall score is given to each of the indexation options considered.

We consider the following three candidates indices:

- An index of wages in the water and wastewater sectors, constructed as a weighted average of ONS indices of wages in the water sector and in the sewerage sector;
- The ONS wage index for "All Manufacturing"; and
- The ONS wage index for "All Employees".

Table A1.1 below summarises the assessment of the three indices considered.

Table A1.1: Analysis of wage indices for ex post indexation

	All employees	Manufacturing	Water and sewerage
Quality of data	Very good	Very good	Very bad
Similarity in nature of work to water sector	Bad	Good	Very good
Correlation with water sector wages	Good	Good	Very good
Does not give rise to incentive problem	Very good	Very good	Very bad
Overall	**Good or sufficient**	**Good**	**Bad**

Source: Europe Economics analysis.

Below we present our analysis of the three candidate wage indices against each of the four criteria above.

Quality of data

The ONS publish information on the coefficient of variation (CV) of the mean weekly pay figure for different sectors of the ASHE dataset. The CV is defined as the ratio of the standard error of an estimate to the estimate (expressed as a percentage) and hence indicates the quality of the estimate provided. In general, the smaller the coefficient of variation, the higher the quality of the estimate.[83]

Table A1.2 below shows the CV of the mean weekly pay figure for different sectors of the ASHE dataset.

Table A1.2: Coefficient of variation of mean weekly pay figure

Labels from 2008	2014	2015	2016	2017	2018	Average over last five years
All Employees	0.2	0.2	0.2	0.2	0.2	**0.2**
All Manufacturing	0.5	0.5	0.7	0.6	0.6	**0.6**
Water collection, treatment and supply	3.1	3.4	3.4	3.4	3.4	**3.3**
Sewerage	4.8	5.6	5.3	4.4	4.8	**5.0**

Source ONS.

As the table indicates, the quality of labour cost estimates for the "Water collection, treatment and supply" and the "Sewerage" sectors are lower by various orders of magnitude than the quality of estimates for "All Employees" and "All Manufacturing". Therefore, both the "All employees" and "Manufacturing" indices score "very good" whereas water and sewerage index scores "very bad" for this criterion.

Similarity in the nature of work to water sector

The "All employees" wage index includes service sectors and public sector wages and therefore it is not a highly comparable wage index for indexing wage rates in the water sector. The manufacturing sector includes many elements which will be similar in nature to the activities undertaken in the water sector, including building and maintaining plant, equipment and machinery, processing an end product, and storing and distributing that product. The "Water and sewerage" index is given the highest possible score against this criterion, given that it covers the sector of interest.

Correlation with water sector wages

Analysis of 5-yearly rolling averages of real growth in mean weekly pay from 2006 to 2018 show that the "All Employees" wage index has a correlation of 0.78 with a constructed water and sewerage index, compared with a correlation of 0.83 for "All Manufacturing". This suggests that the "All Manufacturing" index may be slightly better correlated with water and sewerage wages, but overall both indices would be suitable for indexing wage rates in the water sector. The "Water and sewerage" index will obviously be perfectly correlated with itself and therefore achieves the highest possible score against this criterion.

Does not give rise to incentive problem

Using data from the water and sewerage sectors would potentially cause incentive problems, particularly for larger water companies. This is because any increase in their wage rates would feed through into the index and increase their allowed revenues, thus reducing their incentive to control this input price. No such incentive problems would arise if data from the overall economy or the manufacturing sector is used, as water companies do not have control over these input prices.

[83] ONS (2017): "Annual Survey of Hours and Earnings: 2017 provisional and 2016 revised results", available at: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/bulletins/annualsurveyofhoursandearnings/2017provisionaland2016revisedresults.

Overall assessment

Overall, we would recommend that Ofwat uses either the "All Employees" or the "Manufacturing" index for the purpose of indexing wage rates in the water sector, on the grounds that these data have the highest quality (demonstrated by their low CV value) and that they do not give rise to incentive problems. For reasons relating to data quality and potential incentive problems we reject the use of wage data relating specifically to the water and sewerage sectors for indexation purposes.

Appendix 2: Scale Effect Adjustments

In this appendix, we discuss our investigation into the magnitude of any scale effect adjustment to our TFP growth estimates. The evidence presented below suggests that there is no need to adjust our recommended range as the scale effect averages out at zero.

As explained in Section 3.4 of the main report, TFP growth estimates include components other than frontier shift, one of which is a scale component. Therefore, in order to isolate frontier shift from TFP growth estimates, an investigation into the size of any scale effects is required. A positive scale effect would imply that TFP growth estimates overstate frontier shift, and therefore that the scale effect should be subtracted from the TFP growth estimate to obtain a measure of frontier shift. Similarly, a negative scale effect would imply that TFP growth estimates understate frontier shift and that the TFP estimates should be increased to remove the negative scale effect.

An adjustment to the base TFP growth figure will be required in cases where there are increasing or decreasing returns to scale, coupled with input growth or decline. There will be no scale effect in sectors with constant returns to scale. In order to determine whether a scale effect adjustment is required, we therefore investigate whether our comparator sectors exhibit constant, increasing or decreasing returns to scale, and whether inputs have grown or declined over the time horizons in question.

We have calculated the size of the scale effect for our comparator sectors using the following formula:

$$(\epsilon - 1)\sum_{n}\left(\frac{\epsilon_n}{\epsilon}\right)\dot{x_n}$$

Where:

- ϵ_n is the elasticity of output with respect to a given input (labour and capital) (i.e. $\epsilon_n = \frac{\partial lnf}{\partial lnx_n}$). We source input elasticity estimates from two academic papers. These papers consider manufacturing sectors only, and the sectors evaluated are not entirely consistent with our chosen comparators. Therefore, we conduct a mapping to identify the sectors most similar to our chosen comparator sectors. We make use of calculated input elasticities for: 'Chemicals and chemical products'; 'Machinery, nec'; 'Other manufacturing'; 'Repair and installation of machinery and equipment'; and 'Transport and storage' from Hsieh (1995).[84] We also use calculated input elasticities for 'Total manufacturing' from Dobbelaere et al (2015).[85]

- $\dot{x_n}$ is the growth rate of the factor inputs (labour and capital). We calculate the growth rates of inputs using the EU KLEMS NACE1 and NACE2 databases.

- $\epsilon = \sum_n \epsilon_n$ is the total elasticity of output (with respect to all inputs), with $\epsilon > 1$ denoting increasing returns to scale. We source these figures from the academic papers mentioned above.

We present below our estimates of the scale effects for NACE1 and NACE2 comparator sectors.

[84] Wen-Jen Hsieh (1995), "Test of variable output and scale elasticities for 20 US manufacturing industries". Applied Economics Letters, vol. 2(8), pp. 284-287.

[85] Dobbelaere, S., Kiyota, K. and J. Mairesse (2015), "Product and labor market imperfections and scale economies: Micro-evidence on France, Japan and the Netherlands". Journal of Comparative Economics, Elsevier, vol. 43(2), pp. 290-322.

Table A1: Scale effects for comparator sectors NACE1

Comparator Sector	Average (1971 - 2007)	Average cycle 1 (1980-1989)	Average cycle 2 (1990-2007)	Average 2 cycles (1980-2007)
Chemicals and chemical products	0.0%	0.1%	0.0%	0.0%
Construction	No comparable scale elasticities available			
Machinery, nec	0.0%	0.0%	0.0%	0.0%
Total manufacturing	0.1%	0.1%	0.1%	0.1%
Transport and storage	-0.2%	-0.4%	-0.2%	-0.3%
Average	**0.0%**	**-0.1%**	**0.0%**	**0.0%**

Source: Scale estimates from academic papers (cited earlier), input growth data from EU KLEMs, and Europe Economics' analysis.

Table A2: Scale effects for comparator sectors NACE2

Comparator Sector	Average (1999-2014)	Average (1999-2007)	Average (2010-2014)
Chemicals and chemical products	0.1%	0.0%	0.2%
Construction	No comparable scale elasticities available		
Machinery and equipment n.e.c.	0.0%	0.0%	0.0%
Other manufacturing; repair and installation of machinery and equipment	0.1%	0.1%	0.0%
Professional, scientific, technical, administrative and support service activities	No comparable scale elasticities available		
Total manufacturing	0.1%	0.1%	0.0%
Transport and storage	-0.4%	-0.4%	-0.3%
Average	**0.0%**	**0.0%**	**0.0%**

Source: Scale estimates from academic papers (cited earlier), input growth data from EU KLEMs, and Europe Economics' analysis.

As evident in the tables above, the scale effect is on average zero across all available comparator sectors. This is true of both the pre- and post-crisis periods (and across NACE 1 and NACE datasets). In addition, we find that, for the comparator sectors that inform our upper and lower bound estimates for frontier shift, the scale effect is either zero or else close to zero and working in opposite directions for different sectors and time periods.

Overall, we conclude that, for the comparator sectors chosen in this study, the scale effect is on average zero and hence no adjustment to TFP growth estimates to account for scale effects is required.

Appendix 3: Our Response to Points from Companies and their Consultants

In this appendix we summarise the points made by companies and their consultants in relation to Europe Economics' report on RPEs and frontier shift, along with our response to those points. In cases where we consider that companies and their consultants have raised valid points, we have responded by changing our approach to assessing RPEs and frontier shift, with our revised approach reflected in the main body of this report. In cases where we consider that points are not valid, we explain why we have not made any changes.

We discuss the points made by respondents under the following headings:

- Consistency of RPEs and frontier shift analysis;
- RPEs assessment;
- Frontier shift assessment; and
- Addition for impact of totex and outcomes framework.

Consistency of RPEs and frontier shift analysis

Companies and their consultants made the following points about the consistency of our RPEs assessment with our frontier shift analysis:

- In a report cited by eight companies (Affinity Water, Anglian Water, SES Water, South Staffs Water, Thames Water, Dŵr Cymru, Wessex Water and Yorkshire Water), John Earwaker[86] argued that our analysis was inconsistent, as our framework for assessing RPEs took account of the fact that CPIH inflation reflects input price inflation across the economy, but our framework for assessing frontier shift did not take account of the fact that CPIH inflation also reflects productivity growth across the economy.
- Two consultancies (Oxera on behalf of South East Water and Southern Water and Economic Insight on behalf of Wessex Water and Yorkshire Water) argued that it is inconsistent to assume that there will be no real wage growth at the same time as applying a frontier shift figure which implies significant growth in productivity, as wage rates and productivity are linked.
- Both John Earwaker and Economic Insight (on behalf of Yorkshire Water) stated that we required different levels of evidence for the RPEs analysis compared with the frontier shift analysis, by requiring a compelling case for any RPE allowance but not making such a requirement for frontier shift. A related argument made by Economic Insight on behalf of both Wessex Water and Yorkshire Water is that we adopted an inappropriate null hypothesis of zero real growth in input prices in our RPEs work, rather than a null hypothesis which allowed for positive RPEs.

We respond to these points in turn below.

CPIH and economy-wide productivity

[86] Earwaker (2019): "A review of Ofwat's PR19 Approach to Estimating Frontier Shift".

Earwaker focuses on the second criterion in our original assessment of RPEs in which we considered whether CPIH already adequately captures the input price. In our original report, we did this both by looking at the share of comparable items in CPIH and by considering the share of the input in the cost base of other sectors. By looking at input cost shares in other sectors, we were implicitly using the fact that other sectors were exposed to similar input price pressures as a potential reason for rejecting an RPE allowance.

Earwaker argues that there is an inconsistency in taking account of input price pressures in other sectors in our RPEs assessment when we do not net off productivity growth in other sectors in our assessment of frontier shift, since both things are captured in CPIH.

To explain Earwaker's critique in intuitive terms, if input prices go up across the economy, the impact of this on end-consumer prices for goods and services in the CPIH basket will be mitigated by increases in productivity. For instance, if the wage rate of garage mechanics goes up by 10 per cent, the competitive price for getting a car serviced would not change if the productivity of garage mechanics also increased by 10 per cent such that corresponding fewer hours are required to carry out a car service. The final change in CPIH will therefore reflect both input prices pressures in other sectors and productivity growth in other sectors. Hence, indexation of water company revenues to CPIH effectively requires water companies to achieve the same productivity growth as other sectors if they experience the same input price pressures. In the light of this, Earwaker's point is that if an RPE allowance is rejected on the grounds that other sectors represented in CPIH are similarly affected by input price pressures, then in our frontier shift analysis we should also net off the productivity growth achieved in other sectors for consistency.

We accept that Earwaker's critique has some theoretical validity, although we think that his report exaggerates the issue as his critique relates to only one of the four criteria for assessing RPEs that we employed in our original report, and the recommendations in our original report would have been unchanged even without the criterion that he criticises.

In this revised version of the report, we have taken account of Earwaker's critique by removing consideration of input cost shares in other sectors from our assessment against criterion 2 of whether CPIH indexation adequately captures the relevant input price. This means that we are no longer taking account of input price inflation in other sectors in our RPEs assessment, such that the issues raised by Earwaker no longer apply.

This revised report continues to employ a modified version of criterion 2 in which we assess whether CPIH indexation captures the input price by looking (only) at the share of comparable items in CPIH. For example, in looking at whether CPIH indexation adequately captures the potential for electricity price increases, we consider the percentage share in CPIH of domestic electricity prices and other energy prices that might be expected to move in line with electricity prices. As prices for these comparable items are output prices to end consumers and not input prices, Earwaker's critique does not apply when criterion 2 is employed in this modified form.

By way of example, suppose the share of energy prices in the CPIH basket is about 5 per cent and energy costs represent about 10 per cent of water company wholesale totex. In this case, if energy prices rise by 5 per cent, all other things being equal, CPIH and water sector costs will increase respectively by 0.25 per cent and 0.5 per cent. Therefore the residual impact on water sector costs is only 0.25 per cent after CPIH indexation has been applied (i.e. the difference between 0.25 per cent and 0.52 per cent), which is lower than the total percentage increase in energy prices.

Consistency of assumptions on real wage growth and productivity

Oxera and Economic Insight observe that economic theory predicts that wages will move in line with labour productivity and that labour productivity will tend to grow faster than TFP due to the capital

substitution effect. Hence, they argue that an assumption of zero wage growth is inconsistent with the figure that Ofwat is proposing for frontier shift.

We accept that across the economy as a whole real wages would be expected to grow in line with marginal labour productivity. Growth in labour productivity can in turn be decomposed into growth in TFP, the capital substitution effect, and a labour composition effect (capturing changes in the quality of the labour force). If the combined effect of capital substitution and changes in labour composition is positive, as may often be the case, then real wages will grow faster than TFP. It should be noted, however, that in any sector and time period the capital substitution effect can be negative (i.e. if capital intensity is falling), and so too can the labour composition effect (i.e. if there is a shift towards using more unskilled labour).

We note, however, that the above does not necessarily mean that real wages in any sector will grow in line with productivity in that specific sector. In particular, companies in a specific sector may well be price-takers in wider labour markets, such that the wage rates that they will pay will be driven by economy-wide changes in marginal labour productivity rather than changes in labour productivity in that sector.

In our original report, we argued that water companies were price-takers in wider labour markets in our discussion of whether labour rates our outside management control.[87] Further, the data presented in Table 3.15 in the main body of the report show that post-crisis TFP growth in the overall economy (which may drive the real wages paid by water companies) has been lower than for sectors that are comparable to the water sector. In particular, average post-crisis TFP growth (for 2010-14) for the market economy as a whole was -0.1 per cent per annum, while TFP growth over the same period for our comparator sectors was 0.6 per cent per annum. This tends to support the hypothesis that wage growth in the water sector (if driven by wider labour markets) may be lower than productivity growth in the water sector.

There could also be a difference between average labour productivity (which will drive the productivity performance of water companies) and marginal labour productivity (which will determine wage rates in competitive labour markets). In particular, for a given capital stock, marginal labour productivity will typically fall as the volume of labour increases due to diminishing returns to labour. Hence, if workers in the labour markets from which water companies draw their employees respond to an upward shift in their productivity by working more hours or by more people joining the labour force, marginal labour productivity and wages may remain the same while average productivity has increased.[88,89]

Hence, it cannot necessarily be assumed that zero real wage growth is incompatible with high productivity growth in the water sector.

Nonetheless, our revised report now recommends an ex post indexation mechanism for real wages, rather than recommending no RPE allowance. This reflects a number of changes to our analysis of the potential for real wage growth. This changed recommendation means that if real wages in the water sector do

[87] If in fact water companies are not price takers in labour markets then labour would fail our criterion which considers whether the input cost is outside management control. In this case, labour would potentially fail to qualify for an RPE mechanism on the grounds of having failed this other criterion.

[88] Workers might respond in this way if the value that they place on leisure time is constant (i.e. it does not vary with volume of leisure time) and they substitute between work and leisure time by working until the wage rate that they earn at the margin equals the value that they place on leisure time. The assumption of a value of leisure time that is invariant to hours of leisure is a strong one, but even if this assumption does not fully hold, the mechanism in a weaker form could still lead to a divergence between the growth rate of average and marginal labour productivity, and hence to a divergence between average productivity growth for water companies and the growth rate of real wages.

[89] We note that when a Cobb-Douglas production function is assumed, the marginal productivity of labour will be proportional to average productivity, meaning that the effect we describe would not be possible. However, this simply reflects the limiting nature of this implicit assumption of a Cobb-Douglas production function.

increase in line with the assumed growth in productivity, the additional cost will automatically feed through into water companies' allowed revenues.

Different levels of evidence for RPE allowances and frontier shift

The higher level of evidence that we required for RPE allowances reflects the information asymmetry that exists between Ofwat and the regulated companies. It is a recognised problem in utility regulation that companies will have better information on future costs than the regulator, and will face an incentive to provide high cost estimates to the regulator in order to try to influence the regulator to set allowed revenues at a higher level. In the light of this, the regulator needs to scrutinise carefully any submission from companies arguing for additional revenue, to ensure that the case made by the companies is robust.

In the case of RPEs, companies are typically asking for additional revenue and should therefore provide compelling evidence to justify any allowance that they are asking for. If regulators provide RPE allowances which turn out to be unnecessary, then the costs to consumers can be substantial. For example, CEPA found that out-turn values for RPEs were substantially below Ofgem's ex ante regulatory allowances in the early years of the RIIO-1 price controls for electricity and gas transmission and gas distribution, leading to significant increases in the returns earned by these regulated companies.[90] Similarly, Citizens Advice estimated that out-turn values for RPEs for the RIIO-1 electricity transmission and gas distribution price controls will be £1.9 billion lower than Ofgem assumed, with companies keeping £0.9 billion of the savings as additional profit.[91]

By contrast, the assumption that Ofwat makes on frontier shift is one of the tools that Ofwat uses to challenge the cost figures put forward by companies. It is therefore part of the regulatory response to information asymmetry rather than a figure that needs to be scrutinised in the same way as company arguments for RPE allowances.

RPEs assessment

In this section, we discuss our response to the points made by companies in relation to each of the four criteria that we used in our RPEs assessment in our original report.

Due to the fact that we are no longer using one of our original criteria, the numbering of the criteria in the main body of this revised report differs from the numbering of the criteria in our original report. In the discussion in this section, we use the criteria numbering from our original report except where otherwise stated, given that company responses were commenting on that version of the report. The table below shows how our original numbering maps on to the criteria numbering in the main body of this revised report.

[90] CEPA, "Review of the RIIO framework and RIIO-1 performance", March 2018 https://www.ofgem.gov.uk/system/files/docs/2018/03/cepa_review_of_the_riio_framework_and_riio-1_performance.pdf

[91] Citizens Advice, "Energy Consumers' Missing Billions; The profits gifted to energy networks", July 2017 https://www.citizensadvice.org.uk/Global/CitizensAdvice/Energy/EnergyConsumersMissingBillions.pdf

Table A3.1: Numbering of criteria in our original and revised reports

Criterion	Numbering in	
	Original report	Revised report
Is the input cost item to which the RPE would be applied a material proportion of total company costs?	1	No longer used
Are there compelling reasons to think that CPIH does not adequately capture the input price?	2	2
Is there a significant likelihood that the value of the wedge between the input price and CPIH will differ substantially from zero over the period of the price control?	3	1
Is the expected value of the wedge between the input price and CPIH materially different from zero?	3A	1A
Does the wedge between the input price and CPIH exhibit high volatility over time?	3B	1B
4. Is the input price and exposure to that input price outside management control during the duration of the price control?	4	3

Criterion 1: materiality of cost item

Companies and their consultants made the following points in relation to the materiality criterion that we used in our original report:

- Both John Earwaker and Economic Insight (on behalf of Yorkshire Water) considered that the 10 per cent threshold used by Europe Economics for assessing the materiality of individual cost items was arbitrary. Similarly, NERA remarked that Europe Economics' threshold was prohibitively high.
- Economic Insight argued that Europe Economics was using the wrong test of materiality and stated that a small cost with a large input price difference from CPIH could have an effect as big as a large cost with a small input price difference from CPIH.
- NERA on behalf of Bristol Water and Economic Insight on behalf of Yorkshire Water stated that the threshold applied was sensitive to Europe Economics' choice of cost aggregation. NERA further argued that by applying the threshold to wholesale totex for the industry as a whole, differences in cost shares between different wholesale controls (e.g. water and wastewater, and network plus and resources) and between different groups of companies (WaSCs and WoCs) are overlooked.
- John Earwaker commented that Europe Economics' analysis was limited to two cost categories that accounted only for 55 per cent of totex and hence did not consider an RPE allowance for the remaining 45 per cent of cost items. This reflected not only the materiality test (which meant that energy and chemicals did not quality for an RPE allowance), but also a large "other" cost category, which Earwaker argued should be subject to further analysis.

We respond to these points below.

Materiality test

In this revised report, we have taken on board concerns expressed by companies and their consultants about the materiality test in our original report, and we have removed this criterion from our RPEs assessment. This means that we are no longer rejecting an RPE mechanism on the basis that a cost area accounts for less than 10 per cent of totex.

Percentage of cost base covered by our RPEs assessment

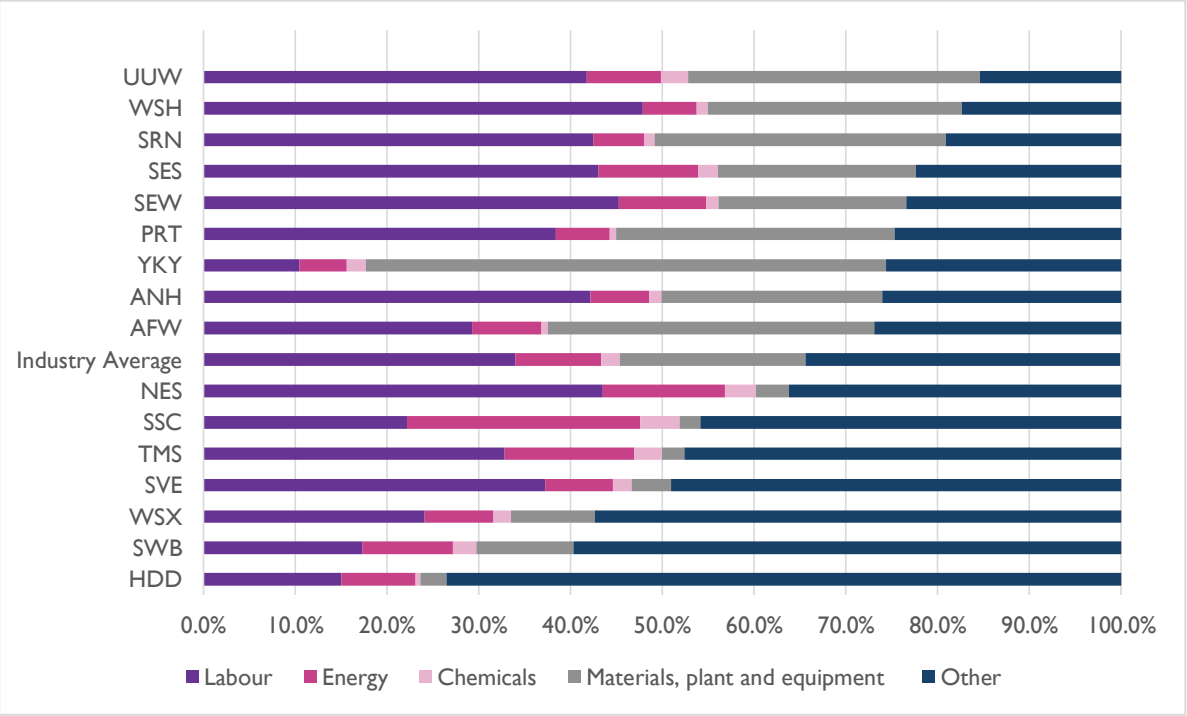
Earwaker's argument that our RPEs assessment only covered 55 per cent of water company costs was based on two things:

- The fact that energy and chemicals failed the materiality criterion of 10 per cent of totex used in our original report.
- The fact that there was a large "other" category for which no RPEs analysis was conducted. (Although this latter point this is not directly related to the materiality threshold, we discuss it in this part of the appendix given that Earwaker links it with his comments about the materiality threshold.)

The first of these issues raised by Earwaker is no longer relevant given that we have removed our original materiality criterion from our revised report.

The "other" cost category that Earwaker highlights accounts for 34.3 per cent of wholesale totex for the industry as a whole.[92] However, as shown by the chart below, the size of this "other" category varies substantially between companies, ranging from 15 per cent to 73 per cent. Possible explanations for these substantial differences could be differences in the degree of outsourcing and/or differences in how companies have categorised costs.

Figure A3.1: Differences in cost breakdown between companies



Clearly, the "other" category does not lend itself easily to RPEs analysis, since it is not clear what these costs are comprised of and hence what input prices may be relevant for this category. The fact that the industry as a whole has allocated a significant proportion of costs to this category therefore limits the percentage of overall totex that can be covered by RPEs analysis for individual cost areas.

Nonetheless, subsequently to our original report we have analysed two cost items which fall within the "other" category — namely, business rates and abstraction charges. We found that:

[92] This is calculated as a simple, unweighted average across companies.

- On average business rates constitute 6.2 per cent of wholesale totex. However, since business rates are indexed to the Consumer Prices Index (CPI) which moves closely in line with CPIH, we would not expect any real price effect for this element of the "other" category.
- On average abstraction charges constitute 1.7 per cent of wholesale totex. However, data from company business plans shows that most companies are not anticipating any real terms increase in the abstraction charges that they pay.

Traffic Management Act costs account for around a further 0.4 per cent of totex.

Data limitations have prevented further analysis of individual cost items within the "other" category.

A crucial point that has been overlooked by Earwaker in his remarks on the "other" category is that our RPEs assessment framework includes a Stage 2 test (discussed in section 2.5) in which we look at an overall input price index for the water sector produced by the ONS and test whether it has displayed a wedge relative to CPIH that is statistically significant. In other words, alongside our analysis of individual cost areas (where analysis of the "other" category is limited by the data available), we also look at a more aggregate input price index for the water sector which is likely to include items that companies have categorised under "other". In the light of this, Earwaker's claim that our RPEs analysis only covered 55 per cent of wholesale totex is incorrect.

Criterion 2: whether costs are adequately captured in CPIH

Under our earlier heading of "Consistency of RPEs and frontier shift analysis", we discussed comments made by Earwaker about the need for consistency between the way in which we implement this criterion and our analysis of frontier shift. We do not repeat that discussion in this section.

Other points made by companies and their consultants in relation to criterion 2 are as follows:

- NERA on behalf of Bristol Water and Economic Insight on behalf of Yorkshire Water stated that criterion 2 does not test whether the level and movement of CPIH adequately tracks the inputs in the water sector, and stated that wage pressures in the water sector may be different from those experienced in the rest of the economy.
- NERA further commented that in addition from goods and services produced domestically, CPIH also includes imports and hence it is illogical to conclude that CPIH captures labour inflation costs as wage pressures abroad could be different from those experienced in the UK.

We respond to these points in turn below.

Water sector wage pressures

The way in which we applied criterion 2 in our original report involved analysis of input cost shares in other sectors, and in this context NERA and Economic Insight argued that wage pressures might be different in other sectors of the economy compared with wage pressures in the water and wastewater sectors.

As explained earlier in the discussion under "CPIH and economy-wide productivity", in the light of other issues that have been raised in relation to criterion 2, we have modified the way in which are implementing it so that we are no longer examining input cost shares in other sectors. This means that this point by NERA and Economic Insight is no longer relevant to criterion 2.

The issue of whether water sector wage pressures are different from wage pressures in the rest of the economy does, however, remain relevant in our analysis for criteria 1 (revised numbering). Our original report used ONS data on the Index of Labour Cost per Hour (ICLH) and Average Weekly Earnings (AWE) for the electricity, gas and water supply sector. While this data relates to energy and water in combination, we consider that it is highly relevant as we might expect the energy and water sectors to face similar wage

pressures. Nonetheless, in this revised report we have gone further and added additional analysis of ONS wage data that specifically relates to the water and sewerage sector, although we acknowledge that there are quality issues with these data that need to be borne in mind.

Our revised report now recommends an indexation mechanism for real wage growth, and discusses different options for which ONS wage data should be used for indexation purposes (see Appendix 1). In this context, we discuss whether data on wage growth for "All employees" or "Manufacturing" is correlated with data on the wage pressures experienced by water companies.

Impact of imports on CPIH

As NERA point out, CPIH will be influenced by the price of imports. Our analysis of ONS data suggests that the direct contribution of imports to CPIH is 13 per cent, with total import intensity once supply chain impacts are also included being 19 per cent.

To investigate the impact that imports have on CPIH, we examined ONS data on how the contribution of different sectors to CPIH varies with the level of import intensity. The ONS has placed sectors into groups based on their import intensity, and has then computed how much of CPIH is accounted for by each group. The ONS figures in the row entitled "Contribution to CPIH" show that the more import intensive sectors contribute less to CPIH. As the groups vary in terms of the percentage of the CPIH basket that they represent (as shown in the "Share of CPIH basket" row), we have also computed figures that normalise for the size of each group, as shown in the row entitled "Contribution to CPIH per 1% share of CPIH basket". Again, these normalised figures show that more import-intensive sectors contribute less to CPIH.

Table A3.2: Contributions of sectors with different import intensities to CPIH (Jan 2016 to Feb 2019)

	Import intensity			
	0-10%	10-25%	25-40%	40% plus
Contribution to CPIH	0.72	0.58	0.26	0.11
Share of CPIH basket	0.23	0.22	0.16	0.15
Contribution to CPIH per 1% share of CPIH basket	0.16	0.13	0.04	0.01

Note: the contribution to CPIH of energy and Owner Occupiers' Housing (OOH) costs is excluded from this table. The overall growth rate of CPIH over the relevant period is equal to the sum of the figures in the row of the table labelled "Contribution to CPIH" plus the contribution from energy and OOH.
Source: ONS data, Europe Economics' analysis.

While this analysis suggests that imports hold down the rate of CPIH inflation, it needs to be borne in mind that imports may also hold down input price pressures for water companies. ONS data show that import intensity is 9.5 per cent in the water sector and 8.7 per cent in the sewerage sector. While these import intensity figures are lower than for CPIH as a whole, it is likely that imports may have some effect in restraining the input price pressures faced by water companies.

Nonetheless, we have taken account of the points made by NERA about the impact of imports on CPIH in our decision to change the way in which criterion 2 is implemented. In our revised report, we no longer consider input cost shares in other sectors, and hence the fact that input price pressures may be different overseas from in the UK is no longer an issue for our analysis.

Criterion 3: whether there is a significant likelihood of wedge

Companies and their consultants made a wide range of points in relation to our analysis of whether there is a significant likelihood of a wedge between relevant input prices and CPIH:

- Economic Insight on behalf of Yorkshire Water argued that a visual inspection of charts in Europe Economics' original report showed a positive wedge between CPIH and the ONS labour cost indices, at least since 2014. Economic Insight suggested that similar positive wedges could be observed for the BEIS industrial electricity price index since 2011 and 2012, and for the ONS chemical price index since around 2014.
- Economic Insight on behalf of Wessex Water and NERA on behalf of Bristol Water commented that examining whether the wedge is statistically different from zero is irrelevant as it is just a measure of probability and ignores whether input price inflation is expected to exceed or fall short of CPIH. A further point raised by NERA was that Europe Economics did not present the detailed results of the statistical wedge analysis, in that it did not state the time period, the granularity / frequency of the data used, nor the significance level chosen.
- NERA was of the view that Europe Economics appears to be "data mining" (for example, in relation to its wedge analysis for energy costs). It also criticised the fact that Europe Economics restricted its analysis to post-2006 data rather than back-casting CPIH estimates.
- John Earwaker, NERA on behalf of Bristol Water and Economic Insight on behalf of Yorkshire Water criticised Europe Economics for dismissing OBR and BEIS forecasts on the basis of a lack of reliability. Oxera on behalf of South East Water and Southern Water and NERA on behalf of Bristol Water further remarked that since RPEs are forward-looking by their nature, some consideration should be given to forecasts that reflect forward-looking expectations.
- Economic Insight on behalf of Yorkshire Water suggested that the five-year rolling average of the standard deviation of the wedge should be used for volatility analysis.
- NERA stated that Europe Economics' wedge volatility analysis relies on a short time series which may fail to detect long-term historical trends.
- Oxera on behalf of Southern Water noted that labour market tightness could have an influence on wage growth.
- NERA on behalf of Bristol Water stated that the reason for Europe Economics' consideration of gas prices was unclear as water companies' primary energy cost is electricity. Economic Insight on behalf of Yorkshire Water commented that different findings for gas and electricity suggest a varying RPE allowance rather than an allowance of zero.

We respond to these various points in turn below.

Alleged existence of wedges in Europe Economics charts

In our original report, we included charts intended to show visually the extent to which different input price indices are correlated with CPIH.

In its report, Economic Insight added included pictures of our charts with added circles around time periods in which it claimed our charts showed a positive wedge between the input price and CPIH. By way of illustration, we show below the charts with added circles that Economic Insight included for labour price indices. It also included similar charts for the BEIS industrial electricity price index and the ONS chemical price index.

Figure A3.2: The "wedges" that Economic Insight claims are visible in our charts

Economic Insight's claim is based on a misreading of the chart, since it has failed to notice that the charts have two different vertical axes. In the above chart, the labour cost indices are shown against the left hand axis and CPIH against the right-hand axis. The charts were produced like this in order to illustrate the extent to which the series move together, without differences in the absolute level of the two series obscuring any co-movement. Since the series are plotted against different axes, the gap between them on the chart is not the wedge between the two series.

Use of statistical significance tests

We disagree with the claim by Economic Insight and NERA that our analysis of whether the wedge is statistically different from zero is irrelevant and that it ignores whether input price inflation is expected to exceed or fall short of CPIH.

As discussed earlier (under the heading "Different levels of evidence for RPE allowances and frontier shift"), the experience of Ofgem with its RIIO-1 price controls shows that there is a danger of substantial consumer harm from setting ex ante RPE allowances which turn out to be based on over-estimates of the future real growth in input prices. In order for Ofwat to meet its statutory objective to protect the interests of consumers, it is therefore important that RPE allowances are only provided where there is a robust evidence that input prices will grow faster than CPIH.

Our statistical significance tests are the tool we use when analysing historical data on the wedge between input prices and CPIH to determine whether there is robust evidence of a positive or negative wedge. Hence, far from ignoring whether input price inflation is expected to exceed or fall short of CPIH, our statistical significance tests are the tool we use to determine whether there is robust evidence that this is likely to the case. If historical data on the wedge between an input price and CPIH fail to pass a significance test, by definition this means that we cannot be confident that the underlying wedge is actually different from zero.

The significance tests have been carried out using a 5 per cent level of significance, which is a standard level of significance to use when testing statistical significance. In this revised report, we have added footnotes supplying information on the frequency of the data that has been used in carrying out significance testing.

Alleged data mining and choice of time period

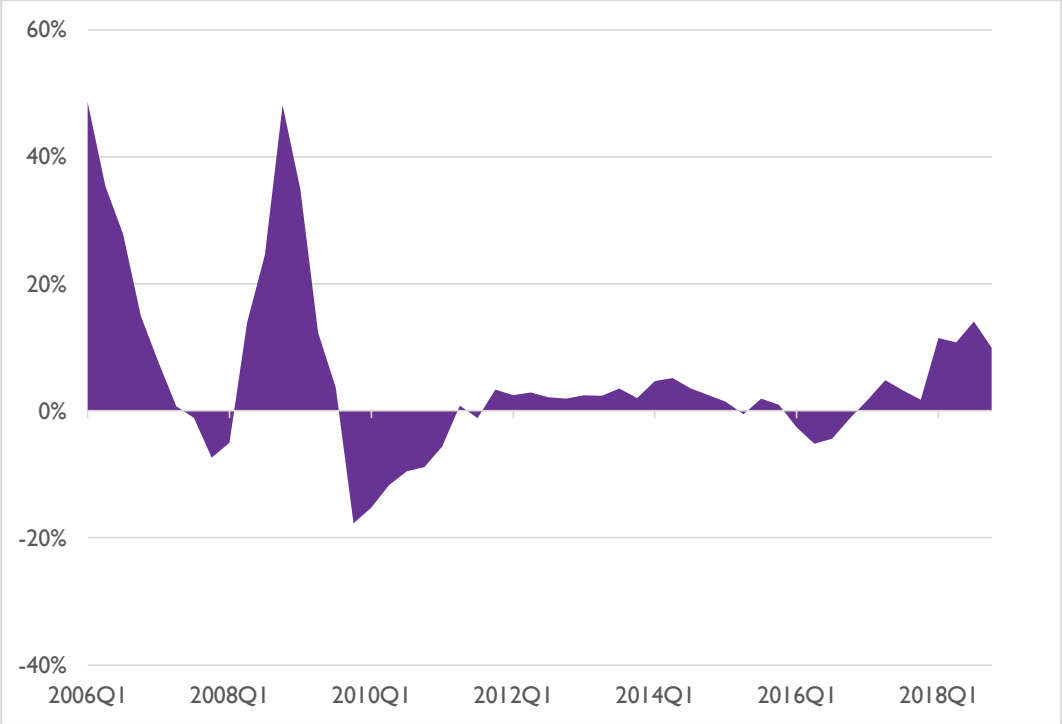
The choice of time period for analysing historical data on the wedge between an input price and CPIH needs to balance two things. On the one hand, going back further in time will provide more data points to analyse, and will help to avoid conclusions being overly influenced by random variations in real price changes in particular periods. On the other hand, what we are interested in is forwards-looking expectations of whether there are likely to be real price effects over the forthcoming price control. Since real price effects may change over time, the older the historical data that is analysed, the more likely it is that it will be "out-of-date" and fail to reflect what may happen in the future.

In our report, we balanced these considerations by looking at data from 2006 onwards, as well as examining relevant changes in the input price within the period and looking at recent data for the current price control period. By going back to 2006 we looked at more than a decade of data, which we consider to be sufficient to determine whether historical data shows a wedge between input prices and CPIH.

In the case of our energy analysis, visual inspection of the chart for the wedge between the BEIS industrial electricity price and CPIH (reproduced below) shows that there was a period of high volatility period to 2010 in which there were two large spikes (in 2006 and 2008) in the wedge of almost 50 per cent. However, the chart shows that since 2010 movements in industrial electricity prices have been less volatile.

Given the danger mentioned above of placing too much weight on older data which no longer reflects current market conditions, we have therefore tested whether there is a positive wedge that is statistically significant for data from 2010 onwards. In our view, inspection of whether there have been changes in the behaviour of a data series within a period does not constitute "data mining". Further, to take account of the possibility that the result might be sensitive to the choice of start year, we also tested whether there was a statistical significant wedge from 2011 onwards and from 2012 onwards. We found that whether the wedge was statistically significant depended on the start year, suggesting that evidence of a real price effect for electricity is mixed and therefore inconclusive.

Figure A3.3: The historical wedge between the BEIS industrial electricity price index and CPIH



In this revised report, we have adjusted our assessment of energy to acknowledge that the answer will depend on what weight is placed on pre-2010 data (as well as what reliance is placed on BEIS forecasts).

OBR and BEIS forecasts

In our revised report, we have adjusted our assessment of labour and energy under criterion 1A to acknowledge that whether these cost areas qualify for an RPE mechanism depends on whether reliance is placed (respectively) on OBR forecasts of real wage growth and BEIS forecasts of future industrial electricity prices.

We continue to take the view that these forecasts are not sufficiently reliable to form the basis for an ex ante RPE allowance. In particular, we note the following points:

- As discussed in section 2.4.1, analysis of past OBR forecasts show that they have often been inaccurate, with its forecasts in recent years typically turning out to be over-estimates. In the context of PR19, the use of these forecasts therefore carries a risk of substantial harm to consumers from RPE allowances for real wage growth that turn out to be unjustified.
- Similarly, our analysis of past BEIS forecast of industrial electricity prices in section 2.4.2 shows that BEIS forecasts have also often failed to accurately predict electricity prices. Differences between forecasts and actual out-turns for industrial electricity prices have sometimes been large, with prices sometimes moving in the opposite direction to what BEIS forecasted. BEIS itself acknowledges the uncertainty in its forecasts since it publishes high and low figures alongside its reference scenario.

Hence, if Ofwat uses either OBR or BEIS forecasts as the basis for ex ante allowances, we recommend that it also includes an ex post indexation mechanism so that consumers are protected if out-turn values for these input prices come in below the forecast values.

Approach to assessing volatility

What we want to find out in our volatility analysis is whether the past history of the wedge between the relevant index and CPIH suggests that volatility is of such materiality that ex post there could be a material impact on totex from unexpected movements in the input price (even if ex ante the expected wedge is not materially different from zero). In such circumstances, there may be a case for an ex post indexation mechanism for that input price, subject to consideration of the other criteria in our RPEs assessment framework.

In the light of this purpose of our volatility analysis, we disagree with Economic Insight's suggestion that the five-year rolling average of the standard deviation of the wedge should be used for volatility analysis. While we recognise that the standard deviation is a widely used measure of volatility, it is less relevant in this specific context, since it does not look at whether historic movements in the input price have had a material impact on totex.

By contrast, the approach we are using for our volatility analysis directly assesses whether past movements in the input price relative to CPIH, averaged over a five-year period, have led to an impact on totex greater than 1 per cent of totex (the same materiality threshold that Ofwat uses when assessing Cost Adjustment Claims). This informs our assessment of whether there is a significant likelihood that unexpected movements in the input price over the five years of the next price control could have a material impact on totex.

Time period for volatility analysis

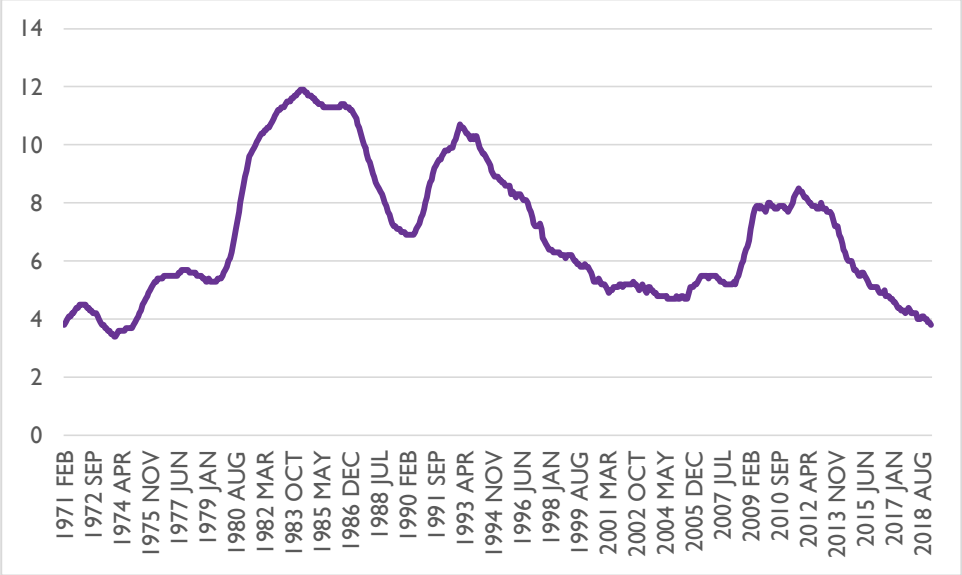
In the volatility analysis in our original report, we focused on five-year averages of the wedge between the input price and CPIH. The first data point shown in our volatility charts was for Q1 2011, based on a five-year average of the wedge between Q1 2006 and Q4 2010.

We recognise that the use of five-year rolling averages starting from Q1 2011 meant that the rolling average was only examined over an 8-year period, which is less than a decade. In this revised report, we have therefore taken on board NERA's criticism of the shortness of this time period by extending our calculation of the five-year rolling average of the wedges between the various input prices and CPIH back to 2006, using back-casted estimates of CPIH produced by the ONS.

Labour market tightness

We agree with Oxera that at this point in time the UK labour market is tight. As shown in the chart below, since the financial crisis the seasonally adjusted unemployment rate has fallen to around 4 per cent — a level last observed in the 1970s.

Figure A3.4: Unemployment rate (aged 16 and over, seasonally adjusted)



However, Oxera have not provided any evidence that this labour market tightness will persist into the next price control period (2020-25). On the contrary, Oxera itself recognises that there is significant economic uncertainty regarding the next price control period, stating:

> "the UK's exit from the European Union casts uncertainty regarding the next economic period".

Further, commentary on the UK labour market has noted the puzzle that the UK's strong performance on employment in recent years has not led to the upwards pressure on wages that might have been expected. Hence, even if employment in the UK remains strong, it is not clear that this will necessarily lead to strong real wage growth.

Our revised report recommends an ex post indexation mechanism for wage rates, which means that if real wage rates do rise due to the tight labour market then this will automatically feed through into allowed revenues. At the same time, an indexation mechanism means that if real wages do not increase (e.g. due to an economic downturn caused by global trade wars), then water consumers will not be paying for forecast increases in real wages which do not actually happen.

Analysis of gas prices

In our original report, we analysed data for both gas and electricity prices, although we stated that more weight should be placed on our assessment of electricity prices as this was the most relevant energy price index.

We have taken on board the point made by NERA about the limited relevance of our gas price analysis, and in our revised report we focus solely on industrial electricity prices. This reflects the fact that power is the most significant energy cost faced by water companies.

Criterion 4: whether input costs are outside management control

Companies and their consultants made the following points about our analysis under criterion 4:

- Economic Insight on behalf of Wessex Water and Yorkshire Water argued that the PR19 framework separately made deductions for efficiency through Ofwat's catch-up and frontier shift efficiency

challenges, and that, once efficiency is accounted for, all input price inflation must by definition be outside company control. It stated that an efficient company must pass on 100 per cent of input price increases since it has no ability or incentive to "absorb" them.

- In contrast to Economic Insight, NERA on behalf of Bristol Water stated that most input costs are within management control to some extent, as water companies can substitute between factors of production when input price changes. However, it argued that input price increases would still lead to costs rising once companies have adjusted the mix of input factors that they use.
- While John Earwaker accepted that controllability was a reasonable test to apply, he argued that Europe Economics' assessment of controllability conflated the question of whether firms can manage input price pressures with the question of whether they can avoid input price pressures entirely.
- NERA on behalf of Bristol Water also stated that Europe Economics' assessment of management control relied on a subjective qualitative assessment and that Europe Economics only gave hypothetical examples of how water companies could control input costs.

We note that these consultants disagree with each other, with Earwaker accepting the reasonableness of the test (while disagreeing with Europe Economics' implementation of it), Economic Insight arguing that all input prices are outside management control, and NERA arguing that all input costs are to some extent within management control.

We discuss the points raised by these consultants below.

Whether controlling input prices is possible for an efficient company

We disagree with Economic Insight's claim that an efficient company cannot do anything in response to increases in input prices. An efficient company will choose the optimal mix of inputs given the relative prices of those inputs. When those relative prices change because one of those input prices increases, an efficient company will re-optimise its mix of inputs by substituting away from the input which has increased in price to other inputs. For example, a firm might respond to an increase in real wages by investing in labour-saving machinery. Hence, even an efficient company can potentially manage exposure to input price increases when there is scope for substitution between inputs.

Further, Economic Insight is incorrect to claim that an efficient company has to pass through 100 per cent of any cost increase. In making this claim, Economic Insight has ignored the literature that exists on the subject of cost pass through in competitive markets.[93] The extent to which cost increases in competitive markets are passed through to customers will depend, for example, on the elasticities of supply and demand.

We also disagree with Economic Insight's view that because Ofwat separately applies catch-up and frontier shift efficiency challenges, it should not take any further account of potential efficiencies when assessing the controllability of input costs in the face of any future increase in input prices. When an input price increases, the benefits of making efficiencies that reduce exposure to that input price increase, and hence companies have a potential incentive to invest further in technologies or business practices that yield efficiency savings in relation to that input, beyond what they would otherwise have done.

Impact of total costs when there is substitution between inputs

While we agree with NERA that a firm's total costs may still increase when it responds to a rising input price by substituting between inputs, NERA fails to recognise that the increase in its total costs will be less

[93] By way of example, see RBB Economics, "Cost pass-through: theory, measurement, and potential policy implications; A Report prepared for the Office of Fair Trading", February 2014. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/320912/Cost_Pass-Through_Report.pdf

than it would have been had the firm not engaged in input substitution. Had no substitution taken place, the firm would have had to pay the increased input price for all of the original volume of the input. By engaging in input substitution, the firm only has to pay the input price for a reduced volume of the input, albeit with this cost saving partly offset by additional spending on other inputs. Overall, there must be a net cost saving from the input substitution, or firms would not wish to substitute between inputs in this way.

Bearing this in mind, it is clear that providing an RPE allowance for the increase in the input price would over-compensate companies in circumstances where they can manage their exposure to that price by input substitution. Further, it should also be borne in mind that the overall price control framework includes a totex cost-sharing mechanism as well as five-year periodic reviews at which cost allowances are reset, meaning that the increase in total costs that may still occur would be shared between the company and customers.

These issues are also relevant to Earwaker's criticism that we have conflated the issues of management of input price pressures and avoidance of input price increases. Where firms can limit exposure to input price increases (even if they cannot avoid them completely), an RPE allowance would over-compensate companies relative to the costs that they actually incur. Further, the totex cost-sharing mechanism and five-year periodic reviews mean that any cost increase which still occurs will be shared between companies and customers. In addition, the "Partial Pass" that we give some cost areas against this criterion takes account of the fact that companies may be able partially but not wholly to control exposure to a rising input price.

Qualitative nature of assessment

We acknowledge that an assessment of whether of whether firms can take action to control input costs will necessarily be qualitative in nature. However, we do not think it is appropriate for Ofwat to ignore important considerations simply because they are not amenable to quantification.

Further, we do not think that an assessment of controllability should be limited to analysis of what companies already do to control input costs. This would fail to provide an adequate efficiency challenge, since it would not take account of additional actions that may be open to companies in the event that an input price increased.

Nonetheless, we have made changes to our assessment of management controllability in this revised report to ensure that our qualitative assessment is as robust as possible. In particular, we have distinguished between actions that companies can take to control the expected level of the input price, to protect against volatility in the input price, and to reduce exposure to the input price by reducing the volume of the input used. Where cost areas are scored as a "Partial Pass" against this criterion, we make clearer what the basis for this is (e.g. can protect against volatility and/or can reduce volume of input).

Frontier shift assessment

In this section, we first discuss points about our choice of comparator sectors, then points about our choice of time period, and then other points relating to this part of our analysis.

Choice of comparator sectors

Companies and their consultants made the following points about our choice of comparator sectors:

- John Earwaker, Oxera on behalf of South East Water and Southern Water, and NERA on behalf of Bristol Water argued that the upper bound of the range for frontier shift should be based on an average of comparator sectors rather than the most strongly performing sectors.
- Oxera on behalf of South East Water and Southern Water stated that Europe Economics failed to consider the representativeness of the comparator sectors used in its analysis. By way of example,

Oxera argued that 'Chemicals' would be overrepresented in an unweighted average with a 25 per cent weight compared to the 2 to 6 per cent weight that chemicals have in water industry costs. Similarly, Oxera argued that the construction sector would be underrepresented in an unweighted average.

Upper bound of our range

We do not consider that using an average of the comparator sectors would be appropriate for setting the upper bound of our range, as the historical performance of some of the comparator sectors shows that it is possible for comparable sectors to perform more strongly than this. By definition, an average provides a measure of the central value of a distribution rather than an upper value.

Ofwat's policy framework for PR19 involves setting stretching performance targets for water companies,[94] and setting the upper bound on the basis of an average of comparator sectors would be inconsistent with this framework.

While we set the lower bound of our range on the basis of the average performance of the comparator sectors in the post-crisis period, this reflects the fact that we are setting a range that is suitable for regulatory use rather than a range intended to capture the full dispersion of the data set. Given Ofwat is seeking to protect customer interests by setting reasonably stretching performance targets, it would be inappropriate to determine a frontier shift range for regulatory purposes which permitted the water sector to perform below the average of comparator sectors.

Irrelevance of weight of comparator sector in industry costs

In our view, Oxera is misguided in linking the choice of comparator sectors for frontier shift analysis to the share of that sector in water companies' costs. The reason for including sectors in a frontier shift analysis should be that they are deemed similar in terms of the nature of activity carried out, and not because the water sector purchases inputs from that sector. In principle, it would be possible for a sector to form a good comparator for the water sector if the nature of the activity is similar, even if water companies purchased no inputs at all from that sector. For example, a gas network has strong similarities with a water network in that both involve a pipeline network for transportation of a commodity, and this comparability is unaffected by the fact that gas may be a small share of water company totex.[95]

We consider the chemicals sector to be a relevant comparator to the water sector not because water companies purchase chemicals, but rather because there are some similarities between industrial processing of chemicals and the treatment and transportation of water and wastewater. Both sectors are capital intensive, and involve the use of materials, plant and equipment to carry out bulk processing activities. Oxera is also incorrect to argue that the chemicals sector would have a 25 per cent weight in an unweighted average — the weight for chemicals would be lower than this as there are seven comparator sectors in our analysis using NACE 2 data and five comparator sectors in our analysis using NACE 1 data.[96]

While we accept that the construction sector is a valid comparator and have included it in our own analysis, we disagree with Oxera's claim that we have under-weighted the construction sector. For the reasons discussed above, we do not consider that the share of totex that companies spend on construction necessarily makes it a closer comparator than other sectors which have a similar nature of activity to the water sector.

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[94] See Ofwat (2017), "Delivering Water 2020: Our final methodology for the 2019 price review"

[95] While we use the example of a gas network to illustrate the point we are making, in practice the EU KLEMS dataset does not provide separate TFP data for the gas sector. Instead, the gas sector is included within a broader sector labelled "Electricity, gas and water supply". As discussed in Section 3.6.1, we do not consider that this sector can be used for the purpose of setting frontier shift estimates, as the TFP figures for this sector appear to be distorted by problems relating to measurement of the quality of output.

[96] Note that our analysis treats "Total manufacturing" as a comparator sector in its own right, alongside the other comparator sectors which are at a more disaggregated level.

We consider that Oxera's own analysis of frontier shift (submitted earlier in the price review process)[97] significantly over-weighted the construction sector. Oxera used 1–2 comparator sectors for each disaggregated element of the value chain that it considered, with construction appearing as one of those comparator sectors for all elements of the value chain except for "Bioresources opex". Oxera's report itself stated "the comparator set remains dominated by construction". Since Oxera estimated a low TFP growth rate (in value added terms) of 0.2 per cent for the construction sector, this over-weighting of construction meant that Oxera's figures for frontier shift were downwardly biased.

Choice of time period

Companies and their consultants made the following points about our choice of time period:

- NERA on behalf of Bristol Water stated that Europe Economics did not consider full business cycles and that this introduced bias into the analysis. At the same time, NERA argued that Europe Economics' definition of a business cycle was subjective. Oxera on behalf of Southern Water also argued that productivity should be considered over full business cycles. NERA criticised Europe Economics for excluding a business cycle in the 1970s (1974-1979).
- Economic Insight on behalf of Wessex Water and NERA criticised Europe Economics' preferred estimates on the grounds that they ignored the years 2008 and 2009 when UK productivity growth was at its lowest.
- NERA on behalf of Bristol Water argued that Europe Economics' numbers rely on a short time period, with the upper bound representing TFP performance in a period of strong economic performance in the pre-financial crisis period (1997-2007).
- Both John Earwaker and Economic Insight on behalf of Yorkshire Water stated that Europe Economics' analysis did not attach sufficient weight to the recent productivity slowdown that the UK has experienced.
- Economic Insight on behalf of Wessex Water commented that Ofwat's decision to put more weight on historical periods is at odds with its position on determining inflation and the cost of equity.

Business cycles

In our report, we acknowledge that TFP growth is pro-cyclical, and that this means there are advantages in analysing TFP growth over an entire business cycle.

NERA and Oxera are incorrect to imply that we did not consider full business cycles. In section 3.7.3 of our report, we explain that two datasets are available from EU KLEMS — a newer dataset using the NACE 2 classification which covers the period 1999-2014, and an older dataset using the NACE 1 classification which covers the period 1971-2007. As we explain in our report, the shorter time period covered by the NACE 2 dataset precluded analysis over complete business cycles using that particular dataset. In particular, we defined business cycles on the basis of the period from one trough in GDP growth to the next trough, and the time period covered by the NACE 2 dataset only included one trough in GDP. However, for the longer NACE 1 dataset we identified the last two business cycles (1980 to 1989, and 1980 to 2007) and reported TFP growth figures over each of these two business cycles and for both of them together. Indeed, the fact that NERA criticise our approach to defining business cycles implicitly recognises that we have taken business cycles into account in our analysis.

[97] See Southern Water's Technical Annex 14.6 entitled "Oxera Report: Estimate of RPE and Frontier Shift", September 2018

Further, our report makes clear that our recommendations for the upper bound are partly based on our analysis of complete business cycles using the NACE 1 dataset. We state explicitly:

> "We also consider the longer time series NACE 1 data in Table 3.18, which provide a longer term view of TFP growth performance. On this basis, the implied upper bound is again in the order of 1.2 per cent **when looking at the latest full economic cycle (1990-2007)**, driven by the "Chemicals and chemical products" sector." [added emphasis]

Hence, the 1.2 upper limit takes account of evidence over full business cycles, in addition to reflecting the more recent evidence (both pre and post-crisis) from the NACE 2 dataset. It should further be noted that in the previous business cycle that we present in our analysis (1980-1989), there were two sectors which had TFP growth rates above our upper bound ("Chemicals and chemical products", which had a TFP growth rate of 1.6 per cent, and "Transport and storage", which had a TFP growth rate of 1.3 per cent).

We disagree with NERA's claim that using trough-to-trough GDP analysis is a subjective way of defining a business cycle. The textbook definition of a business cycle relates to the cycle of expansion and contraction in economic activity. By taking the period from just after one trough in GDP has finished to just after the next trough in GPR has finished, we are ensuring that each of our business cycles contains a full period of expansion and a full period of contraction, thus representing a complete cycle. We note that Economic Insight's analysis of frontier shift (submitted earlier in the price review process) defines business cycles on the basis of peaks and troughs in GDP.

We also disagree with NERA's suggestion that an earlier business cycle in the 1970s should also be included in the analysis. The purpose of our TFP analysis is to derive a forward looking estimate of frontier shift over the next price control period. While we do this by looking at the TFP growth that has been achieved historically by comparator sectors, the older the data included in the analysis the more likely it is that the data will be "out-of-date", given that the potential for frontier shift may change over time. We consider that using the NACE 1 dataset to examine the last two complete business cycles for which we have data is sufficient to provide evidence of the productivity growth has been achieved historically in comparable sectors. Further, the period that NERA suggests including (1974-79) was a period in which the UK was suffering the economic consequences of oil price shocks. In our view, it is not credible to suggest that such historical and idiosyncratic events should drive the frontier shift number for 2020-25.

Exclusion of crisis years from pre-crisis and post-crisis averages

Both Economic Insight and NERA criticise the exclusion of the crisis years of 2008 and 2009 from the pre-crisis and post-crisis numbers that we calculated from the NACE 2 dataset.

To understand the issue, two important points about the NACE 2 dataset should be recognised:

- First, as stated above, the time period covered by the NACE 2 dataset (1999-2014) does not cover a complete economic cycle — an issue which was also recognised by Economic Insight[98] and Oxera[99] in their own frontier shift analysis (submitted earlier in the price review process).
- Second, as discussed in Section 3.8.2, it is possible that there may be a structural break in the data partway through the period, with trend pre-crisis productivity growth being higher than trend post-crisis productivity growth. The possibility that there may have been a productivity slowdown post-crisis

[98] Referring to the NACE 2 dataset, Economic Insight stated "the EU KLEMS data does not contain a 'whole' business cycle".

[99] Referring to the 1996-2014 period that it focuses on using the NACE 2 dataset, Oxera states that "this might not necessarily represent a "full" business cycle".

is mentioned by Earwaker, as well being central to the approach adopted by Economic Insight in its own analysis of frontier shift (submitted earlier in the price review process).

In the light of this, we calculated TFP growth from the NACE 2 dataset over three periods:

- the full data period (1999 to 2014);
- the pre-crisis period from 1999 to 2007; and
- the post-crisis period from 2010 to 2014.

While the full data period may perhaps be the closest to a business cycle that can be obtained from this dataset, as stated above it does not necessarily represent a complete cycle. TFP growth estimates for this period are likely to be downwardly biased, since the period includes a full economic contraction but not necessarily a full period of economic expansion. If there is a structural break part-way through the period, it will also represent an arbitrary weighted average of pre-crisis and post-crisis TFP growth.

Given these issues with the figures for the full period, we use the pre-crisis numbers to inform our upper bound (alongside evidence from complete business cycles in the NACE 1 dataset) and the post-crisis numbers to inform our lower bound. This allows our range to capture the potential structural break in TFP growth between the pre-crisis and post-crisis periods and the uncertainty that exists about whether and how soon TFP growth may return to pre-crisis levels.

In this context, we disagree with the suggestion from Economic Insight and NERA that the pre-crisis and post-crisis numbers should include the crisis years of 2008 and 2009 when productivity growth was strongly negative. First, if the crisis period were to be included in these figures, then they would not genuinely be "pre-crisis" and "post-crisis" figures. More importantly, inclusion of these crisis years would make the figures severely downward biased, since the figures would then include a full economic contraction but only a very incomplete part of the period of economic expansion either side of the crisis.

To take account of the danger that excluding the crisis years may create a bias in the other direction, in arriving at our upper bound estimate we draw on the NACE 1 data which uses complete business cycles (see earlier discussion), alongside our pre-crisis figures from the NACE 2 dataset. In examining post-crisis numbers to set the lower bound, the NACE 1 dataset is obviously not useful, since all of the NACE 1 data precedes the crisis. However, in our view, TFP growth in the years from 2010 onwards represents the best available evidence of the productivity growth that has been achieved in the years since the crisis.

Recent UK productivity slowdown

We believe that Earwaker is incorrect to suggest that our analysis does not attach sufficient weight to the recent UK productivity slowdown. As discussed above, our lower bound estimate for frontier shift is driven by our analysis of post-crisis TFP growth.

In this context, it is important to note that comparator sectors have not been affected by the slowdown in productivity growth to the same extent as the overall economy. Earwaker himself states:

> "When economists have dug below the whole-economy productivity data, they have found that certain sectors of the economy have contributed disproportionately to lower/flat productivity growth"

The data presented in Table 3.13 in the main body of our report show that TFP growth in the UK market economy as a whole fell from 0.7 per cent per annum in our pre-crisis period to zero post-crisis, while average annual TFP growth across our comparator sectors only fell from 0.9 per cent to 0.6 per cent. Further, four out of our seven comparator sectors actually achieved higher TFP growth in the post-crisis period than in the pre-crisis period.

The fact that Ofwat chose a figure above our lower bound does not necessarily reflect a view by Ofwat that productivity will rebound from post-crisis figures, since the stated rationale for going to upper end of

the range that was presented by both Europe Economics and Ofwat was to place some weight on GVA TFP figures and to take account of embodied technical change. Put another way, a figure toward the upper end of the range is consistent with a view that productivity growth in the next price control period may continue to be at post-crisis levels or may only start to rebound from those levels, but that measured TFP growth using the GO method is understating frontier shift for the two reasons given. In this case, the upper bound is simply acting as a backstop — in other words, given uncertainty over how much aiming up is appropriate to take account of embodied technical change and to place some weight on GVA numbers, we limit the degree of aiming up such that the frontier shift figure cannot exceed the measured GO TFP growth rate for strongly performing sectors in the pre-crisis period.

Consistency with cost of capital analysis

The issue of consistency between our cost of capital and productivity analysis raised by Economic Insight is an issue that goes wider than our analysis of RPEs and frontier shift, and hence is being considered more widely in Ofwat's work.

Further comments

Companies and their consultants also made the following comments about our frontier shift analysis:

- Both Economic Insight on behalf of Yorkshire Water and NERA on behalf of Bristol Water argued that Ofwat's decision to attach some weight to the GVA measure of TFP growth was incorrect, and that it went against the stated preference for GO-based TFP measures in the Europe Economics report. NERA stated that Europe Economics did not present a rationale for placing any weight at all on GVA-based TFP measures, and that there is no regulatory precedent for doing so.
- NERA stated that Europe Economics had no basis for quantifying the extent of the bias related to embodied technological change, and argued that we had ignored other offsetting biases.
- Economic Insight on behalf of Yorkshire Water included an Annex in which Dr Karli Glass and Dr Anthony Glass express the view that some of the academic literature cited by Europe Economics is dated and of little or no relevance to frontier shift.

Gross Value Added measure of TFP

Economic Insight's report misrepresents how we and Ofwat treated GVA-based measures of TFP. Economic Insight claim that Ofwat attached more weight to the GVA-based measure of TFP than to the GO-based measure. That is not correct – both the upper and lower bounds to our range were based on GO-based TFP figures, and therefore GO-based TFP figures were the key driver of the range that Ofwat used. The fact that GVA-based TFP figures are higher than GO-based TFP figures was simply used as a qualitative reason for aiming up within the GO-based TFP range. If the range itself had been driven by GVA-based TFP data, both the lower and upper bounds would have been much higher.

While we consider that GO-based TFP measures are generally better suited for estimating frontier shift for totex or botex, as explained in our report we consider that it is nonetheless appropriate to place some weight on GVA-based TFP figures. As explained in the OECD's manual on measuring productivity,[100] GO-based TFP growth represents technical change when technical progress affects all factors of production proportionally (in technical terms, when technical change is "Hicks neutral" and "output augmenting"). However, if instead technical change only affects primary inputs and not intermediate goods (in technical terms, if it is "primary input augmenting"), then GVA-based TFP growth becomes the true measure of technical change and GO-based TFP measures are no longer relevant. As stated in the OCED manual,

[100] OCED, "Measuring Productivity; OCED Manual; Measurement of Aggregate and Industry-Level Productivity Growth", 2001. http://www.oecd.org/sdd/productivity-stats/2352458.pdf

neither assumption about the nature of technical change receives full empirical support, suggesting that some elements of technical change may be output augmenting and other elements may affect individual inputs separately. Given this, we consider that there is a valid theoretical rationale for placing some weight on GVA-based measures by taking GVA-based TFP growth into account when selecting a point estimate from within a range based on GO-based TFP growth.

We note that Oxera supported the use of both GO- and GVA-based measures of TFP growth in its original report estimating frontier shift (submitted earlier in the price review process). In particular, Oxera stated:[101]

> Both types of TFP measure are theoretically valid means of measuring productivity. … Ideally, both VA- and GO-based TFP measures could be used to inform the potential for productivity growth in the industry.

NERA is also incorrect to suggest that consideration of GVA-based TFP measures is not supported by any regulatory precedent. For example, in its initial proposals for the RIIO-T1/GD1 price control, Ofgem stated:[102]

> In determining our ongoing efficiency assumptions, we draw on evidence for both GO and VA measures of productivity

Hence, placing some weight on GVA-based TFP measures is supported by theoretical considerations, by one of the consultants (Oxera) working on behalf of water companies, and by regulatory precedent.

The figures for GVA-based TFP growth presented in section 3.10.2 of our report show that placing some weight on GVA-based TFP figures tends to support a frontier shift figure from the upper end of our GO-based TFP range of 0.6 to 1.2 per cent. In particular:

- The average post-crisis GVA-based TFP growth rate for our comparator sectors is 1.3 per cent — above the upper end of our GO-based TFP range.
- GVA-based TFP growth rates were even higher before the financial crisis. For GVA-based TFP data, EU KLEMS provides a NACE-2 dataset which allows analysis across complete economic cycles (see Table Table 3.16), and this shows that the average GVA-based TFP growth rate across comparator sectors was 1.5 per cent in both of the last two economic cycles. Further, the most strongly performing sectors achieved much faster GVA-based TFP growth than this — for example, in the last economic cycle (1990-2007) the GVA-based TFP growth rate was 1.9 per cent for "Total Manufacturing" and 2.0 per cent for "Machinery and equipment n.e.c.", with "Chemicals and chemical products" achieving a GVA-based TFP growth rate as high as 4.1 per cent. These figures are substantially above the upper end of our GO-based TFP range.

Embodied technical change

NERA has conceded that TFP data understates frontier shift due to embodied technological change. In particular, it states:[103]

> … we agree this factor may cause the EU KLEMS TFP series to understate true productivity growth

[101] See Southern Water's Technical Annex 14.6 entitled "Oxera Report: Estimate of RPE and Frontier Shift", September 2018

[102] Ofgem, "RIIO-T1/GD1: Initial Proposals – Real price effects and ongoing efficiency assumptions", July 2012. https://www.ofgem.gov.uk/ofgem-publications/48211/riiot1andgd1initialproposalsrealeffectspdf

[103] NERA, "Review of Ofwat's Proposed Approach to Frontier Shift, Real Price Effects and Output Growth at PR19; Prepared for Bristol Water", 30 March 2019

However, NERA criticises the illustrative calculations we undertake in our report using academic papers as not being reliable, and appears to imply that because there are caveats around the calculation, the effect of embodied technological change should be ignored altogether.

In contrast to NERA, we consider that in selecting a frontier shift figure Ofwat needs to take account of the further efficiency gains that NERA acknowledges companies can realise from embodied technological change. While we acknowledge in our report that the evidence base is limited, the academic evidence that we were able to find suggests that that embodied technical change not captured by TFP growth may amount to a further 60 per cent efficiency gain on top of TFP growth estimates (see section 3.6.2). Applied to our TFP range of 0.6 to 1.2 per cent, an uplift of 60 per cent would give a range of 1.0 to 1.9. Due to the caveats surrounding the quantification of this effect, we do not present this uplifted range as our recommended range. Nonetheless, we consider that embodied technical shift provides an important rationale (alongside consideration of GVA-based TFP data) for why Ofwat should select a point estimate from the upper end of the range derived from TFP growth data.

We disagree with NERA's claim that we have ignored other offsetting biases. In support of this claim, NERA refers to the fact that TFP growth rates may include catch-up efficiency, economies of scale, variations in capacity utilisation and measurement errors. However, to the extent possible, these issues have already been considered in our analysis. In particular:

- We discuss catch-up efficiency in Section 3.4 of our report, and take it into account by looking at TFP growth in comparator sectors which are competitive. As we explain in Section 3.4, in a reasonably competitive industry, we might expect limited variation in efficiency between firms, and to the extent that there is some dispersion in efficiency levels there would be no reason for expecting the degree of dispersion to change over time. Hence, we would not expect TFP growth rates in competitive sectors to incorporate catch-up efficiency to any significant degree.
- We also discuss economies of scale in Section 3.4 of our report, and quantify the effect of scale economies for our comparator sectors in Appendix 2. We find that on average there is no scale effect in our chosen comparator sectors.
- Variations in capacity utilisation represent one reason by TFP growth rates may be pro-cyclical, since capacity utilisation may be lower in economic downturns and higher during economic booms. We discuss the pro-cyclicality of TFP growth in Section 3.8.3 of our report, and take it into account by looking at TFP growth rates over complete economic cycles when analysing the NACE-1 dataset (see earlier discussion).
- NERA does not specify what other "measurement errors" it is referring to and hence has no basis for saying what direction of effect such errors may have on TFP estimates. Consequently, NERA has no basis for claiming that such measurement errors offset the effect of embodied technical shift.

In summary, qualitative considerations suggest that Ofwat needs to take account of embodied technological change, and the quantitative evidence available, while limited, suggests that this factor supports a point estimate for frontier shift that comes from the upper end of the range derived from data on TFP growth rates.

Academic literature

The criticisms of the academic literature that we use that are levelled by Dr Karli Glass and Dr Anthony Glass in Annex 1 of Economic Insight's report relate only to two specific areas of our report: our analysis of scale economies and our analysis of embodied technical shift.

We would make the following points about the criticisms levelled by Dr Karli Glass and Dr Anthony Glass:

- It is not always clear what conclusion they are arguing for in their criticism of the literature. For example, they go into detail about alleged shortcomings in the literature that we used to quantify scale effects in comparator sectors. Using parameters drawn from this literature, we found that scale effects

were, on average, zero in our comparator sectors. While critiquing the literature that we used, Economic Insight nowhere argue that scale economies included in TFP data for our comparator sectors are different from zero. Hence, it is unclear what their point is in critiquing the literature that we used.

- In a number of places, Dr Karli Glass and Dr Anthony Glass appear to misunderstand how we use the literature. For example, they state that it is not appropriate for us to use elasticities from Hsieh (1995) and Dobbelaere et al (2015) in analysing scale effects in Appendix 2 of our report because these elasticities are from empirical analyses of industries that not comparable to the water sector in terms of size and scale. However, this misunderstands the purpose of our analysis at this point: we are seeking to quantify scale effects in our comparator sectors (not in the water sector) in order to work out whether TFP data in other sectors needs to be adjusted to remove scale effects in order to isolate the frontier shift component of TFP growth in those sectors. Likewise, they have not understood that in the final row of Table 3.7 we are saying that our calculation is consistent with Uri (1983) solely because it gives a figure for embodied technical change that is of the same magnitude as disembodied technical change, in line with Uri's findings.
- We consider that the findings of the literature that we quote are more transferable across time periods and sectors than suggested by Dr Karli Glass and Dr Anthony Glass. For example, they criticise us for quoting Hsieh (1995) as evidence that some manufacturing industries exhibit approximately constant returns to scale, on the grounds that the study is "outdated" because it used data for the period 1987-91. However, if some manufacturing industries exhibited approximately constant returns to scale over period 1987-91, then it seems likely that some manufacturing industries today may also exhibit approximately constant returns to scale.
- They fail to recognise the status of some of the academic evidence that we quote. For example, the paper by Hulten (1992) that we quote in our analysis of embodied technical shift is a seminal contribution. It was published by the American Economic Review, a highly credible and well-respected journal, and has been cited almost 500 times since its publication.
- They fail to acknowledge that in our discussion of embodied technical shift we mentioned the caveats around the academic evidence that we used in our illustrative calculations. We take these caveats into account by not uplifting our TFP range for embodied technical shift, but instead treating embodied technical shift as a qualitative factor which justifies aiming up within the range for frontier shift that we have derived from EU KLEMS data.
- Finally, while Dr Karli Glass and Dr Anthony Glass level criticisms at the academic evidence that we use, they do not provide any more relevant or up-to-date academic evidence themselves.

Addition for impact of totex and outcomes framework

In this section we discuss issues relating to the validity of adding a further addition to the frontier shift number to account for the impact of the totex and outcomes framework. Points relating to the size of that additional impact are outside the scope of our work.[104]

Companies and their consultants made the following points:

- Economic Insight on behalf of Wessex Water and Yorkshire Water stated that adding an increment to TFP figures would result in double counting of the impact of totex and outcomes framework on efficiency. It argued that while the totex and outcomes framework gives regulated companies flexibility, it does not give them greater flexibility than comparator companies have. In the light of this, Economic Insight argued that if the comparators can achieve 1 per cent productivity gains, then it would not be feasible for regulated water companies to achieve 1.5 per cent productivity gains from having the same flexibility.

[104] KPMG advised Ofwat on the size of the additional impact.

- NERA on behalf of Bristol Water claimed that Ofwat included a capital substitution effect alongside the impact of the totex and outcomes framework, which Europe Economics advised against doing in its report.

Alleged double counting

We disagree with Economic Insight's claim that it is double-counting to add an increment to frontier shift to account for the impact of the totex and outcomes framework.

In our view, there are reasons for believing that the totex and outcomes framework introduced by Ofwat at PR14 will allow water companies to achieve additional efficiency gains. Ofwat had concerns that the previous regulatory framework gave water companies a biased incentive to adopt solutions involving capital expenditure (capex) rather than operating expenditure (opex). The totex framework aims to remove any bias towards capex and will therefore give water companies an incentive to re-optimise between opex and capex in order to reduce overall costs. Similarly, the outcomes framework gives water companies greater freedom in how they achieve outcomes than the previous approach which specified the specific outputs that water companies had to put in place in order to deliver outcomes. This greater flexibility allows water companies to innovate and to adopt lower cost solutions.

The greater efficiency benefits that water companies can achieve as a result of the totex and outcomes framework will take two forms:

- First, ongoing frontier shift could be higher, as firms now have greater flexibility on an ongoing basis to innovate and employ more cost-effective solutions. This is captured in our analysis by the fact that our range for frontier shift is based on the trend productivity gains achieved in competitive sectors where firms have always had flexibility to choose an efficient mix of inputs and to deliver outcomes in the most efficient way.
- Second, however, there should also be a period of time in which the water sector makes additional "industry catch-up" efficiency gains as its input mix and approach to delivering outcomes are re-optimised, thus moving the sector closer to the productivity levels that comparator sectors have already been able to achieve.[105] This scope for a temporary period of faster productivity gains from re-optimisation is not open to the comparator sectors because their existing capex-opex balance has not been distorted by a historical capital bias. Since this temporary period of efficiency gains from re-optimisation is additional to ongoing frontier shift, we consider that Ofwat is justified in adding an increment to the frontier shift numbers that we have estimated in our report to take account of these additional efficiency gains.

Capital substitution effect

We do not agree with NERA's assumption that Ofwat included a capital substitution effect in its frontier shift figure against our advice. While the capital substitution effect is included in the Europe Economics range that Ofwat showed in Table 11 of its Technical Appendix 2 to its Initial Assessment of Plans,[106] Ofwat's text shows that it was aware that the capital substitution effect should be excluded if the impact of the totex/outcomes framework is added on. In particular, on page 40 of its Technical Appendix 2, Ofwat states:

[105] The effect we have labelled as "industry catch-up" is referring to the industry as a whole catching up with the level of productivity that can be achieved through an optimal balance of opex and capex and an optimal approach to delivering outcomes. It should not be confused with the company-specific catch-up estimates which come out of Ofwat's totex benchmarking, which relate to individual companies catching up with the level of efficiency already being achieved by the most efficient firms in the industry.

[106] Ofwat, Initial Assessment of Plans, "Technical appendix 2: Securing cost efficiency", January 2019

Both KPMG and Europe Economics indicate that the impact of the totex and outcomes framework would be additional to frontier shift efficiency, although Europe Economics suggest an adjustment is made to on-going frontier shift efficiency to account for capital intensity.

We would understand this to mean that Ofwat did in fact take into account our advice on excluding the capital substitution effect when it decided what figure to use for frontier shift.