Europe Economics

Real Price Effects and Frontier Shift

2 January 2018

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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 in turn, for both wholesale and retail controls.

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 (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 material RPEs outside management control that are not captured by CPIH indexation. The following criteria are used to assess this, with each criterion needing to be passed[1] for a given cost item for there to be a material RPE:

1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?
3. 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?
4. 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:

- In the case of wholesale – labour, energy, chemicals, and materials, plant and equipment.
- In the case of retail – labour, bad debt and meter reading.

As shown in Table 1 and 2 below, only one of the cost items passed all of the criteria in Stage 1A of the framework – this is bad debt costs in the retail control, for which we recommend a negative RPE allowance. For all other cost items, both wholesale and retail, we do not recommend any RPEs. By definition, if there is no RPE it means that the allowed input price does not increase either faster or slower than CPIH, meaning that the cost allowance has to be linked in some way to CPIH. For wholesale controls, this link to CPIH is provided through CPIH indexation of price controls, whereas for retail controls (which are not indexed to CPIH) it is provided through an *ex ante* Input Price Inflation (IPI) allowance based on projected CPIH. In the case of bad debt, a negative RPE allowance implies and IPI of less than projected CPIH.

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

(For those cost areas that passed Stage 1A of the assessment (i.e. just bad debt), then under our assessment framework those cost areas are advanced to Stage 1B which considers what, if anything, should be done about the RPE. Therefore, even if a cost item passes Stage 1A of the framework, an RPE may still not be deemed appropriate.)

Table 0.1: Summary of RPEs assessment for wholesale

Cost Item	Labour	Energy	Chemicals	Materials, plant and equipment
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass	Fail	Fail	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail	Fail	Fail	Fail
3. 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	Fail	Fail	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Fail	Fail	Fail
4. 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	Fail
Overall	**Fail**	**Fail**	**Fail**	**Fail**

Source: Europe Economics' analysis.

Table 0.2: Summary of RPEs assessment for retail

Cost Item	Labour	Bad Debt	Meter reading
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass	Pass	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail	Pass	Fail
3. 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	Pass	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Fail	Fail
4. Is the input price and exposure to that input price outside management control during the duration of the price control?	Partial Pass	Partial Pass	Partial Pass
Overall	**Fail**	**Partial Pass**	**Fail**

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 PPI for the water sector as a whole ('GSI groups input PPI for water collection, treatment and supply'), but again we did not find sufficiently strong evidence for an RPE. No comparable assessment was possible to assess the case an RPE for retail totex in aggregate, due to the lack of a suitable input price index for retail water.

Overall, both Stages 1 and 2 of our framework identified no robust case for the inclusion of RPE allowances for either wholesale or retail, with the exception of bad debt costs in retail for which we find evidence for a negative RPE.

For wholesale controls, the implication of this analysis is that CPIH indexation is sufficient to capture changes in the input costs over the next price control.

For retail controls (where there is no indexation to CPIH), the finding of no RPEs for labour and meter reading is on the basis that an input price inflation (IPI) allowance, based on projected CPIH, is sufficient to capture expected changes in input costs. For bad debt, given a negative RPE, we recommend an IPI allowance of less than projected CPIH.

Final recommendations:

- For wholesale controls, we recommend that CPIH indexation is sufficient to capture changes in the input costs over the next price control.
- For labour and meter reading in retail controls, we recommend *ex ante* IPI allowances based on projected CPIH.
- For bad debt in retail controls, we recommend an *ex ante* IPI allowance less than projected CPIH.

Frontier shift

Our assessment of frontier shift used an approach based on TFP analysis in comparator sectors using EU KLEMS 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 and retail (and for 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 3 and 4 below.

Table 3: 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

Table 4: Comparator sectors for retail

Comparator sectors in NACE 2	NACE 1 closest equivalent
Professional, scientific, technical, administrative and support service activities	*(No NACE 1 equivalent)*
Retail trade, except of motor vehicles and motorcycles	Retail trade, except of motor vehicles and motorcycles; repair of household goods
IT and other information services	*(No NACE 1 equivalent)*

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 5 below, and use the data in the round to derive our recommended ranges for wholesale and retail 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.

Table 5: 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 for both wholesale and retail parts of the water industry, as shown in Table 6 below.

Table 6: 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%**
Retail totex	**0.4% - 1.2%**

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 apprpriate if a frontier shift estimate is applied to botex, as frontier shift estimates using TFP growth are more directly applicable to totex. To convert to a frontier shift estimate for botex, an adjustment can be made to capture the additional efficiency gains in botex due to substitution towards capital over time. 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 substation 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 each of the ranges set out above. The reasons for selecting a number towards the upper end of the ranges 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.

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 both wholesale and residential retail.

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.[2]

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. This report reflects 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 recommended if there is a clear and robust case for including such an allowance. The case must be seen as

[2] See the slides from the Ofwat workshop held on 15 March 2018 on "PR19 – Innovation and Efficiency Gains from the Totex Framework". These slides can be found at: https://www.ofwat.gov.uk/wp-content/uploads/2018/03/Ofwat-totex-efficiency_workshop-pack_FINAL.pdf

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 relied on in the assessment of RPEs are various published input price indices, as well as data on 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 total factor productivity (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 retail totex, and 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.

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 two appendices: the first sets out further details of our RPEs assessment framework; and the second describes in more detail our estimation of scale effect adjustments for TFP.

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 separately for the wholesale and retail segments 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 can 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. As such, 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.[3]
- 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 set out our own framework for assessing RPEs.
- In Sections 2.3 and 2.4, we implement that framework.

[3] 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 2.5, 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:

- In the case of both wholesale and retail segments: labour.
- In the case of wholesale only: energy; chemicals; and materials, plant and equipment.
- In the case of retail only: bad debt; and meter reading costs.

We consider the evidence submitted by companies, and assess the robustness of that evidence, at appropriate points in Sections 2.3 and 2.4 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[4] 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 company business plans.

For the retail segment, companies reported an average IPI of 2.6 per cent, with a lower bound varying between 1.9 and 2.2 per cent and an upper bound between 3.0 and 3.1 per cent depending on the year.

Table 2.2: Analysis of retail IPI for labour costs proposed by companies

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	1.9%	2.1%	2.2%	2.2%	2.2%
Max	3.0%	3.1%	3.0%	3.0%	3.0%
Average	2.4%	2.6%	2.6%	2.6%	2.6%

Source: Europe Economics' analysis of company business plans.

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

Below, we discuss the analysis put forward by companies to support their projections (which we evaluate later in Section 2.3.1 in assessing whether there is a material wedge in expectation between the price of labour 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, which it did by mapping company specific employee data to ONS wage data[5] 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,[6] 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' PAFI index published by the Building Cost Information Service (BCIS) and the Construction 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 claims 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

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

[6] Specifically, Economic Insight states that it prefers using the wedge between the company specific labour cost index and the average UK wage inflation index, rather than the wedge with CPI inflation.

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 Office for Budget Responsibility (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 available for the full period, Economic Insight assume that they persist at the same rate as in the last available year of 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.

In estimating labour costs in residential retail, Oxera (on behalf of Portsmouth Water, South East Water and Southern Water) made use of forecasts published by the ONS from monthly updates on the UK labour market. For later years in which forecasts are not available, Oxera uses the average of annual changes in earlier years to forecast ahead. In some cases, to forecast input price inflation for specialist labour costs, Oxera makes use of the BCIS 90/1 civil engineering labour price index.

2.1.2 Energy

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

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

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	0.0%	-0.5%	-2.0%	-3.5%	0.0%
Max	12.6%	9.0%	2.0%	3.0%	3.9%
Average	4.6%	1.8%	0.3%	0.6%	1.7%

Source: Europe Economics' analysis of company business plans.

We summarise below the analysis put forward by companies to support these projections. (This analysis is evaluated later in Section 2.3.2 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 of -1.2 per cent and an upper bound of 3.0 per cent.

Table 2.4: Analysis of wholesale RPE for chemicals costs proposed by companies

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	-1.2%	-1.2%	-1.2%	-1.2%	-1.2%
Max	2.8%	3.0%	2.7%	2.9%	2.9%
Average	0.7%	0.6%	0.6%	0.6%	0.6%

Source: Europe Economics' analysis of company business plans.

We describe below the analysis put forward by companies to support these projections. (This analysis is evaluated later in Section 2.3.3 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 2.5: 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 company business plans.

We describe below the analysis put forward by companies to support the above projections. (This analysis is evaluated later in Section 2.1.4 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.

2.1.5 Bad debt

The average IPI for bad debt proposed across companies is 1.5 per cent, with a lower bound of 1.0 per cent and an upper bound varying between 1.9 and 2.0 per cent depending on the year.

Table 2.6: Analysis of retail IPP for bad debt proposed by companies

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	1.0%	1.0%	1.0%	1.0%	1.0%
Max	1.9%	2.0%	2.0%	2.0%	2.0%
Average	1.4%	1.7%	1.5%	1.5%	1.6%

Source: Europe Economics' analysis of company business plans.

We describe below the analysis put forward by companies to support the above projections.

Analysis of relationship with economic fundamentals

Economic Insight (on behalf of Affinity Water, Bristol Water, Northumbrian Water, South West Water, Wessex Water and Yorkshire Water) notes that the two key drivers of bad (or doubtful) debt are bill size and socioeconomic factors, and points out that bill size is highly influenced by the regulated prices that are set at the wholesale level. Consequently, the input price pressure relating to bad debt will primarily be determined by the 'K factors'[7] set by Ofwat.

As these factors cannot be determined beforehand, Economic Insight considers using CPIH as a basis for projecting bad debt IPI. However, Economic Insight states that an important caveat to this approach is that it does not take into account changes in the UK macroeconomic environment (such as Brexit). Therefore, Economic Insight proposes an econometric modelling approach consisting of three steps to forecast future bad debt costs for the water companies.

First, Economic Insight estimates the relationship between bad debt per unique customer, average wholesale bill size and benefits expenditure (used as a proxy for the health of regional economies) using historical data from 2010-11 to 2016-17.[8] Economic Insight uses a random effects model instead of OLS arguing that this helps to avoid bias arising from unobserved differences between water companies. The second step entails

[7] These are the wholesale price limits.

[8] Data on bad debt per unique customer and bill size come from each water company's regulatory accounts, while benefit data is obtained from the Department for Work and Pensions (DWP).

forecasting the average wholesale bill size and benefits expenditure. Using the assumption that the wholesale water bill will increase in line with CPIH (and hence assuming the K factor set by Ofwat to be zero for wholesale water), Economic Insight projects CPIH growth by applying the average wedge between CPI and CPIH to the CPI forecasts published by the OBR. To forecast benefits expenditure, Economic Insight considers two approaches: one assumes that benefits expenditure rises in line with DWP forecasts at the national level, while the other regional approach takes the average gap between the national level of benefits and a weighted average of the level of benefits in those regions that fall within each company's respective supply area (for example East of England, London, North East and South East for the case of Affinity Water). The final step combines the results from the previous two steps: first, the projected average bill size and national/regional benefits figures are multiplied by the corresponding coefficients of the econometric model above, and then these are added to give the final estimates.

The estimates based on the regional benefits expenditure give Economic Insight's central case estimates, the figures based on the national level give its low case estimates, and CPIH forecasts are used as the high case estimates.

Using independent forecasts

Oxera (on behalf of Portsmouth Water, South East Water and Southern Water) notes that the key determinants of doubtful debt are bill size and economic deprivation. However, in contrast to Economic Insight, Oxera considers the use of CPI inflation forecasts[9] published by the OBR to project bad debt input price inflation, noting that this already accounts for changes in the UK's macroeconomic environment.

2.1.6 Meter reading

Metering costs in retail refer specifically to the costs of meter reading and do not encompass the costs of the metering equipment itself.[10]

Two companies (Affinity Water and Yorkshire Water) provided figures on projected IPIs for meter reading costs. The average IPI for meter reading proposed across these companies is 2.0 per cent, with a lower bound varying between 1.6 and 1.9 per cent and an upper bound varying between 2.0 and 2.4 per cent depending on the year.

Table 2.7: Analysis of retail IPP for meter reading proposed by companies

	2020-21	2021-22	2022-23	2023-24	2024-25
Min	1.6%	1.8%	1.9%	1.9%	1.9%
Max	2.0%	2.2%	2.4%	2.4%	2.4%
Average	1.8%	2.0%	2.1%	2.1%	2.2%

Source: Europe Economics' analysis of company business plans.

We describe below the analysis put forward by companies to support the above projections.

Economic Insight (on behalf of both Affinity Water and Yorkshire Water) notes that while meter reading would include various inputs such as labour, transportation and fuel, it assumes it to be a labour-intensive process. Therefore, it focuses on the labour cost component, applying an approach very similar to the approach discussed above for forecasting general labour cost inflation. However, in the case of meter reading costs, Economic Insight creates a historical wage inflation index using the 'Sales Occupations' series from the

[9] Oxera also mentions the absence of reliable forecasts for CPIH and concludes that CPI forecasts are sufficient for the purpose of its analysis.

[10] Meter reading is specifically defined as including the costs of *ad hoc* read requests, cyclical reading, scheduling, transport, physical reading, reading queries and read processing costs, managing meter data plus supervision and management of meter readers. See: Ofwat (2017), "RAG 4.07 – Guideline for the table definitions in the annual performance report".

ONS Annual Survey of Hours and Earnings dataset, arguing that this category gives the closest match to meter reading activities.

2.2 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.

2.2.1 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 and retail cost items, i.e.:

- labour costs for both wholesale and retail;
- energy, chemicals, and materials, plant and equipment costs for wholesale; and
- bad debt and meter reading costs for retail.

These are the major wholesale and retail 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. Details of the criteria that would be applied at Stage 1B are provided in Appendix 1.

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 the input cost item to which the RPE would be applied a material proportion of total company costs? This criterion is assessed by considering the share in totex of different company cost items, separately for the wholesale and retail segments (e.g. energy costs as a percentage share of wholesale totex, or bad debt costs as a percentage share of retail totex). In order to consider RPEs only for those costs which represent a material proportion of totex, we apply a threshold above which cost items are considered material. We use a threshold of 10 per cent for this purpose. Therefore, those cost items which represent more than 10 per cent of wholesale or retail totex pass this criterion.
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 two things:
    - The share of a cost item in (wholesale or retail) 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.

- The indirect influence of the cost item on CPIH, compared with its influence on water company costs. For example, while labour costs will not directly be captured in CPIH, they will indirectly affect many prices that are captured by CPIH.

A cost item fails against this criterion if there is no conclusive evidence that CPIH fails to adequately capture the input price.

3. 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 and/or forecast data where available).[11] If this criterion holds true then there may be a case for an ex ante RPE allowance 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 (wholesale or retail) totex, and consider that a wedge exhibits high volatility if the five-year rolling average wedge frequently exceeds 2 per cent of totex.[12] If this criterion holds true then there may be a case for an ex post mechanism if other necessary criteria are also met.[13]

   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.

4. 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. This could include strategies such as substituting to alternative inputs, investing in new technologies and/or signing long-term contracts to reduce exposure to future price movements. This criterion is passed if there are significant limitations to what management can do to reduce exposure to the input price. If management have somewhat more scope to reduce exposure then we consider this a 'partial pass', while if there is material scope to reduce exposure the criterion is failed.

Each criterion is scored as a pass or fail (or a partial pass in some cases for the fourth criterion). If criteria 1, 2 and 4 are all passed and at least one of sub-criteria 3A or 3B is passed, then the cost item in question advances to Stage 1B of the RPEs assessment framework. If, however, any of the above criteria (1, 2, 3A and 3B, or 4) are failed, then the cost item is not advanced to Stage 1B, and no RPE allowance is recommended for that cost item. If criterion 4 receives a 'partial pass' and all other criteria are passed, then Ofwat would need to investigate the cost item in question in more detail to reach a more informed judgement as to the scope for management control (and ultimately the case for an RPE allowance).

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

[12] We also evaluate the volatility on the basis of how frequently the five-year rolling average wedge exceeds 1 per cent of (wholesale or retail) totex.

[13] 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.

Details of Stage 1B of the assessment framework can be found in Appendix 1. (We have not described Stage 1B of the framework here, because in practice we find that only one cost item passes all of the criteria in Stage 1A.)

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. Retail controls, on the other hand, are not indexed to out-turn inflation, any hence any allowance for inflation has to be built into retail cost allowances ex ante. Hence, an IPI allowance based on projected CPIH should be applied in cases where we recommend no RPE for a retail cost item.

2.2.2 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.

In practice, because no cost item pass Stage 1A of the framework, the full Stage 2 framework is not applied. Nevertheless, full details of this framework can be found in the Appendix 1.

The part of the Stage 2 that is still relevant involves 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.

2.3 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 against the criterion, and conclude by stating whether the criterion is passed or failed.

2.3.1 Labour

We analyse this cost item against each criterion for both the wholesale and retail segments.

Is the input cost item to which the RPE would be applied a material proportion of total company costs?

Company business plan submissions[14] provide figures on the forecast share of different cost items in totex over the next price control period. Based on these data, the average share for labour costs in totex is 35 per cent in the case of wholesale activities,[15] and 36 per cent in the case of residential retail activities.

These forecasts of labour cost shares are higher than the shares implied by historical June Returns data which runs from 2002/3 to 2010/11. Taking labour costs as the sum of reported 'employment costs', 'hired and contracted services' and 'customer services', this represents on average just over one fifth (20.7 per cent) of totex. This may be a lower bound for the share of labour costs in totex, as labour costs will have fed into

[14] Table App24.

[15] The labour cost shares for the different wholesale activities are: 24 per cent for wholesale water resources; 34 per cent for wholesale water network plus; 33 per cent for wholesale wastewater network plus; and 46 per cent for wholesale wastewater bioresources.

other reported cost items in the June Returns data indirectly. A similar exercise with more recent Regulatory Accounts data is not possible, as employment costs are not reported separately.

Overall, the evidence clearly shows that labour costs are in excess of 10 per cent of both wholesale and retail totex and therefore constitute a material proportion of costs for both wholesale and retail activities.

Criterion passed for both wholesale and retail.

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. Nevertheless, labour costs feed into the various items in the CPIH basket indirectly, to the extent that labour contributes to the production of goods and services which are in the CPIH basket. We acknowledge that imports make up a significant proportion of CPIH, but these imports will themselves be affected by labour costs in other countries.

To understand the potential materiality of labour costs in the CPIH basket, we have looked at the share of labour in total output for all industries across the economy (the goods and services of which are feeding into the CPIH basket).[16] Across all sectors we find the average labour share to be 29 per cent. Focusing specifically on the service industries, which now comprise almost half (48.1 per cent) of the CPIH basket, we find the average share of labour in output to be 36 per cent. For manufacturing industries the share of labour is lower at 22 per cent.

These economy-wide figures are broadly consistent with the figures for the share of labour in the wholesale and retail segments of the water sector. The implication is that changes in labour costs are feeding into CPIH in a similar way to how they feed into water company totex. As such, we have no strong basis on which to conclude that changes in labour costs are not already well captured by changes in CPIH.

Criterion failed for both wholesale and retail.[17]

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; there are no wage indices solely focused on the water sector. 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 correlations 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

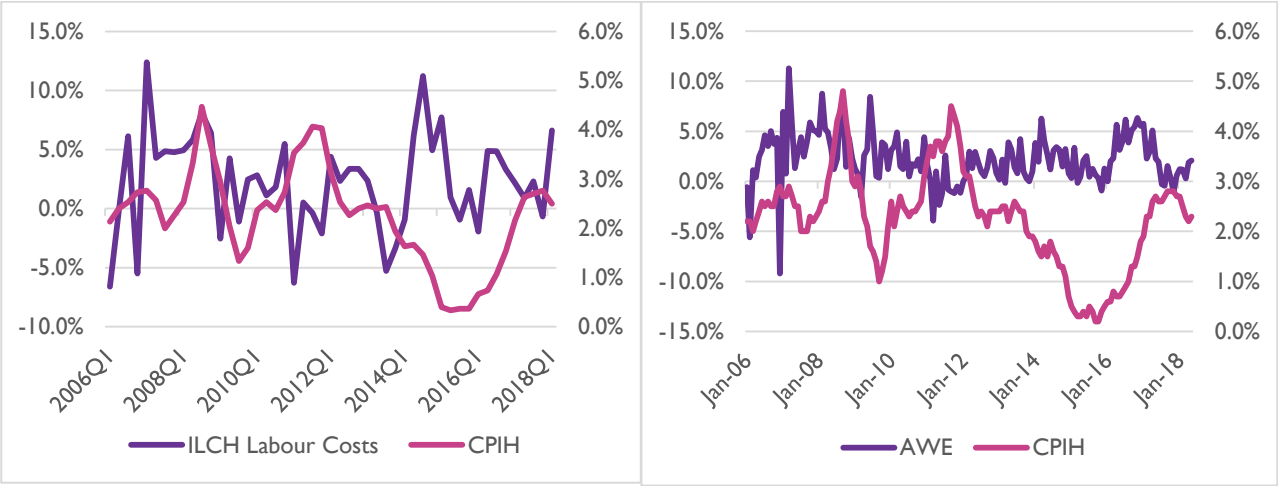
[16] Industrial sector data on labour shares in total output have been computed based on the ONS "Input-output supply and use tables" dataset. Available at: https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables

[17] The differing implications of this for wholesale and retail controls are discussed in Section 2.2.1.

growth rates in Figure 2.1. Moreover, with no lag, we estimate the correlation coefficient for the ILCH labour costs measure and CPIH to be -0.05, and the equivalent figure for the AWE measure to be -0.09 (based on data from 2006 to 2018). 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 either of the subsequent two years, or vice versa.

Figure 2.1: Growth rates of wages indices and CPIH (2006 to 2018)

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



NB. 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 that the average 'wedge' between changes in CPIH and changes in the electricity, gas and water supply sector wage index from 2006[18] to 2018 is zero (both for ILCH and AWE indices). 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.

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.[19] This has then be mapped to ONS wage indices[20] 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 wage index 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, including forecasts from Oxford Economics analysed by Economic Insight, but these data are not in the public domain.

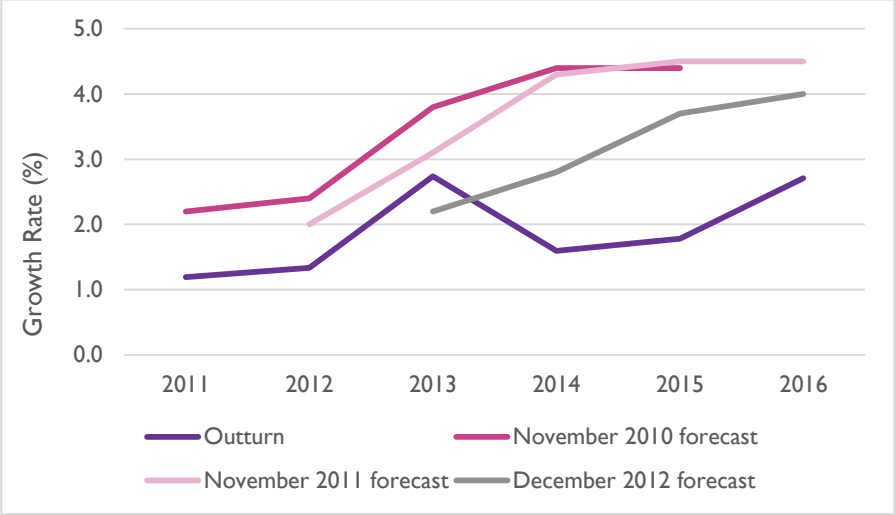
The OBR currently forecasts nominal average earnings growth and CPI growth out to 2022. As OBR do not forecast CPIH directly, we have adjusted the OBR's CPI forecasts into CPIH terms using the observed historical wedge between CPIH and CPI of +0.1 per cent (i.e. the CPIH has exceeded the CPI on average by 0.1 per cent based on monthly data from 2006 to 2018). The OBR forecast that average nominal earnings will grow by 2.5 per cent in 2020, 2.8 per cent in 2021 and 3.0 per cent in 2022. This implies an average wedge over CPIH of 0.7 per cent. 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 CPIH is also 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 2.2 below compares actual outturn growth rates (the dark purple line), 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.

[19] 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.

[20] 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.

Figure 2.2: Comparison of outturn growth rates for average earnings with OBR forecasts



Given the lack of reliability of previous OBR forecasts of average earnings growth, in our assessment against this sub-criterion we rely on historical wedge analysis and do not place weight on these OBR forecasts. Based on this historical wedge analysis, we find that there is no strong basis on which to conclude that there is a material real price effect in expectation.

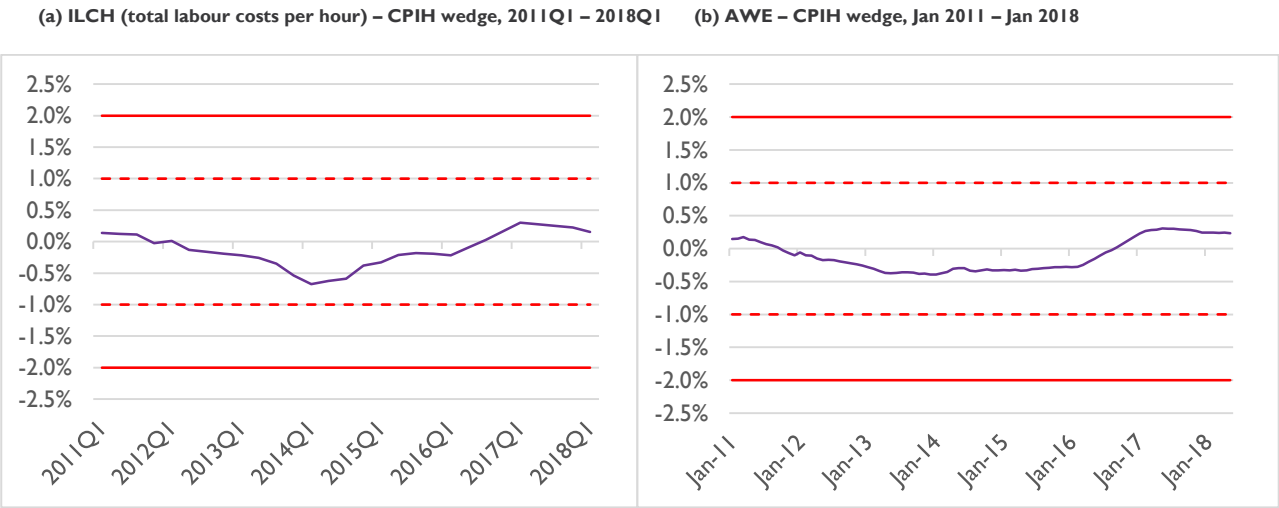
Sub-criterion failed for both wholesale and retail.

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. As such, we investigate the volatility of the five-year rolling average wedge between the wage indices and CPIH. We then consider this in terms of the volatility on overall totex, by adjusting for the share of the cost item in question (in this case labour). The results of this exercise are shown in Figure 2.3 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 +0.3 per cent; and in the case of the AWE index the variation is between approximately -0.4 and +0.3 per cent. Therefore, over the course of time period analysed, at no point does the magnitude of the five-year rolling average wedge exceed either 1 or 2 per cent of totex (as denoted by the dotted red and solid red lines respectively in Figure 2.3. Moreover, accounting for the fact that wages are already likely to be well captured by CPIH (as explained under the second criterion), the residual or net volatility on totex is negligible.

Figure 2.3: Five-year rolling average of wage index – CPIH wedges as a share of totex, 2011 – 2018



Source: ONS.

Sub-criterion failed for both wholesale and retail.

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

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 wage increases 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. That said, some labour skills are more sector specific and, therefore, not as susceptible to these economy-wide pressures.

In Europe Economics 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).

However, there are some mechanisms by which companies can reduce their exposure to changes in labour prices (both in the wholesale and retail segments):

- Use of external staff under long-term contracts – water companies 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 labour costs, although contractors would be expected to build expected increases in labour costs into their bid prices.
- Reprofiling work – water companies can bring forward or delay work as necessary to reduce their exposure to expected price changes.
- 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, including:
  - 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.
  - Reduce retail staff requirements – new communication tools supported by artificial intelligence (AI), such as AI chatbots have the potential to reduce the number of staff required in responding to customers.

- Internal training – companies can 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. (That said, once they have been trained staff may leave for higher paying jobs elsewhere if the company does not remunerate them for their new level of skill.)

Overall, though 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 above) to reduce their exposure to changes in the price of labour.

Criterion partially passed for both wholesale and retail.

Summary of assessment

Table 2.8 below summarises our assessment of labour for both wholesale and retail controls. Overall, since labour costs fail the second criterion (as CPIH does capture well changes in the input price) and the third criterion (as it does not seem likely that the RPE will differ substantially from zero over the period of the price control), we do not advance labour to Stage 1B of the RPE assessment. As such, we do not recommend an RPE allowance for labour.

Table 2.8: Summary of assessment of RPE allowance for labour

Assessment criteria	Decision	
	Wholesale	Retail
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail	Fail
3. 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	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Fail
4. Is the input price and exposure to that input price outside management control during the duration of the price control?	Partial Pass	Partial Pass
Overall	**Fail**	**Fail**

Source: Europe Economics' analysis.

Our recommendation of no RPE for labour by definition means that the allowed input price for labour should change neither faster nor slower than CPIH. This means that the allowance for labour costs needs to be linked in some way to CPIH. For wholesale controls, costs are indexed to CPIH and so this is sufficient to reflect changes in labour costs. Retail costs, however, are not indexed to CPIH, and so the finding of no RPE implies setting an input price inflation allowance for retail labour costs equal to projected CPIH.

2.3.2 Energy

Is the input cost item to which the RPE would be applied a material proportion of total company costs?

Based on company business plan submissions,[21] we find the average projected share of energy costs in wholesale totex to be 8 per cent. This comprises: 9 per cent in the case of wholesale water – network plus; 11 per cent in the case of wholesale wastewater – network plus; 13 per cent in the case of wholesale water – water resources; and -20 per cent in the case of wholesale wastewater – bioresources (due to cost savings from energy generation).

The wholesale figures are broadly consistent with historical data reported in Regulatory Accounts and June Returns data. The average share of power costs in totex based on June Returns data (2002/3 to 2010/11) is 6.7 per cent, and for the Regulatory Accounts data (2011/12 to 2016/17) is 7.9 per cent. It should be noted, however, that these data only cover power costs and so exclude other types of energy cost.

Applying our materiality threshold of 10 per cent of wholesale totex, energy costs of around 8 per cent of wholesale totex fail this criterion.

Criterion failed.

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

In the CPIH basket, energy (including fuel for transport) has a share of 5.2 per cent based on the latest 2018 weights.[22] This is less than the estimated share of energy costs in water company totex of 8 per cent in wholesale activities. However, we also need to take into account energy costs that feed into the CPIH basket 'indirectly' through the use of energy in other industries, which produce goods and services that are part of the CPIH basket.

Analysing ONS input-output data, we estimate the average share of energy costs across industries to be 2.0 per cent.[23] For the manufacturing industries the average is 3.1 per cent and for the services industries 0.6 per cent. Moreover, we find that 70 per cent of industries have energy costs as a share of output of less than 2 per cent; and 85 per cent of industries with energy costs less than 4 per cent of output. This evidence would suggest some second order effects of energy costs on the CPIH basket in the order of a couple of percentage points.

We must however also recognise that other components of water industry costs will be underpinned by energy costs (e.g. the energy costs that go into producing materials and chemicals used in the water sector). As such, the 'true' share of energy costs in water company wholesale costs – taking into account second order effects in the supply chain – is likely to be slightly higher than the 8 per cent estimated above.

On balance, while it is difficult to compare the materiality of second order effects of energy costs on CPIH and water company costs, there is not sufficient compelling evidence to conclude that CPIH fails to adequately capture the impact of energy costs on wholesale totex.

Criterion failed.

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?

[21] Table App24.

[22] In undertaking such analysis, we acknowledge that imports make up a significant proportion of CPIH. However, these imports will themselves be affected by energy costs in other countries.

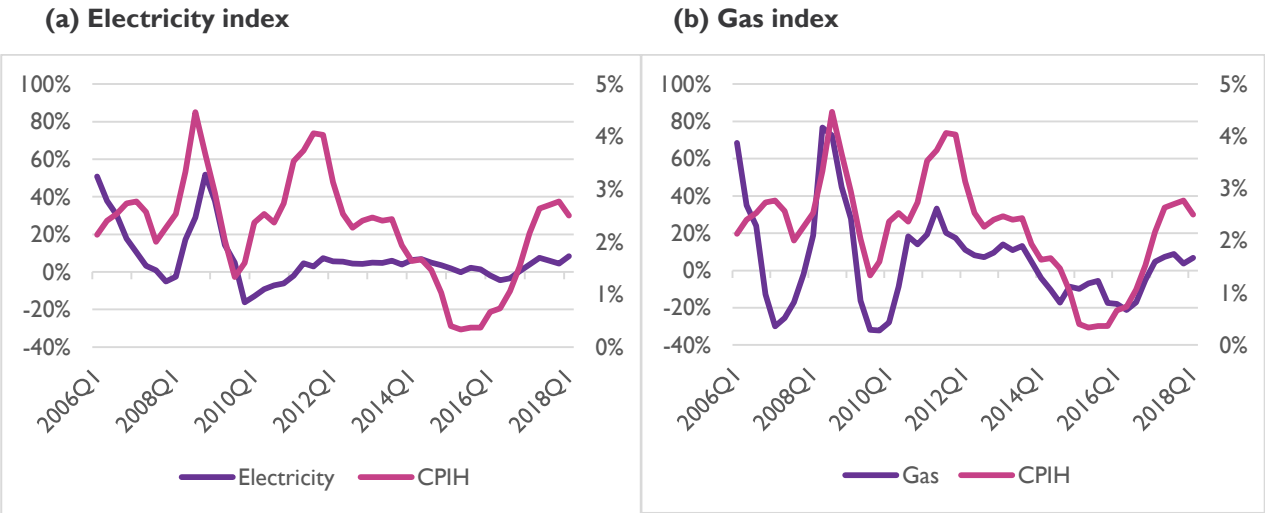
[23] This figure excludes the electricity and gas industries themselves (specifically, "Electric power generation, transmission and distribution", and "Manufacture of gas; distribution of gaseous fuels through mains; steam and aircon supply"). If these industries were included the average rises to 2.5 per cent.

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 no statistically significant correlation between the two series (a correlation coefficient of +0.03 for 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 relevant price indices for energy relative to the evolution of the CPIH. In particular we examine two measures – the electricity and gas price indices for industrial/ small-medium non-residential customers published by the Department for Business, Energy & Industrial Strategy (BEIS).[24] We recognise that the most relevant index is that for electricity prices and hence more weight is placed on this evidence in assessing against this criterion, but we also consider the evidence on the gas price index.

Figure 2.4 below shows the evolution of growth rates for the gas and electricity price indices as compared to CPIH. It can be seen that the gas price index has exhibited similar movements to the CPIH index over the full period. The electricity price index, on the other hand, appears to show similar movements to CPIH prior to 2010 but this relationship has broken down since then. We find the correlations between changes in these energy price indices and changes in CPIH (assuming no lag) to be moderately positive, and higher in the case of the gas price index (+0.61) than the electricity price index (+0.34).[25]

Figure 2.4: Growth rates of wages indices and CPIH (2006 to 2018)



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 their 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 preclude the construction of a composite energy price index here, but we nevertheless investigate the historical wedge

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

[25] 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 2.4 above.

between the price indices of the two key energy components for water companies (electricity and gas) and general price inflation.

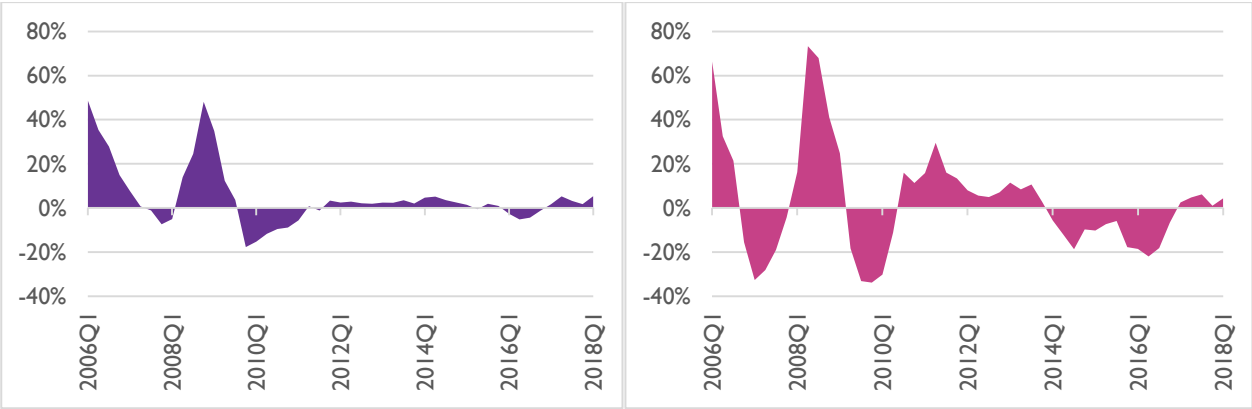
We find evidence of a significant positive wedge relative to changes in CPIH for both energy price indices. Since CPIH was introduced in 2006, we find an average wedge of +3.0 per cent for the BEIS gas price index and +4.8 per cent for the BEIS electricity price index. However, these significant wedges are largely driven by very high positive wedges prior to 2010 (as shown in Figure 2.5).[26]

Focusing on data from 2010 onwards (i.e. excluding the period Energy of high volatility prior to 2010), we find that neither wedge (for electricity or gas) is significantly different from zero in statistical terms. This continues to be the case for the gas price index looking at data from 2011 or 2012 onwards. However, in the case of the electricity price index, we do find evidence of a statistically significant positive wedge since 2011 or 2012 of 1.4 and 1.7 per cent respectively. As such, evidence of a material real price effect based on historical wedge analysis is inconclusive.

The inconclusive nature of the analysis 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 2.5: Wedge between annual change in fuel price indices and CPIH, 2006Q1 - 2018Q1

(a) Electricity index – CPIH wedge, 2006Q1-2018Q1 **(b) Gas index – CPIH wedge, 2006Q1-2018Q1**



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.[27] This includes forecasts of wholesale energy prices (including electricity and gas) out to 2035 for a reference scenario, as well as for high and low price and growth scenarios.

Based on the latest BEIS forecasts (the 2017 edition), electricity prices are expected to rise by on average 2.5 per cent per year in nominal terms between 2020 and 2025. This compares with average CPIH growth over the period of 2.1 per cent,[28] thus implying a 0.4 per cent positive wedge over the price control period. The gas price forecasts show an expected increase of 4.2 per cent per year in nominal terms from 2020 to 2025, implying a 2.1 per cent positive wedge. However, analysis of past BEIS electricity and gas price forecasts against outturns shows significant differences and thus raises serious questions about the reliability of such forecasts:

[26] In the case of the 'electricity' wedge, we find peak wedges of +48.6 per cent in 2006 Q1 and +48.1 per cent in 2008 Q4. In the case of the 'gas' wedge, we find peak wedges of +66.3 per cent in 2006 Q1 and +73.3 per cent in 2008 Q2.

[27] 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

[28] Based on OBR forecasts for CPI, plus 0.1 per cent historical wedge between CPIH and CPI.

- In the case of electricity prices, the BEIS 2014 edition forecasted a rise of 17 per cent over the next year, while in practice prices fell by 6 per cent. In the 2015 edition, electricity prices were forecast to rise by 10 per cent the next year, but actually fell by almost 2 per cent.
- In the case of gas prices, the BEIS 2014 edition forecasted an 11 per cent rise in 2015, but actual data showed an almost 15 per cent fall. In the 2015 edition, gas prices were forecast to rise by 3 per cent the next year, but actually fell by 20 per cent.

Given the significance of the discrepancies between forecast and outturn data, we believe the forecasts lack reliability and that it would be inappropriate to place weight on these forecasts in judging whether there is a material real price effect.

Oxera investigates a different index published by National Grid on Future Energy Price Scenarios.[29] 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 1.9 per cent positive wedge over the period, similar to that implied by the BEIS energy price forecasts. We do not have earlier forecast data against which to assess the reliability of past forecast against actual outturns. However, given the significant discrepancies between previous BEIS energy price forecasts and actual outturns, we are reluctant to place any significant weight on forecast data.

We do not believe there is a conclusive case for saying that there is a material real price effect in expectation. The different sources of evidence present a mixed picture, with the historical wedge analysis showing either a non-statistically significant wedge or a slight positive wedge depending on the precise time period chosen. Although the forecast data typically suggests a positive wedge, comparisons of past forecasts with actual outturns calls into question the reliability of these forecasts. Overall, therefore, we do not believe that there is sufficiently strong evidence of a material real price effect.

Sub-criterion failed.

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

The wedge between the electricity price index and CPIH varies between -2 and 10 per cent, although it appears to have been more stable in recent years. The wedge between the gas price index and CPIH has varied between approximately -5 and 11 per cent. 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 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 assess volatility by looking at the five-year rolling average wedge as a share of totex. The results are shown in Figure 2.6 below. In the case of the electricity index, the wedge (as a proportion of totex)[30] varies between approximately -0.1 and +0.8 per cent. For the gas index, the equivalent figures are -0.4 and +0.9 per cent. Therefore, in neither case does the five-year rolling average wedge exceed either 1 or 2 per cent of totex. Moreover, if (as for labour) we account for the fact that energy costs are already likely to be well captured by CPIH, then the residual or net volatility on totex becomes negligible. Hence, overall, we are of the view that there is not sufficient compelling evidence to pass this criterion.

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

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

Figure 2.6: Five-year rolling average of fuel price index – CPIH wedges as a share of totex

(a) Electricity index **(b) Gas index**

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

Sub-criterion failed.

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

There are a number of actions management can take to reduce exposure to changes in energy prices:

- Payment arrangements – 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.
- 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.[31]
- 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,[32] as well as renewable

[31] 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 the 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.

[32] 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

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.[33] Evidence from company business plan submissions shows that the value of energy generation is forecast to constitute on average 20 per cent of wholesale wastewater bioresources totex. This represents 1.3 per cent of total wholesale totex (reducing energy costs as a proportion of wholesale totex from 9.7 to 8.4 per cent).

The key question is whether these mechanisms are sufficient to dispute the contention that the input price is largely outside management control during the duration of the price control. In the case of payment arrangements, while this can reduce exposure to short-term (e.g. within year) fluctuations, it cannot reduce exposure over the whole price control, since contracts are typically agreed on an annual or biennial basis. 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 only some of the above mechanisms are well suited to reducing energy price exposure over the period of a price control. 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.

Summary of assessment

Table 2.9 below summarises our assessment of energy. Since energy costs fail all of the first three criterion, we do not advance energy costs to Stage 1B of the assessment criteria.

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.

[33] 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 the input cost item to which the RPE would be applied a material proportion of total company costs?	Fail
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail
3. 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
4. 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.

2.3.3 Chemicals

Is the input cost item to which the RPE would be applied a material proportion of total company costs?

Based on data in company business plan submissions,[34] we find the average share for chemicals costs in totex to be 2 per cent for wholesale activities. This comprises: 0.2 per cent in the case of wholesale water – water resources; 2 per cent for wholesale water – network plus; 1 per cent for wholesale wastewater – network plus; and 6 per cent in the case of wholesale water – bioresources.

Chemicals are not a distinct cost item reported by companies in either Regulatory Accounts or June Returns data. June Returns data report the cost of 'materials and consumables' of which chemicals would be a subset. On average, 'materials and consumables' are found to constitute 2.8 per cent of totex, implying that chemicals are likely to account for less than 2.8 per cent of totex on average. This finding is therefore consistent with the average figure of 2 per cent based on company business plan submissions.

Overall, chemicals costs fall significantly below our materiality threshold of 10 per cent of wholesale totex.

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 most relevant categories 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.[35]

Again, however, we need to take into account the indirect influence of chemicals costs on CPIH. Based on analysis of ONS input-output data, we estimate the average share of chemical costs in an industry to be 1.4 per cent. These are the chemical costs we can expect to feed into the basket indirectly through other goods

[34] Table App24.

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

and services which require chemicals in their manufacture/provision. When comparing the weight of chemicals in CPIH with that in wholesale totex, we must also again acknowledge that chemicals costs will indirectly feed into other water industry input costs, such that the true share of chemicals costs in wholesale totex is higher than the direct measure of the share of chemicals costs.

Overall, while it is difficult to calculate the combined direct and indirect effects of chemicals prices on CPIH, it seems unlikely to be materially below the share of 2 per cent in wholesale totex. As such, we have no strong basis to conclude that changes in chemicals costs are not already well captured by changes in CPIH.

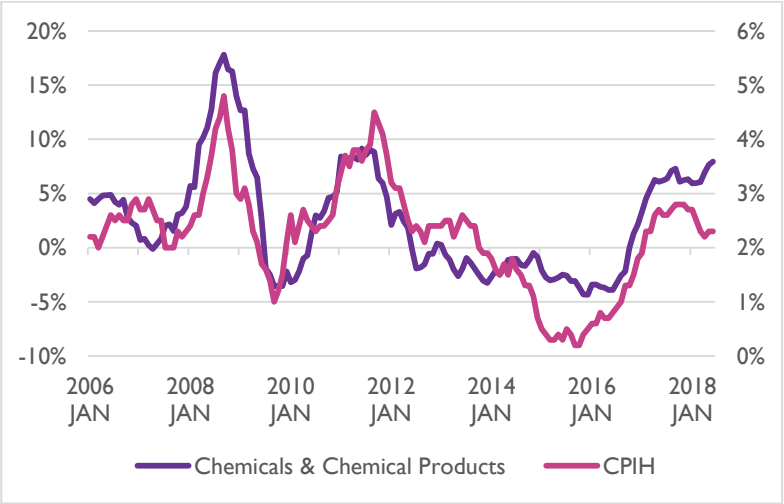
Criterion failed.

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 again here 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 volume changes.

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 +0.78 (based on monthly data from January 2006 to June 2018, and with no lag).[36] This strong correlation is evident from below which plots growth rates in the chemicals and chemical products PPI alongside growth rates in CPIH.

Figure 2.7: Growth rates of 'Chemicals & Chemical Products' PPI and CPIH (2006 to 2018)



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 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

[36] 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).

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 not been statistically different from zero. Historical wedge analysis does therefore 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.[37] These data show average nominal price increases for different chemicals over the period 2020 to 2025 ranging from -0.5 to 1.6 per cent.[38] Given the forecasted CPIH of 2.1 per cent per year over this period, this implies negative wedges ranging from 0.5 to 2.6 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 of 0.1 per cent, with estimates of the wedge ranging between -1.2 and +1.2 per cent.

Sub-criterion failed.

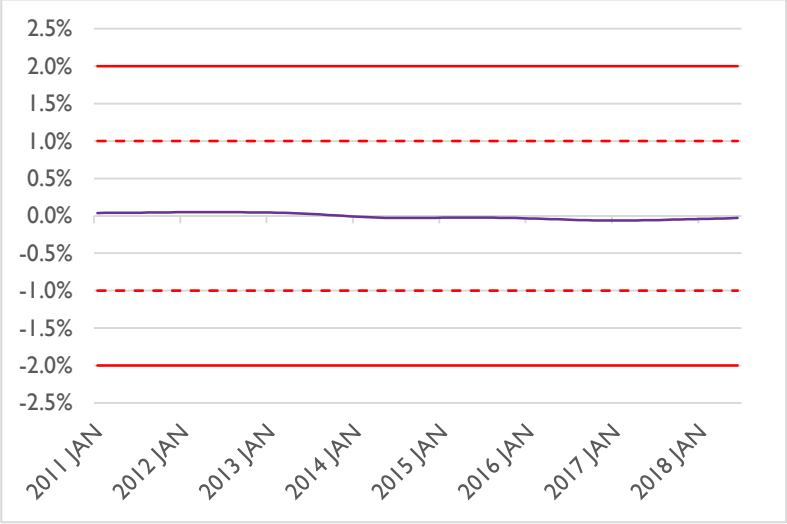
Does the wedge between the input price and CPIH exhibit high volatility over time?

Figure 2.8 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 -0.07 per cent to +0.05 per cent). Therefore, for the period for which data are available, at no point (when evaluating over a five-year horizon) does the wedge exceed either 1 or 2 per cent of wholesale totex.

[37] World Bank Commodities Price Forecast (nominal US dollars), April 24, 2018. Available at: http://pubdocs.worldbank.org/en/458391524495555669/CMO-April-2018-Forecasts.pdf

[38] Average nominal growth rates from 2020 to 2025 inclusive: DP at -0.5 per cent; TSP at -0.2 per cent; phosphate rock at 0.5 per cent; urea at 0.9 per cent; and potassium chloride at 1.6 per cent.

Figure 2.8: Five-year rolling average of Chemicals PPI – CPIH wedge as a share of totex



Source: ONS data.

Sub-criterion failed.

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

Companies 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.

When chemical prices increase significantly, e.g. due to availability, it may become cost efficient to switch to an alternative chemical or process. 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 is 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 would be more difficult for water companies to limit their exposure to these 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 (materiality of cost item), second criterion (failure of CPIH to adequately capture the input price) and both sub-criteria for the third 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 the input cost item to which the RPE would be applied a material proportion of total company costs?	Fail
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail
3. 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
4. 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.

2.3.4 Materials, plant and equipment

Is the input cost item to which the RPE would be applied a material proportion of total company costs?

Based on data in company business plan submissions,[39] we find the average share for materials, plant and equipment costs in wholesale totex to be 20 per cent. This comprises: 14 per cent in the case of wholesale water – water resources; 20 per cent in the case of wholesale water – network plus; 20 per cent in the case of wholesale wastewater – network plus; and 21 per cent in the case of wholesale water – bioresources.

There are no corresponding cost items in historical Regulatory Accounts and June Returns data that allow us to estimate a share for materials, plant and equipment.

Therefore, based on data in company business plan submissions, it is clear that 'materials, plant and equipment' constitute a material proportion of wholesale totex.

Criterion passed.

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. Nevertheless, a parallel can be drawn 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.[40,41]

[39] Table App24.

[40] 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).

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

We also need to take into account 'materials, plant and equipment' costs that feed into the CPIH basket indirectly, insofar as consumers spend their money on goods and services that rely on materials, plant and equipment in their manufacture/provision.

Using ONS input-output data we have looked at how 'construction' and 'machinery and equipment' inputs feed into other sectors in the economy.[42] We find that they contribute on average 2.1 per cent to each sector. We also find that over 90 per cent of industries have a total 'construction' and 'machinery and equipment' share of less than 5 per cent. Though some of this may be in the form of imports (as imports constitute a significant proportion of CPIH), these imports will nevertheless themselves be affected by materials, plant and equipment costs in other countries.

This analysis suggests that the share of expenditure on 'materials, plant and equipment' in the water sector is materially higher than that in other sectors. This finding is strengthened by the fact that 'materials, plant and equipment' costs will also be feeding into wholesale totex indirectly, through their impact on other water industry input costs.

Overall, given the above evidence, we believe there are no compelling grounds for thinking that the impact of 'materials, plant and equipment' costs on total water company costs would not be adequately captured by changes in CPIH. An important caveat to this analysis is that 'materials, plant and equipment' costs include the purchase or lease of buildings, but these are excluded from the estimates using input-output data.

Criterion failed.

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; electricity and gas price indices for energy costs; and a chemicals and chemical products index for chemical costs. However, there is no one single index that captures well changes in prices of 'materials, plant and equipment'. Instead, what can be done is to look at indices which should capture well movements in the price of individual components and thus 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 ONS the 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,

[42] In doing so, it should be noted that construction cost itself includes various different cost components, including labour as well as materials, plant and equipment.

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 2.4 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:

- For the NOCOS index, we find a statistically significant positive wedge of 1.4 per cent between 2006Q1 and 2012Q1.[43]
- 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 June 2018.
- For the 'Machinery and equipment n.e.c.'[44] output PPI, we do not find a statistically significant wedge for the period January 2006 to June 2018.
- For the 'Other pumps and compressors' output PPI, we do not find a statistically significant wedge for the period January 2006 to June 2018.
- For the 'Construction Material Price Index', we find a statistically significant positive wedge of 0.7 per cent for the period January 2007 to June 2018.[45]

The evidence presents a mixed picture. For some indices, we find evidence of a positive RPE (in the order of 0.7 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. 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 2.9 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.[46] 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, neither of these five-year rolling average wedges exceed the 2 per cent threshold (on any occasion) that is required to pass this criterion. These series therefore do not exhibit sufficient volatility to conclude that the water companies should not be expected to bear the risk of movements in the price of such inputs.

[43] 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.

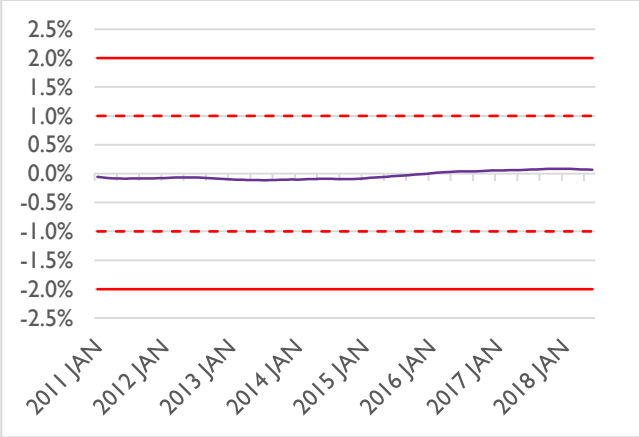
[44] The acronym n.e.c. stands for 'not elsewhere classified'.

[45] Data before January 2007 are not available.

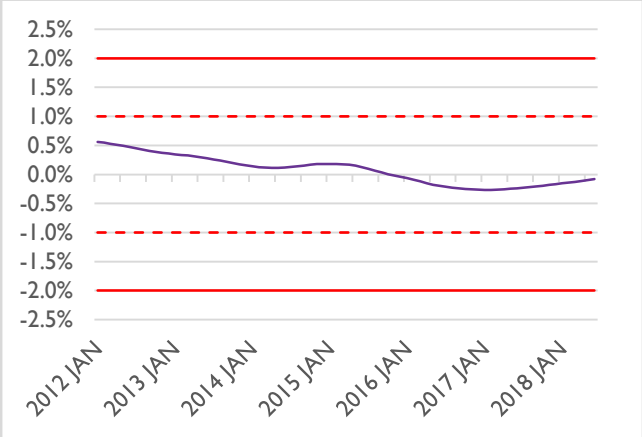
[46] Based on the finding from company business plan submissions that materials, plant and equipment costs represent on average 21 per cent of wholesale totex.

Figure 2.9: Five-year rolling average of annual changes in price index – CPIH wedge as a share of totex

(a) 'Machinery and equipment n.e.c.' PPI – CPIH wedge



(b) 'Construction Material Price Index' – CPIH wedge



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

Sub-criterion failed.

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

For capital maintenance activities, companies typically enter long term frameworks with suppliers, covering the duration of the regulatory control period, and in some cases, multiple AMP periods. These frameworks can include price agreements for delivering certain asset types, and therefore control prices for materials, labour and plant hire.

Overall, we believe that given the typical practice of signing long-term contracts that can cover multiple AMP periods, water companies can largely insulate themselves from short-term materials, plant and equipment price movements within a given price control period.

Criterion failed.

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 second, third criterion and fourth criterion.

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

Assessment criteria	Decision
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail
3. 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
4. Is the input price and exposure to that input price outside management control during the duration of the price control?	Fail
Overall	**Fail**

Source: Europe Economics' analysis.

2.3.5 Bad debt

Is the input cost item to which the RPE would be applied a material proportion of total company costs?

Based on data in company business plan submissions,[47] the average share of bad debt costs in retail totex is 34 per cent. There are no comparative historical data from Regulatory Accounts or June Returns.

Criterion passed.

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

Bad debt is a function of the bill size, which is primarily driven by wholesale costs (as the wholesale segment represents the significant majority of the overall value chain). The evolution of wholesale costs in turn depends on the outcome of PR19, as this determines how much wholesale costs will increase or decrease in real terms (i.e. relative to CPIH).

Since bad debt costs driven by wholesale water prices represent 34 per cent of retail totex, it does not seem plausible to suggest that CPIH adequately captures the relevant input price. Water costs represent just 0.9 per cent of CPIH, and therefore, even after taking into account second round effects of water costs in other industries, the impact of changes in wholesale water prices on CPIH will fall significantly below the likely impact on water retail businesses through changes in their bad debt costs.

Criterion passed.

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?

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

The majority of business plan submissions propose that real water bills will fall over the forthcoming price control.[48] Of the 17 submitted business plans, 11 propose a fall in bills over this period (with two proposing

[47] Table App24.

[48] https://www.ofwat.gov.uk/regulated-companies/price-review/2019-price-review-final-methodology/business-plans/ Though not explicitly stated, we take the proposed bill figures for 'Change in bills' to be reported in real terms.

no change, and the remaining four proposing an increase). Among those who project a fall in bills, estimates range from 3 per cent to 14 per cent across the whole period. We assume that Ofwat's final decision is likely to propose an even greater fall in bills, given that regulators typically reduce the cost allowances that companies have proposed. Altogether this suggests a significant negative wedge over the period of the price control.

Criterion passed.

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

The purpose of this criterion is to assess whether the input price is subject to substantial uncertainty within the five years of a price control. The relevant input price in the case of bad debt is the wholesale price. This is fixed in real terms at the start of the price control period by the wholesale price control and is therefore not subject to uncertainty within the period (except for any limited uncertainty caused by incentive and uncertainty mechanisms that involve within-period adjustments).

Criterion failed.

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

The primary input price in the context of bad debt costs for the retail control is the wholesale water cost. This is determined by the outcome of the wholesale price control, and hence outside the control of management of retail water businesses.

That said, water companies can reduce their exposure to bad debt costs through better debt management and debt collection practices. Ofwat has set out a number of steps that can be taken by water companies in this regard:[49]

- Increasing availability and take-up of affordability schemes.
- Moving towards smaller, more frequent billing.
- Improving communication with customers, and customer awareness of help available.
- Utilising customer data to predict where bad debt issues are likely to occur so they can be tackled early.
- Ensuring customers are on the most appropriate tariff and payment method.

Criterion partially passed.

Summary of assessment

Overall, on the basis that Criterion 1, 2 and 3A are passed, and Criterion 4 is partially passed, we find that bad debt costs receive a partial pass of Stage 1A of the RPEs assessment framework.

Table 2.12: Summary of assessment of RPE allowance for bad debt

Assessment criteria	Decision
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Pass
3. 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?	Pass

[49] Ofwat website: https://www.ofwat.gov.uk/pn-1317-water-companies-must-address-customer-bad-debt/

B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail
4. Is the input price and exposure to that input price outside management control during the duration of the price control?	Partial pass
Overall	**Partial Pass**

Source: Europe Economics' analysis.

As bad debt achieves a 'partial pass' in Stage 1A of the RPE assessment framework, we advance it for consideration in Stage 1B of the framework. As mentioned earlier, Stage 1B of the assessment framework is set out fully in Appendix 1.

Working through the assessment map presented in Figure A1 (Appendix 1), we conclude the following with respect to bad debt costs:

1. Is there a robust basis for forecasting the input price? Yes – the input price is known over the forthcoming price control period as it is determined by the price review.
2. Would ex ante RPE allowances create significant perverse incentives? No – to get a more favourable RPE allowance for bad debt water companies would need to persuade Ofwat to give them a higher wholesale price at price reviews. However, since they have a strong incentive to try to achieve this outcome anyway, the marginal effect on incentives of basing the retail bad debt RPE allowance on the wholesale price is likely to be limited.

Given the above assessment, our framework leads to a recommendation that there should be an ex ante RPE allowance for bad debt. Moreover, based on our finding of a significant negative wedge under Criterion 3A, this implies a negative RPE allowance. Given that bad debt is a retail cost and hence there is no CPIH indexation, in practice this means an IPI allowance for bad debt of less than CPIH.

2.3.6 Meter reading

As explained in Section 2.1.6, metering costs in retail refer specifically to the costs of meter reading and thus do not include the costs of the metering equipment itself.[50] Metering in retail is therefore predominantly a labour-based activity.

Is the input cost item to which the RPE would be applied a material proportion of total company costs?

Based on data in company business plan submissions,[51] the average share of meter reading costs in retail totex is 19 per cent. This is above our materiality threshold of 10 per cent. There are no comparative historical data from Regulatory Accounts of June Returns.

Criterion passed.

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

Given that meter reading is primarily a labour-based activity, the relevant input price is the input price of labour. This has already been analysed in Section 2.3.1, where we found that changes in labour costs are feeding into CPIH in a similar way to how they feed into water company totex. Therefore, we reached the

[50] Meter reading is specifically defined as including the costs of ad hoc read requests, cyclical reading, scheduling, transport, physical reading, reading queries and read processing costs, managing meter data plus supervision and management of meter readers. See: Ofwat (2017), "RAG 4.07 – Guideline for the table definitions in the annual performance report".

[51] Table App24.

conclusion that there is no strong basis on which to conclude that changes in labour costs are not already well captured by changes in CPIH.

Criterion failed.

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?

Since meter reading costs are primarily driven by labour costs, the analysis here is consistent with that presented in Section 2.3.1, where we investigated a variety of wage indices to assess whether there is a significant likelihood that the wedge differs substantially from zero over the period of the price control.

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

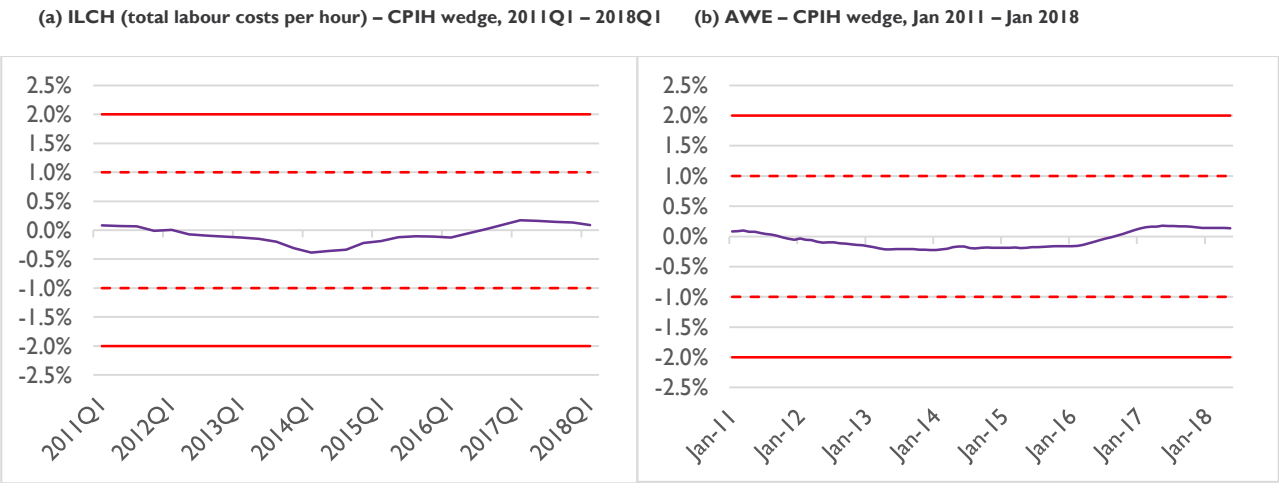
As set out in Section 2.3.1, given a lack of reliable forecasts for wages, we rely primarily on analysis of the historical wedge between wage indices and CPIH. This wedge analysis finds that there is no strong basis on which to conclude that there is a material real price effect in expectation.

Sub-criterion failed.

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

To assess this criterion, we analysed the five-year rolling average volatility of the labour price – CPIH wedges, scaled by the share of meter reading costs in retail totex (19 per cent). We find that for neither wage index (ILCH or AWE) does the five-year rolling average wedge exhibit high volatility over time (at no point exceeding our totex threshold of 2 per cent in order to pass this criterion). Moreover, given that wages are already likely to be well captured by CPIH, the residual volatility on totex can be considered negligible.

Figure 2.10: Five-year rolling average of wage index – CPIH wedges, scaled by share of meter reading costs in retail totex, 2011 – 2018



Source: ONS.

Sub-criterion failed.

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

We set out in Section 2.3.1, some mechanisms that management can use to reduce their exposure to labour prices. One such pathway is through the substitution of labour with capital. In the context of meter reading, this can include the use of technology such as AMR which allows meters to be read electronically outside a property, and smart meters which allow meter readings to be collected remotely reduces the number of staff required to take meter readings. (More accurate readings on bills rather than estimates can in turn reduce the number of staff required to handle complaints.) Companies may also be able to make use of external staff

on contracts agreed for the duration of a price control. Therefore, though 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 of labour), there is some scope for companies to reduce their exposure to labour price changes with respect to meter reading activities (as well as more broadly, as described in Section 2.3.1).

Criterion partially passed.

Summary of assessment

Overall, due to the failure of the second and third criterion, we propose no RPE allowance for meter reading costs in the retail segment.

Table 2.13: Summary of assessment of RPE allowance for bad debt

Assessment criteria	Decision
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail
3. 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
4. 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.

2.3.7 Summary of assessment for all cost items

Overall, we do not recommend an RPE for any wholesale cost item, nor for labour or meter reading in retail. In the case of bad debt costs, we recommend an IPI allowance of less than CPIH (i.e. a negative RPE allowance). The scores against the criteria which underpin this decision are summarised in Table 2.14. In the next section we look at how this assessment of RPEs on a cost item by cost item basis compares with an assessment of RPEs which looks at all input costs collectively.

Table 2.14: Summary of RPEs assessment for wholesale

Cost Item	Labour	Energy	Chemicals	Materials, plant and equipment
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass	Fail	Fail	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail	Fail	Fail	Fail
3. 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	Fail	Fail	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Fail	Fail	Fail
4. 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	Fail
Overall	**Fail**	**Fail**	**Fail**	**Fail**

Source: Europe Economics' analysis.

Table 2.15: Summary of RPEs assessment for retail

Cost Item	Labour	Bad Debt	Meter reading
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass	Pass	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail	Pass	Fail
3. 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	Pass	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Fail	Fail
4. Is the input price and exposure to that input price outside management control during the duration of the price control?	Partial Pass	Partial Pass	Partial Pass
Overall	**Fail**	**Partial Pass**	**Fail**

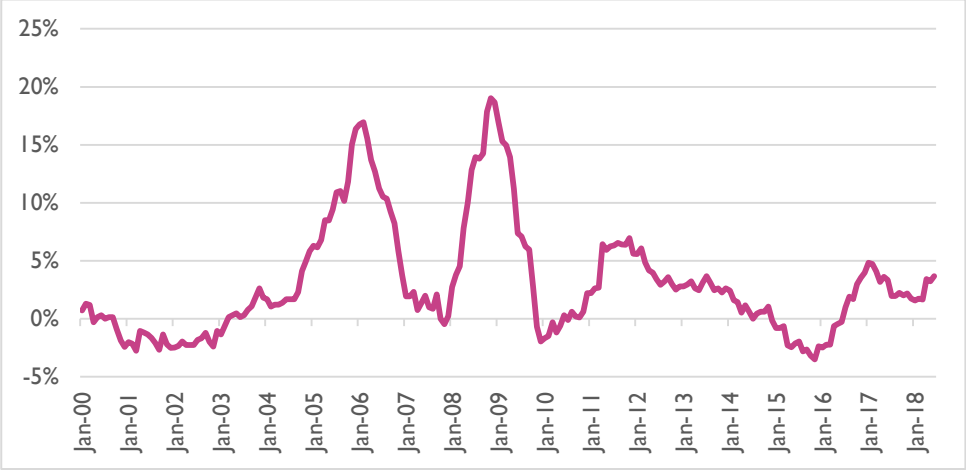
Source: Europe Economics' analysis.

2.4 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 and found no case for RPE allowances, with an assessment which looks at whether there is a case for an RPE allowance when analysing all cost items in aggregate. For wholesale, we investigate this using the "GSI groups input PPI for water collection, treatment and supply" which looks at the changes in the price of all water sector inputs. For retail, there is no equivalent measure that adequately captures all cost items, and so this cannot be explored further in Stage 2.

Figure 2.11 below shows the evolution of the GSI input PPI from January 2000 to June 2018.

Figure 2.11: Change in GSI PPI for water collection, treatment and supply

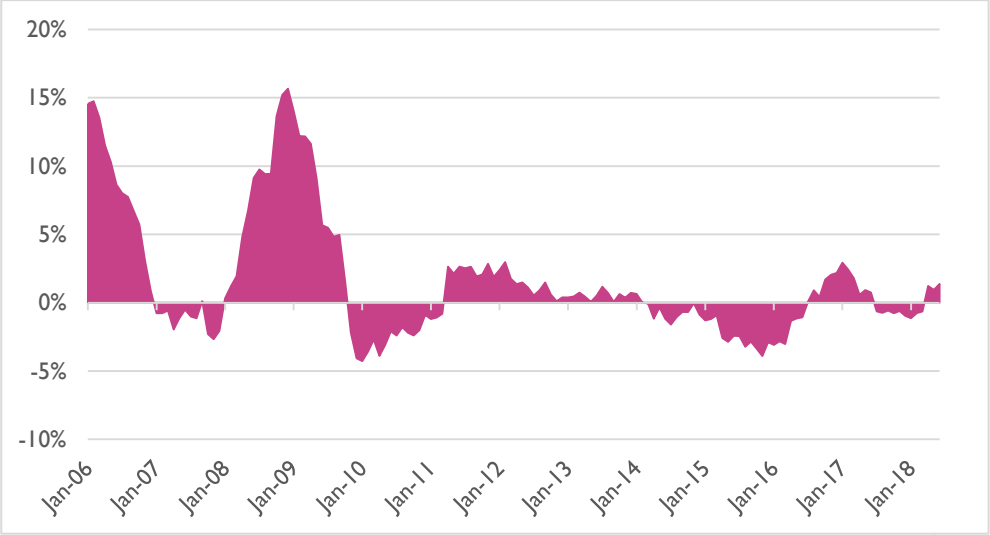


Source: ONS data, Europe Economics' analysis.

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).[52]

Figure 2.12 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 since 2010, the wedge has not been significantly different from zero.

Figure 2.12: 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.

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

2.5 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 RPE allowances for wholesale totex. Stage 1 assessed individual cost items against a consistent set of criteria, and found that for none of the cost items was there a 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, but again did not find sufficiently strong evidence for an RPE.

In the case of retail, we find no case for an RPE allowance for labour or meter reading costs, while for bad debt costs we tentatively recommend a negative RPE (based on the evidence of a majority of companies proposing reduced bills in their business plans).

A recommendation of no RPE allowance by definition means that allowed input prices should change neither faster nor slower than CPIH. Hence, our recommendation implies that cost allowances need to be linked in some way to CPIH (for all wholesale and retail cost items except bad debt). In the case of wholesale controls, this is achieved through indexation of these controls are indexed to CPIH. As retail controls are not indexed to CPIH, the finding of no RPEs for labour and meter reading implies that an IPI allowance based on projected CPIH should be used for these retail costs. In the case of bad debt costs, our recommendation of a negative RPE allowance implies an IPI allowance less than projected CPIH.

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. Productivity growth can be understood as the difference between the rate of growth of output and the rate of growth of a weighted average of inputs.

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. TFP growth 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. We present evidence from company submissions on frontier shift estimates for wholesale and retail separately.

3.1.1 Frontier shift estimates for wholesale

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 for wholesale segment

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 (not specified whether refers to wholesale or retail segment)	Anglian Water	In-house
1% (not specified whether refers to wholesale or retail segment)	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.

Wholesale efficiency estimates

In the wholesale segment, 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 wholesale 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.

3.1.2 Frontier shift estimates for retail

Table 3.3 below presents the frontier shift estimates for the retail segment reported by water companies.

Table 3.3: Summary of company frontier shift proposals for retail segment

Frontier shift estimates (per year)	Water companies	External consultancy or in-house?
Opex: 0.42% as central estimate with -0.42% and 1.10% as lower and upper bounds Capex: 0.28% as central estimate with -0.31% and 0.56% as lower and upper bounds[53]	Affinity Water, Bristol Water, Northumbrian Water, South West Water, Wessex Water and Yorkshire Water	Economic Insight
Opex: 0.9% or between 0.9% and 1.0% Capex: 0.6% or between 0.6% and 0.7%	Portsmouth Water and South East Water	Oxera
-1.5% as central estimate for dynamic efficiency relative to CPIH with -2.2% and -1.2% as lower and upper bounds	United Utilities Water	In-house
1% (not specified whether refers to wholesale or retail segment)	Severn Dee Water	In-house
1% for both opex and capex (not specified whether refers to wholesale or retail segment)	Anglian Water	In-house
No frontier shift estimates reported (see 'Efficiencies' section)	Southern Water, Sutton and East Surrey Water, South Staffordshire Water, Thames Water, Welsh Water and Severn Trent Water	-

Source: Company business plans.

[53] The reports note that while capex estimates are provided for five companies, they may only wish to use the opex numbers due to the asset light nature of the household retail segment.

Retail efficiency estimates

For the retail segment, six companies (South Staffordshire Water, Thames Water, Welsh Water, Severn Trent Water, Sutton and East Surrey Water and Southern Water) have provided efficiency forecasts instead of frontier shift figures. Again these estimates would generally include both frontier shift and catch-up, and therefore are not directly comparable to the frontier shift estimates for the retail segment presented above.

Table 3.4: Summary of company efficiency proposals for retail segment

Efficiency estimates (per year)	Water companies	Basis for efficiency estimates
1.5% in real terms	South Staffordshire Water	Year-on-year changes to cost projections from 2019-2020
9.7% over next price control period	Thames Water	Comparing actual and forecast costs based on property served
3.5% for residential retail and 0.4% for business retail	Welsh Water	Efficiencies mostly driven by automation strategy of company
7.67% in first year of price control period (based on submitted data table)	Severn Trent Water	Efficiencies calculated as a percentage of inflated base costs
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
Overall retail cost would be 34% lower than for previous price control period	Southern Water	Based on gap between actual cost and estimated efficient frontier at next price control period

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 3.5: 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*
Wholesale	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
Retail[54]	Affinity Water, Bristol Water, Northumbrian Water, South West Water, Wessex Water, Yorkshire Water, Portsmouth Water and South East Water	United Utilities Water	Severn Dee Water	Southern Water, Sutton and East Surrey Water, South Staffordshire Water, Severn Trent 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.

54 Anglian Water does not specify a separate adjusted figure for the household retail segment.

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[55] and Oxera[56] 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 (on behalf of Bristol Water for the wholesale segment)[57] 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. Separate comparators are typically chosen for the wholesale and retail parts of the value chain. 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 3.6.

Table 3.6: Comparators for the wholesale and retail segments based on similarities in activities

Wholesale	Retail
Total industries (whole UK)	Total industries (whole UK)
Agriculture, forestry and fishing	Professional scientific, technical, administrative and support service activities
Wholesale trade, except of motor vehicles and motorcycles	Financial and insurance activities
Real estate activities	IT and other information services
Total manufacturing	Transport and storage
Chemicals and chemical products	Retail trade, except of motor vehicles and motorcycles
Other manufacturing; repair and installation of machinery and equipment	Electricity, gas and water supply (as a sensitivity)
Construction	Market economy
Electricity, gas and water supply (as a cross-check)	

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.

[55] Economic Insight on behalf of Northumbrian Water, Wessex Water and Yorkshire Water for the wholesale segment and on behalf of Affinity Water, Bristol Water, Northumbrian Water, South West Water, Wessex Water and Yorkshire Water for the retail segment. Future references to the work done by Economic Insight always refers to the work it did on behalf of these water companies, depending on the segment concerned.

[56] Oxera on behalf of South East Water and Southern Water for the wholesale segment and on behalf of Portsmouth Water and South East Water for the retail segment. Future references to the work done by Oxera always refers to the work it did on behalf of these water companies, depending on the segment concerned.

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

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 3.7.

Table 3.7: Comparators for wholesale based on those used in previous regulatory decisions

Wholesale
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:

- The full time series of 1970 and 2007 for which EUKLEMS NACE 1 data are available. This timeframe was used by NERA for estimating TFP figures for wholesale.
- 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. This approach has been used by Oxera in two cases for estimating TFP for wholesale comparators, and in two further cases for estimating TFP for retail comparators.
- 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). Economic Insight has used this approach in three cases for estimating TFP for wholesale comparators, and in six cases for estimating TFP for retail comparators.

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 also states that it considers the GO measure appropriate as this also captures TFP growth in intermediate inputs, but uses the VA measure

noting that this is the one published in the EU KLEMS dataset. Economic Insight does not explicitly discuss or make a choice between the 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 weights 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 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 3.5.2, 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. As such, 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 in TFP estimates, an established approach is look at TFP growth in comparator sectors which are competitive. There are two key rationales for this approach:

- In a reasonably competitive industry, the survival of firms might imply very small inefficiency differentials, so that the efficiency change component might be small too.
- In a reasonably competitive industry, efficiency levels of individual producers might vary a lot but that, 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, then one might think that TFP growth largely stems 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.[58] 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 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

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

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.[59] 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 3.6). As such, no adjustment to TFP estimates for a scale effect is required in our analysis. Details of the estimates that support this decision can be found in Appendix 2.

3.4 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.[60]

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 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 which 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[61] 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 retail totex, and for both wholesale totex and wholesale botex. For retail, no adjustment for the capital substitution effect is necessary as the frontier shift estimate is applied to retail totex. The same is true of wholesale totex. 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

[59] 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.

[60] 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.

[61] 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

capital expenditure. By doing so, we in effect consider substitution between capital enhancements and botex only (and 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 actually engage in opex-capex substitution 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 out findings on the scale of the partial capital substitution effect in Section 3.9.4.

3.5 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:

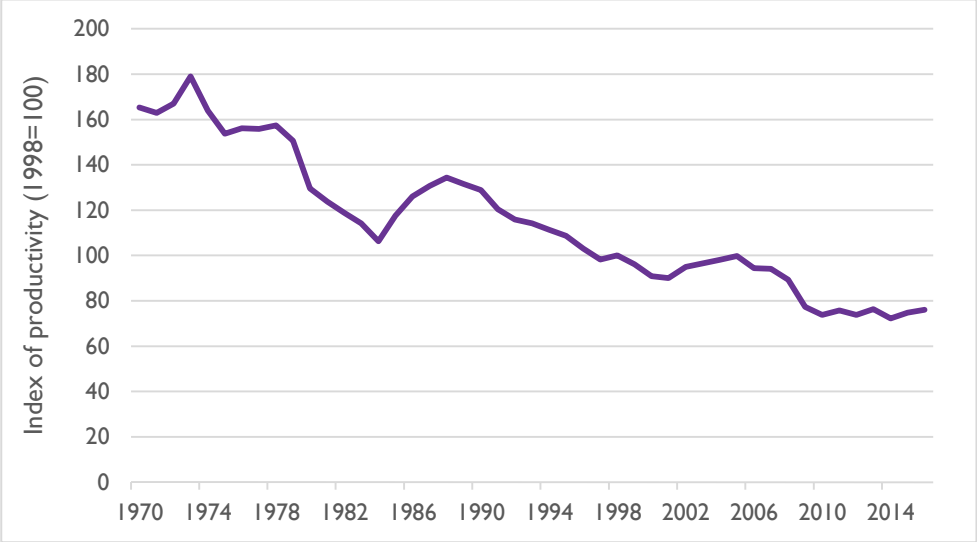
- Changes in the quality of output need to be included in the analysis, as a superior quality of output (not just a greater volume of output) can be a reflection of inputs being used more efficiently.
- Changes in the quality of inputs need to be excluded from measures of input growth, in order to estimate 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.

3.5.1 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 indeed 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 invested in demand management programmes, then 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.[62] 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

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

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.[63] 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 3.8 below is a reproduction from the Water UK report, which 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 3.8: 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 these fundamental concerns over TFP estimates for the water sector, due to the failure to account for improvements in the quality of outputs which have seen significant resources dedicated to them, it is important to consider TFP estimates in other sectors in which this concern is less material.

3.5.2 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 are used to produce the output.

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

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)[64] 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).[65]

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. 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)[66] 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)[67] 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

[64] Jager (2018), "EU KLEMS Growth and Productivity Accounts: 2017 Release, Statistical Module". Available at: http://euklems.net/TCB/2018/Metholology_EUKLEMS_2017_revised.pdf

[65] 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".

[66] 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.

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

(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.[68] 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 3.9 below.

Table 3.9: 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).

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.

3.6 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).

[68] 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.

We therefore look at TFP growth in comparator sectors as a more robust measure of 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.

3.6.1 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 first of all 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 what sectors 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, we have considered the nature of water wholesale and retail activities separately. For wholesale water, 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. In the case of retail water, the focus was on identifying sectors with customer-oriented activities. In both cases, 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.[69]

3.6.2 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 3.10 presents the list of wholesale comparators, and Table 3.11 for the retail comparators. We have

[69] 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 that of "Electricity, gas and water supply" figure in the case of wholesale comparators, and with the "Retail trade, except of motor vehicles and motorcycles" figure in the case of retail comparators. 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 water wholesale or retail industry.

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 3.10: Comparator sectors for wholesale used by other consultancies

Industry	Economic Insight[70]	NERA[71]	Oxera[72]	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				✓
Electricity, gas and water supply[73]			✓	

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

Our chosen comparators (as indicated in the final column of Table 3.10) 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 is a broad category many elements of which will be reflective of activities undertaken in the water sector, e.g. building and maintaining plant, equipment and machinery, processing an end product, and storing and distributing that product.
- "Construction" – this is similar in nature to the building of new infrastructure in the water and wastewater sectors, such as new water and wastewater treatment works, new dams or new pipeline network.

[70] Economic Insight reports prepared for Yorkshire Water, Affinity Water, Bristol Water, Northumbrian Water, South West Water and Wessex Water.
[71] NERA report prepared for Bristol Water.
[72] Oxera reports prepared for South East Water and Southern Water.
[73] Used as a sensitivity check only.

- "Chemicals and chemical products" – the processing of chemicals and chemical products can be seen as having similarities to 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" – as with "total manufacturing", this captures different elements which share similarities with the wholesale water sector, including the repair and installation of machinery and equipment associated with abstraction, treatment and distribution.
- "Transport and storage" – other transport networks can be seen as having similarities to the building and operation of networks for transporting water and wastewater.
- "Machinery and equipment n.e.c" – the same logic applies here as for "total manufacturing" and "other manufacturing; repair and installation of machinery and equipment".

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.
- "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 also includes estate agency and real estate management activities that are not reflective of wholesale water activity.

Table 3.11: Comparator sectors for retail used by other consultancies

Industry	Economic Insight	Oxera[74]	In our list?
Total industries	✓		
Market economy		✓	
Financial and insurance activities	✓	✓	
Retail trade, except of motor vehicles and motorcycles	✓	✓	✓
Professional, scientific, technical, administrative and support service activities		✓	✓
IT and other information services		✓	✓
Transport and storage		✓	
Electricity, gas and water supply[75]		✓	

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

As before, our chosen comparator sectors (as indicated in the final column of Table 3.11Table 3.10) are primarily competitive sectors and similar to the retail water sector in terms of the nature of activity undertaken. More specifically:

- "Retail trade, except of motor vehicles and motorcycles" – this is a general category which captures many different types of retail trade. It has direct relevance as a comparator for water retailing, given that retailing in some other sectors will involve similar processes as for water retailing (e.g. customer account management, billing, customer credit).
- "Professional, scientific, technical, administrative and support service activities" – these activities, particularly the latter two (i.e. administrative and support service activities) are similar to the types of activities undertaken in the retail water sector (e.g. setting up new customer accounts, handling customer issues, processing bills, etc.).
- "IT and other information services" – many of the activities undertaken in the retail water sector are driven by IT and other information services – for example, using retailing software to bill customers, and providing customer information on the internet.

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

- "Total Industries" and "Market Economy" – we exclude these sectors, as they include a significant portion of manufacturing activity which is not representative of water retail.
- "Financial and insurance activities" – as with "financial intermediation", we exclude this sector because of the impacts of the global financial crisis on productivity in the financial sector (which has seen negative post-crisis productivity growth).
- "Transport and storage" – we consider this a better comparator for wholesale water, rather than retail water, because of the operation of logistics networks and storage facilities.

[74] Oxera report prepared for Portsmouth Water.
[75] Used as a sensitivity check only.

3.6.3 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 tables 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 3.12: 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.

Table 3.13: Comparator sectors for retail

Comparator sectors in NACE 2	NACE 1 closest equivalent
Professional, scientific, technical, administrative and support service activities	*(No NACE 1 equivalent)*
Retail trade, except of motor vehicles and motorcycles	Retail trade, except of motor vehicles and motorcycles; repair of household goods
IT and other information services	*(No NACE 1 equivalent)*

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

3.7 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.[76] Given the procyclicality of productivity, the choice of time period could have a significant effect on TFP estimates.

3.7.1 Time periods used by other consultancies and regulators

In Table 3.14 below, we summarise the time periods used by other consultancies in their TFP analysis undertaken on behalf of water companies.

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

Table 3.14 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 3.15 below, we present examples of what other consultancies have used as time periods in the past for other regulators.

Table 3.15 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.

3.7.2 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. In its latest report, it 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.

The 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.[77] Its 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 "Retail trade", "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.

3.7.3 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:

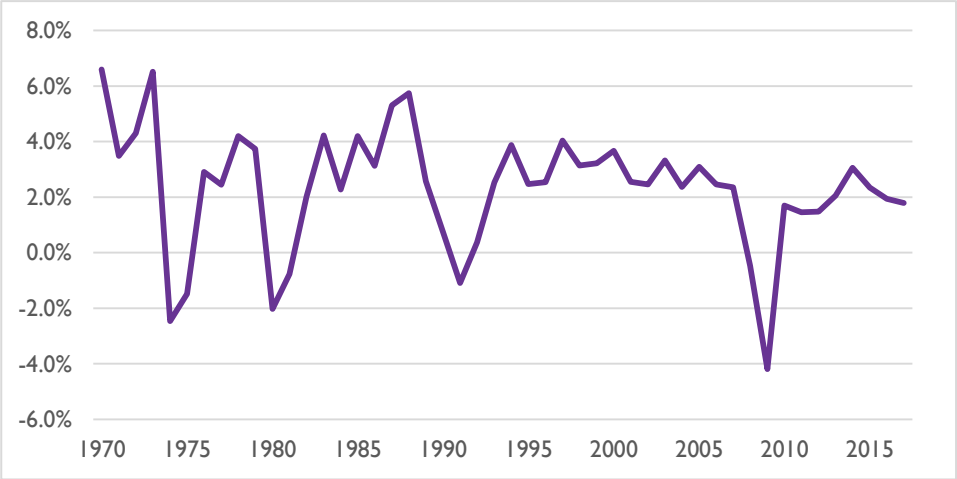
[77] Fiscal sustainability report July 2018, Office of Budget Responsibility.

- 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.[78]

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 Economic Insight, these

[78] 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 0.

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.[79]

Table 3.16: 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).

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

[79] 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 0 for a discussion of gross output and value added measures of TFP growth.

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 at the time only included value added TFP data.[80] 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 latest release suggest earlier figures are 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 carry 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.[81] A gross output measure of TFP is also less sensitive to changes in the degree of outsourcing over time.[82] 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.

Overall, 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.[83]

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.

3.9 TFP estimates for the chosen comparator sectors for wholesale

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.

[80] 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

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

[82] 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".

[83] 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.

3.9.1 TFP growth in gross output terms

In Table 3.17, we present the TFP growth values in gross output terms using the shorter, more recent EU KLEMS database which uses NACE 2 sector definitions.

Table 3.17: 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	**0.6%**	**0.9%**	**0.6%**

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 3.18, we present the TFP growth values in gross output terms using the longer EU KLEMS database which uses NACE 1 sector definitions.

Table 3.18: 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	**0.7%**	**1.0%**	**0.7%**	**0.8%**

Source: Europe Economics' analysis of EU KLEMS data.

3.9.2 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. However, we also present estimates of TFP growth for the comparator sectors in value added terms. Table 3.19 shows TFP growth estimates in value added terms using the NACE 2 database; Table 3.20 reports TFP growth estimates based on a longer time series in NACE 2;[84] and Table 3.21 presents TFP growth estimates using the NACE 1 database.

[84] 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 3.19: 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	**1.3%**	**2.1%**	**1.3%**

Source: Europe Economics' analysis of EU KLEMS data.

Table 3.20: 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	**0.9%**	**1.5%**	**1.5%**	**1.5%**

Source: Europe Economics' analysis of EU KLEMS data.

Table 3.21: 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	**1.9%**	**2.6%**	**2.0%**	**2.2%**

Source: Europe Economics' analysis of EU KLEMS data.

3.9.3 Interpreting TFP growth estimates for wholesale

We first of all derive a frontier shift range for wholesale 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, we consider which values can be interpreted as a lower bound and which can be interpreted as an upper bound.

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, and therefore we believe represents a lower bound estimate of TFP growth over the next price control period. As described in Section 3.7.2, since the global financial crisis the economy as a whole has seen markedly lower productivity growth, relative to the years pre-crisis. Looking ahead to the forthcoming control period, we believe 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 consider 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 3.17, 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.[85] 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 3.17) 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.
- 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.

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

Later, in Section 3.9, we consider the implications of the TFP growth estimates in value added terms for the choice of a point estimate from within this range.

3.9.4 Estimating the partial capital substitution effect for wholesale botex

As explained in Section 3.4, a partial capital substitution effect should be added to our TFP estimates for frontier shift if applied to wholesale botex. (For retail and wholesale totex, no capital substation effect is necessary – hence, the analysis below applies exclusively to wholesale botex.)

Table 3.22 and Table 3.23 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, and analysing over the various time

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

periods described.[86] The data presented below are the size of the adjustments required to TFP growth in gross output terms.

Table 3.22: Partial capital substitution effect for NACE 1 comparator sectors

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

Source: Europe Economics' analysis of EU KLEMS data.

Table 3.23: 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	**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 3.23), it can be seen that the average size of the partial capital substitution effect is 0.0 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 two full business cycles of our comparator sectors in NACE 1. In both cases this points to an increase of our upper bound by 0.2 per cent.

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

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

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.

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

3.10 TFP estimates for the chosen comparator sectors for retail

In this section, we present the TFP growth values for each of our comparator sectors for the retail part of the water sector for the selected time periods and comparator sectors.

3.10.1 TFP growth in gross output measure

In Table 3.24, we present the TFP growth values in gross output terms for retail comparator sectors using the shorter, more recent EU KLEMS database which uses NACE 2 sector definitions.

Table 3.24: TFP growth in gross output (NACE 2)

Industry Comparators	Average full period (1999-2014)	Average pre-crisis (1999-2007)	Average post-crisis (2010-2014)
IT and other information services	0.8%	1.3%	0.7%
Professional, scientific, technical, administrative and support service activities	0.9%	1.1%	1.5%
Retail trade, except of motor vehicles and motorcycles	0.1%	0.6%	-0.8%
Average	**0.6%**	**1.0%**	**0.4%**

Source: Europe Economics' analysis of EU KLEMS data.

In Table 3.25, we present the TFP growth values in gross output terms based on the longer EU KLEMS dataset which uses NACE 1 sector definitions.

Table 3.25: TFP growth in gross output (NACE 1)

Industry Comparators	Average full period (1971 - 2007)	Average cycle 1 (1980-1989)	Average cycle 2 (1990-2007)	Average two cycles (1980-2007)
Retail trade, except of motor vehicles and motorcycles; repair of household goods	0.3%	1.6%	0.7%	1.0%
Average	**0.3%**	**1.6%**	**0.7%**	**1.0%**

Source: Europe Economics' analysis of EU KLEMS data.

3.10.2 TFP growth in value added measure

As explained above, we believe the more appropriate measure of frontier shift is TFP growth in gross output terms, but that some lesser weight can also be placed on the value added measure. Hence, we now present calculations of TFP growth in value added terms for the retail comparator sectors.

Table 3.26: TFP growth in value added (NACE 2)

Industry Comparators	Average full period (1999-2014)	Average pre-crisis (1999-2007)	Average post-crisis (2010-2014)
IT and other information services	1.3%	2.1%	1.1%
Professional, scientific, technical, administrative and support service activities	1.5%	1.9%	2.6%
Retail trade, except of motor vehicles and motorcycles	0.1%	0.9%	-1.4%
Average	**1.0%**	**1.6%**	**0.8%**

Source: Europe Economics' analysis of EU KLEMS data.

Table 3.27: TFP in value added (NACE 2)

Industry Comparators	Average full period (1973 - 2009)	Average cycle 2 (1980-1989)	Average cycle 3 (1990-2007)	Average two cycles (1980-2007)
IT and other information services	-2.0%	-3.2%	-0.7%	-1.6%
Professional, scientific, technical, administrative and support service activities	-0.5%	-0.2%	0.8%	0.4%
Retail trade, except of motor vehicles and motorcycles	0.2%	2.6%	0.3%	1.1%
Average	**-0.8%**	**-0.3%**	**0.1%**	**0.0%**

Source: Europe Economics' analysis of EU KLEMS data.

Table 3.28: TFP growth in value added (NACE 1)

Industry Comparators	Average full period (1971 - 2007)	Average cycle 1 (1980-1989)	Average cycle 2 (1990-2007)	Average two cycles (1980-2007)
Retail trade, except of motor vehicles and motorcycles; repair of household goods	0.5%	2.5%	1.0%	1.5%
Average	**0.5%**	**2.5%**	**1.0%**	**1.5%**

Source: Europe Economics' analysis of EU KLEMS data.

3.10.3 Interpreting TFP growth estimates for retail

Lower bound

For retail, our lower bound recommendation is 0.4 per cent. As with wholesale, this is based on using the low productivity post-crisis period (NACE 2 data for 2010-2014) as a lower bound estimate of TFP growth in the water retail sector over the forthcoming control period. We again take an average of the TFP growth estimates for our chosen comparator sectors. The final column of Table 3.24 shows this to be 0.4 per cent.

Upper bound

Our recommended upper bound for retail is 1.2 per cent. As for our wholesale range, in deriving an upper bound we take note of Ofwat's approach of setting stretching performance targets for the water companies.[87] We therefore 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). Our upper bound is based on the following pieces of evidence:

- The best performing comparator sectors in the pre-crisis period (based on NACE 2 data from 1999 to 2007, as shown in Table 3.24) have an average TFP growth of 1.2 per cent (1.1 per cent in the case of 'Professional, scientific, technical, administrative and support service activities' and 1.3 per cent in the case of 'IT and other information services').
- In the longer run time series (NACE 1 data, as shown in Table 3.25) we only have one comparator sector for retail, thus making it more difficult to draw out a range from this dataset. While our chosen comparator sector in this dataset has a TFP growth rate of 1.0 on average over the last two cycles, over one of these cycles its TFP growth rate was as high as 1.6, suggesting that an upper limit of above 1.0 is appropriate.

Overall, therefore, our proposed range for retail totex is **0.4 to 1.2 per cent**.

As we did for wholesale, we consider in Section 3.9 below the implications of the TFP growth estimates in value added terms for the choice of a point estimate from within this range.

3.11 Our recommended frontier shift ranges

Table 3.29 below summarises our proposed frontier shift ranges, for: wholesale totex; wholesale botex; and retail totex.

Table 3.29: Proposed frontier shift ranges

Cost base	Frontier shift range
Wholesale totex	**0.6% - 1.2%**
Wholesale botex	**0.6% - 1.4%**
Retail totex	**0.4% - 1.2%**

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 shown in Section 3.3 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 3.9.4).

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

- Some weight should be placed on TFP growth in value added terms. We explained in Section 3.8 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

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

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 3.5.2, 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 embodied technical change 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 embodied technical change. 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.

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 both wholesale and retail 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:

- In the case of wholesale – labour, energy, chemicals, and materials, plant and equipment.
- In the case of retail – labour, bad debt and meter reading.

As shown in Table 4.1 and Table 4.2 below, only one of the cost items analysed passed all of the criteria necessary in the framework – this was bad debt. For all other cost items, both wholesale and retail, we do not recommend any RPEs. In the case of bad debt costs, we recommend a negative RPE allowance.

Table 4.1: Summary of RPEs assessment for wholesale

Cost Item	Labour	Energy	Chemicals	Materials, plant and equipment
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass	Fail	Fail	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail	Fail	Fail	Fail
3. 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	Fail	Fail	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Fail	Fail	Fail

Cost Item	Labour	Energy	Chemicals	Materials, plant and equipment
4. 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	Fail
Overall	**Fail**	**Fail**	**Fail**	**Fail**

Source: Europe Economics' analysis.

Table 4.2: Summary of RPEs assessment for retail

Cost Item	Labour	Bad Debt	Meter reading
1. Is the input cost item to which the RPE would be applied a material proportion of total company costs?	Pass	Pass	Pass
2. Are there compelling reasons to think that CPIH does not adequately capture the input price?	Fail	Pass	Fail
3. 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	Pass	Fail
B. Does the wedge between the input price and CPIH exhibit high volatility over time?	Fail	Fail	Fail
4. Is the input price and exposure to that input price outside management control during the duration of the price control?	Partial Pass	Partial Pass	Partial Pass
Overall	**Fail**	**Partial Pass**	**Fail**

Source: Europe Economics' analysis.

Stage 2 specifically considered the case for an RPE for wholesale totex in aggregate by analysing a relevant input PPI for the water sector as a whole, but again did not find sufficiently strong evidence for an RPE. No comparable assessment was possible to judge the case an RPE for retail totex in aggregate, due to the lack of a suitable input price index for retail water.

Overall, both Stages 1 and 2 of our framework identified no robust case for the inclusion of RPE allowances for either wholesale or retail, with the exception of bad debt costs in retail. By definition, if there is no RPE it means that the allowed input price does not increase either faster or slower than CPIH, meaning that the cost allowance has to be linked in some way to CPIH. The implication of this analysis for wholesale cost items is that the CPIH indexation is sufficient to capture changes in the input costs over the next price control. For labour and meter reading costs in retail, as there is no indexation to CPIH, the finding of no RPEs can be provided through an *ex ante* IPI allowance based on projected CPIH. For bad debt costs, the recommendation of a negative RPE implies an *ex ante* IPI allowance lower than projected CPIH.

Final recommendations:

- For wholesale controls, we recommend that CPIH indexation is sufficient to capture changes in the input costs over the next price control.

- For labour and meter reading in retail controls, we recommend *ex ante* IPI allowances based on projected CPIH.
- For bad debt in retail controls, we recommend an *ex ante* IPI allowance less than projected CPIH.

4.2 Frontier shift

Our assessment of frontier used an approach based on TFP analysis in comparator sectors. Based on that analysis we have derived our proposed frontier shift ranges for both wholesale and retail parts of the water industry, as shown in Table 4.3 below.

Table 4.3: 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%**
Retail totex	**0.4% - 1.2%**

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 0.0 to 0.2 per cent (as explained in Section 3.9.4).

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 0.0 per cent.

Our recommendation is to select a number towards the upper end of each of the ranges set out above. In each case, the reasons for selecting a number towards the upper end of the ranges are twofold:

- Some weight should be placed on TFP growth in value added terms. We explained in detail in Section 0 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 3.5.2, 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 embodied technical change. 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 embodied technical change, a number towards the upper end of each range should be chosen.

The frontier shift efficiency ranges presented above are in addition to any efficiency gains expected from the move to totex and outcomes-based regulation.[88]

[88] 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: Additional Stages of RPEs Framework

In this appendix we set out in detail Stages 1B and 2 of our framework for assessing RPEs. Stage 1B of the framework has not been described in the main body of the report in detail, due to the fact that only one cost item passed Stage 1A of the RPE framework. Stage 2 could only be undertaken in the case of wholesale totex, not retail totex. Therefore, despite not being described in detail in the main body of the report, these stages nevertheless form part of our overall RPE assessment framework.

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 these cost items through the second stage of our framework to assess whether anything should be done to account for these RPEs. In practice, this was only applied in the case of 'bad debt' costs for the retail control.

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:

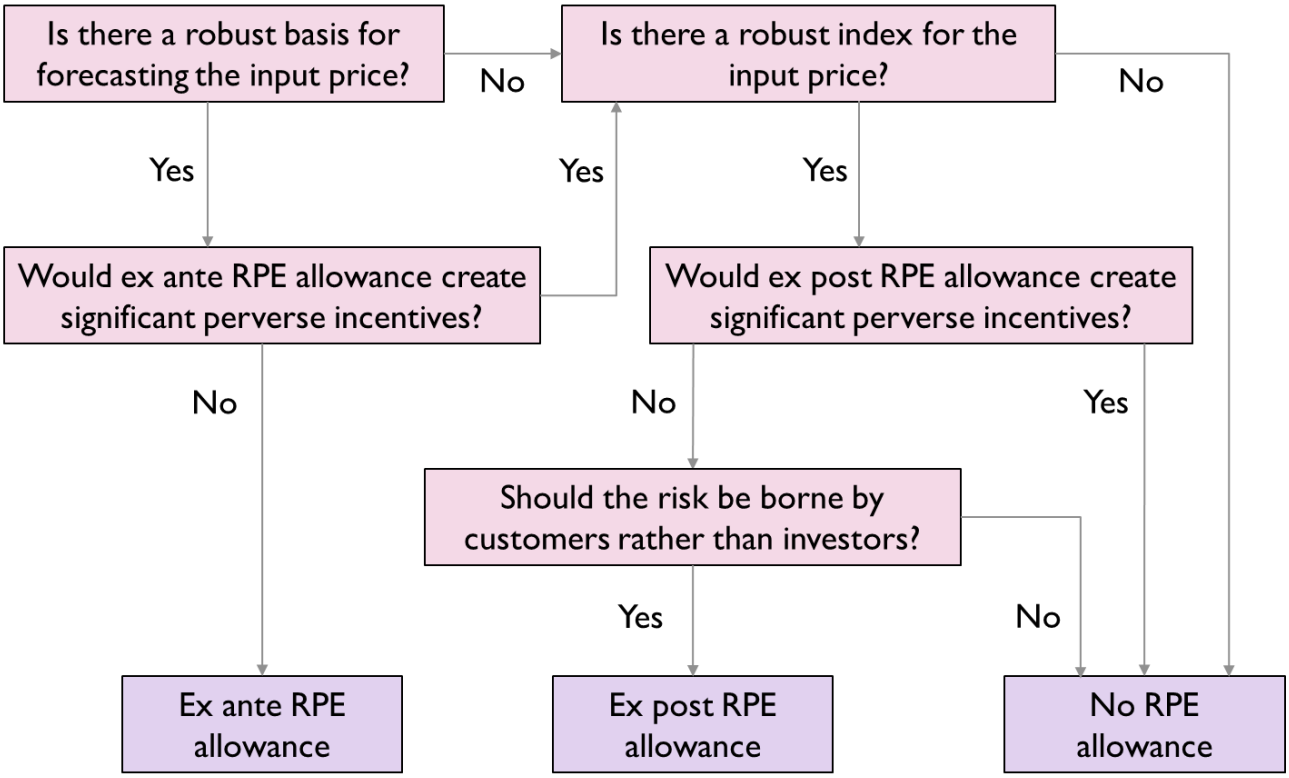
- Is there a robust basis for forecasting the input price? There could be a good basis for forecasting the RPE if: firstly, the input price trend (and wedge relative to CPIH) is relatively stable over time such that past changes in input prices are a good proxy for future price changes; or, secondly, if the input price is well captured by an index (see above) for which reliable forecasts are made (i.e. indices for which past forecasts 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. This can be assessed by comparing the index (or indices) in question with past evolutions in the relevant company cost item, to ascertain whether changes in the company cost item are well captured by changes in the index (i.e. are the index and company cost item well correlated?).[89]
- Would an RPE allowance 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

[89] A caveat to such analysis is that water company costs will be affected by changes in the volume of activity as well as changes in input prices. Hence, while we might expect some correlation between water company costs and relevant input price indices, we would not expect that correlation to be perfect.

post RPE allowance the risk is borne by investors with any systematic component to this risk feeding into the cost of capital,[90] 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 A1: 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.

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. In particular, Stage 2 considers:

- Consistency of regulatory mechanisms across cost items (if relevant). This takes account of:
  - Ofwat's preference for avoiding too many different ad hoc mechanisms for different cost items – for example, if the outcome for Stage 1 suggested an ex ante allowance for some RPEs and an ex post mechanism for others, we would consider whether it might be possible to adopt a more consistent approach across different cost areas.

[90] 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.

  - Incentive effects due to the interaction of different RPE allowance mechanisms – this considers whether the mix of RPE allowance tools arising from Stage 1 could generate perverse incentives. This could, for example, include the possibility of water companies substituting from an input where costs are linked to an exogenous index to an input where costs are linked to an endogenous index (i.e. an index affected directly by reported water company costs).

- The effect at the level of overall totex of any RPE allowances for individual cost items – this considers the RPE allowances in the round, by estimating the weighted average of the different RPE allowances determined in Stage 1. To do this, the RPE allowances for different cost items are weighted by the share of that cost item in totex to estimate the implicit RPE allowance for totex as a whole. If some input prices are expected to increase in real terms while others are expected to decrease with a net effect on totex of close to zero, then the case for RPE allowances may fall away. We also compare the weighted average RPE for totex as a whole with the RPE implied by the relevant input PPI(s) for the water and wastewater sector.

There are four possible outcomes from Stage 2:

- No change to the RPE tools recommended by Stage 1.
- Change the mix of RPE tools across different cost areas recommended by Stage 1.
- Use a relevant input PPI as the best proxy for RPEs, in place of individual RPEs for individual cost areas.
- Provide no RPE allowance, on the basis that RPEs for different cost areas net off each other.

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 3.3 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 the TFP growth estimates overstate frontier shift, and therefore that the 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 TFP growth estimates understate frontier shift, and thus that the scale effect would need to be added to the TFP growth figure.

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 explore our data to determine 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:

$$(\in -1)\sum_{n}\left(\frac{\in_n}{\in}\right)\dot{x_n}$$

Where:

- $\in_n$ is the elasticity of output with respect to a given input (labour and capital) (i.e. $\in_n = \frac{\partial lnf}{\partial lnx_n}$). 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 for wholesale. Since elasticities are only available for manufacturing sectors, no mapping to our retail comparators is possible. 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).[91] We also use calculated input elasticities for 'Total manufacturing' from Dobbelaere et al (2015).[92]

- $\dot{x_n}$ 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.

- $\in = \sum_n \in_n$ is the total elasticity of output (with respect to all inputs), with $\in > 1$ 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.

[91] 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.

[92] 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 0 per cent for 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.