Appendix
YKY24_Frontier shift

YorkshireWater

Economic Insight

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Economic Insight Ltd

PRODUCTIVITY AND FRONTIER SHIFT AT PR24

A report on behalf of a consortium of water companies

CONTENTS

1 Introduction and executive summary

In this report, we undertake a comparator analysis using total factor productivity (TFP) data to arrive at estimates for an appropriate frontier shift challenge for water companies at PR24. We summarise our results (for the total water value chain) with respect to three estimated ranges: (i) our *'plausible range'* is **0.3%-0.8%** (we think it is implausible, but not impossible, for frontier shift to lie outside of this range); (ii) our *'PR24 focused range'* is **0.3%-0.7%** (we think it is likely frontier shift will be within this range at PR24); and (iii) our *'sensitivity analysis range'* is **0.1%-1.1%** (this shows what frontier shift *could* be, under alternative sets of comparators and time periods to those we recommend). In addition, for water retail specifically, we derive a *'plausible range'* of **0.3%-0.6%**.

1A. Introduction

Aims of our study

A consortium of water companies[1] commissioned Economic Insight to provide a report on the scope for frontier shift at PR24. The primary aim of this study is to reach our own independent and robust view on the appropriate range for frontier shift at PR24. In order to do this, we:

- review data on economic conditions, so as to determine the appropriate time period for our analysis; and
- provide a set of criteria that we apply in order to reach a view on an appropriate set of comparable sectors to the water industry.

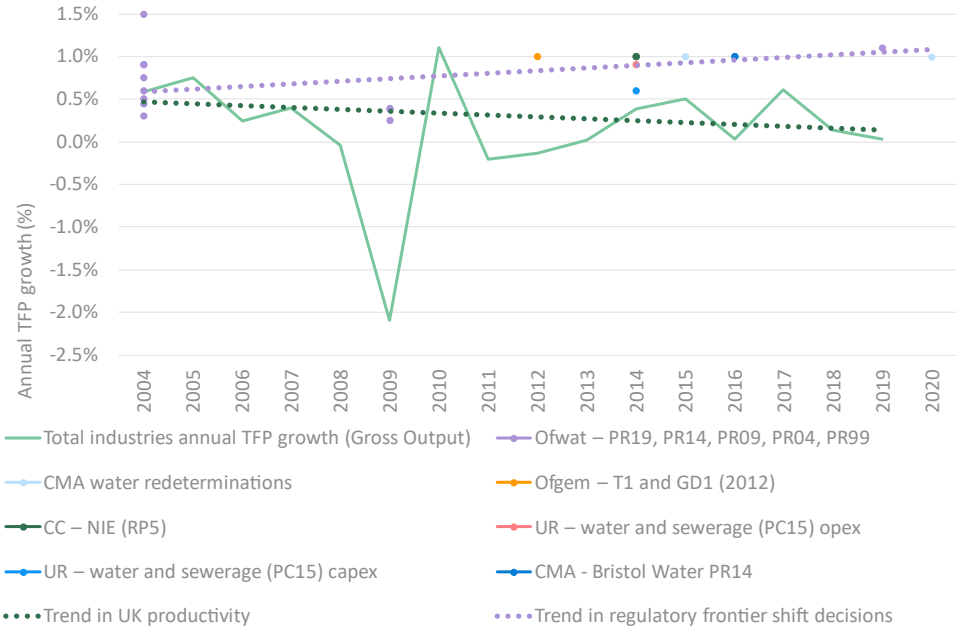
[1] *Affinity Water; Anglian Water; Bristol Water; Northumbrian Water; Severn Trent Water; South East Water; South Staffordshire Water; South West Water; Southern Water; Thames Water; United Utilities; Welsh Water; Wessex Water; and Yorkshire Water.*

In addition to the above primary aims, our work seeks to provide clarity as to the relevant economics theory and analytical considerations that should inform the appropriate approach to frontier shift at PR24. Accordingly, this report sets out our findings and recommendations.

Context

Following the 2008 financial crisis, the UK has now experienced 15 years of falling, and low, productivity performance (as measured by total factor productivity - TFP); a pattern that is consistently seen across the majority of UK industries (i.e. it is not unique to the water industry). However, as shown in Figure 1, at the same time sectoral regulators have been setting increasingly challenging frontier shift targets. This appears counterintuitive.

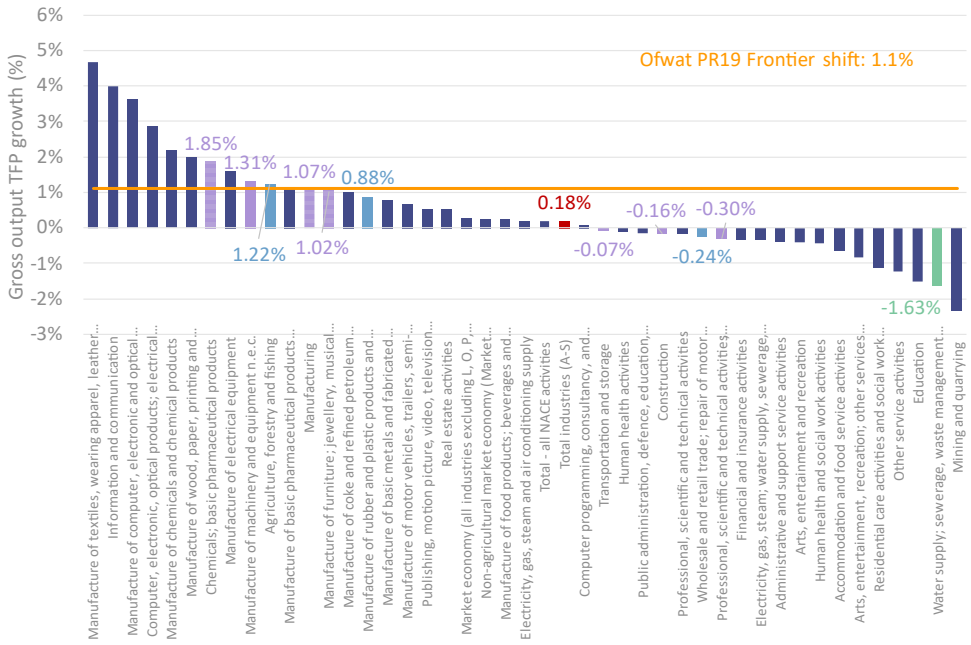
Figure 1: Falling UK productivity; increasing regulatory frontier shift decisions



Source: Economic Insight analysis

Further to the above, when one examines regulatory decisions from a cross-sectional (across industry) perspective, they imply regulated industries are (on regulators' assessments) 'outliers', with unusually high expected productivity. For example, in relation to Ofwat's PR19 frontier shift challenge (1.1%), Ofwat's position suggests that the water industry should have productivity growth above the majority of other industries in the UK. Indeed, Figure 2 shows that, between 1995 and 2019, only 12 out of 46 sectors in the UK had TFP growth of 1.1% or above (and many of these, as one would expect, relate to high-tech industries, such as telecoms; chemicals; and computing). Furthermore, Figure 2 shows (in red) that average annual TFP growth for "Total industries" between 1995 and 2019 was 0.18% (which is significantly lower than Ofwat's PR19 challenge of 1.1%).

Figure 2: Sector level gross output TFP growth (1995 to 2019)



Source: Economic Insight analysis of EU KLEMS data

Notes: We have not included "Telecommunications" in this chart in order to improve readability, as its average TFP growth is 12.9%.

Put simply, the persistence and consistency of low productivity in the UK over time, and across industries, calls into question the trajectory of regulatory determined frontier shift, as we look ahead to PR24. In this context, it should also be recalled that in the water industry, prior to PR14, frontier shift was typically set well below 1.0% by Ofwat.

The above data means that it is important to consider the approach to frontier shift at PR24 with care. In particular, there are a number of analytical complexities regarding the inference of frontier shift from TFP data that require attention. Similarly, the choice of comparator sectors, and time periods, over which TFP is assessed must be duly weighed.

1B. Executive summary

Analytical considerations

Estimates for frontier shift are typically derived from TFP data. Indeed, this is the approach we have taken in this report, drawing primarily on the EU KLEMS database, which is split into: NACE I (1970-2007); and NACE II (1995-2019).[2] However, TFP itself is *not* a direct measure of frontier shift. Rather, being a measure of productivity, it merely measures a change in outputs for a given change in inputs. Here, the key issues are as follows:

- TFP will include catch-up, as well as frontier shift related, efficiency gains. Raw TFP data will therefore always *overestimate* frontier shift to some degree for this reason. This holds under our analysis (although we seek to mitigate this, by taking the competitiveness of industries into account when selecting comparator sectors).

- TFP will include efficiencies from economies of scale. In principle, this could lead to frontier shift being either over, or under, stated (depending on whether the comparators have similar scope for economies of scale to that in the water industry).[3] We seek to control for this in comparator selection in our analysis. However, as regards the comparators we ultimately include, in practice there may be some *understatement* of frontier shift relating to economies of scale (although the magnitude of this understatement is logically *smaller* than the equivalent overstatement for catch-up efficiency).

- The question of whether an adjustment is needed for embodied technological change is complex, with no clear cut or easy answer. We find both on intuition and the evidence that TFP data includes *some* element of embodied technological change; it is a matter of degree (as confirmed to us by the ONS). Furthermore, the extent to which TFP data includes / excludes embodied technological change will vary by industry. Based on our recommended comparators, we consider *some* uplift for excluded embodied technological change may be appropriate (but we cannot preclude the possibility that a downwards adjustment is, in fact, appropriate). Box 1 below summarises our views on the theory and evidence on the embodied change issue.

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[2] *We note that an updated version of the EU KLEMS NACE II database was released in February 2023. This database includes an extra year of data but, in addition, compared to the previous iteration of this database, much of the data has changed for the same years and the same comparators. We have raised a query with EU KLEMS as to exactly what has driven this change.*

[3] *That is to say, it is not (strictly) necessary to 'strip out' all scale related gains from the TFP data of comparators. This is because, if the productivity (TFP) gains that comparators could achieve were similar to those the water industry could achieve, the fact that economies of scale are included is not problematic. Rather, what matters is whether the 'scope' for TFP gains from economies of scale are materially different for the comparators than for water. This contrasts to catch-up efficiency, whereby Ofwat's approach already identifies and applies a catch-up challenge to water companies, meaning that any catch-up efficiencies in the TFP data of comparators results in an overstatement of frontier shift.*

Box 1: Our views on the embodied change issue

Ongoing efficiency (frontier shift) consists of productivity gains from both: (i) embodied change (gains made from higher quality inputs / new technology); and (ii) disembodied change (gains made from existing inputs / existing technology). The consensus is that TFP estimates do not fully account for embodied change. However, this, in and of itself, does not mean that frontier shift for the water industry (as inferred from the TFP of comparator industries) should be adjusted upwards to account for omitted embodied change. Rather, this depends on two considerations.

1. The amount of embodied change that is included in / excluded from TFP

We recognise the challenges in quantifying an exact amount of excluded embodied change. Nonetheless, we consider that there is a greater degree of embodied change captured within TFP, than regulators have recognised to date, since:

- Firstly, TFP growth is shown to be highly volatile, with regular peaks and troughs. If TFP growth corresponded only to disembodied change, the volatility would imply the effectiveness with which companies can use their existing assets and resources is highly variable (i.e. making 'gains' in one year, only to 'lose' those gains the next). This seems doubtful.
- Secondly, TFP and economic growth are shown to be highly correlated; as are levels of investment and economic growth. As investment in new technologies leads to embodied (rather than disembodied) change, one would not expect such a strong relationship between TFP and economic growth, were embodied change fully (or even mostly) excluded from TFP estimates.
- Thirdly, there is neither a consensus in the academic literature, nor between the ONS and EU KLEMS, on the degree of excluded embodied change.

We also consider that the amount of embodied change that is included in TFP varies significantly by industry – with more embodied change captured in those industries that use relatively more capital and intermediate inputs.

2. The applicability of embodied change from comparator sectors to water

We consider that the water sector likely contains low rates of technological progress, relative to many industries. As such, given that embodied change results from investment in new technologies, the water industry is unlikely to be able to achieve high productivity due to embodied change. Indeed, if the comparators used to infer frontier shift have higher scope to achieve gains from embodied change than the water industry then, even if some of that embodied change is excluded from their TFP data, the proportion that is included within TFP may in fact result in an overstatement of frontier shift for water. The key point, therefore, is simply that the relative scope of the water industry to benefit from new technology, relative to the comparators, is also important.

Source: Economic Insight

Beyond the above analytical considerations that arise due to the use of TFP to estimate frontier shift, there are two further important issues pertinent to setting frontier shift at PR24:

- CPIH (which is used to index the RCV under the regulatory framework) must logically capture productivity gains. CPIH is a broad measure of consumer inflation faced in the UK, and efficiency savings made by firms producing goods and services are a key driver of general movements in consumer prices. At PR19, Ofwat compensated companies for input cost changes (real price effects) where these differed from CPIH – which is inconsistent with the approach taken for frontier shift. Specifically, we consider that, at PR24, Ofwat should adopt an internally consistent approach. By this, we mean that the frontier shift challenge should be set to the extent that the 'industry specific' frontier shift differs from the productivity gains already implicitly captured within CPIH (consistent with real price effects).

- It is important to highlight that in setting performance commitments that companies must achieve from base funding, Ofwat is setting said companies an efficiency challenge that is *in addition* to both the frontier shift and catch-up % challenges applied to costs. Put another way, the total efficiency challenge for any firm can be considered as being four parts of a pie. Within both catch-up and frontier shift, efficiency gains can be realised through any combination of cost reductions and / or quality improvements (output increase). The point being, however, that the total efficiency can never be more than the sum of its parts. Consequently, setting aside the fact that TFP does not strictly accord to frontier shift (i.e. it includes some degree of other efficiencies, as above) the frontier shift itself captures productivity gains made by comparator firms via cost reductions and quality improvements. Thus, when applying any estimate of frontier shift derived from a comparator approach, the figures should be allocated between cost reductions and quality improvements, in order to avoid a double-count. In practice in the water industry, the starting point should be to measure the efficiency challenge implicit in the performance commitments.

Choice of time period

TFP varies considerably, depending on the time period over which it is assessed. In this report, we have therefore weighed four considerations in determining the appropriate period for determining frontier shift at PR24.

- **Internal consistency**, such that the time period used to assess frontier shift is consistent with the time period (and assumed economic context) used to inform other key components of the price control (e.g. equity returns, given their correlation with productivity and growth).

- The **structural break** arising from the financial crisis, which has marked a 15-year period of falling and persistently low productivity.

- The inclusion of **full business cycles**, as productivity is shown to be pro-cyclical.
- The **utilisation of the data** available, to reduce the impact of outliers.

Applying the above four considerations, in our *'plausible range'* we assess frontier shift over the following time periods (noting that the availability of data also constrains the start and end of these periods): (i) 2010-2019; (ii) 1995-2019; and (iii) 1970-2007. In our *'PR24 focused range'*, we use: (i) 2010-2019; and (ii) a weighted average of 1995-2019 and 1970-2007.[4] In addition, in our *'sensitivity analysis range'*, we include the period: 1992-2007.

Choice of comparators

The choice of comparator industries is important - primarily in order to mitigate the impact of economic efficiencies that are captured in TFP, but that do not correspond to frontier shift. We select comparators based on three criteria.

- **Criterion 1:** the activities undertaken in the comparator sector should be similar to those in water.
- **Criterion 2:** the comparator sector should be competitive (to mitigate the impact of catch-up efficiencies).
- **Criterion 3:** the extent of fixed costs and growth rates over time should be similar between comparators and the water industry (to mitigate the impact of scale effects).

We have applied a three-colour grading to each of the criteria detailed above, ranking possible comparator industries as: "Red"; "Amber"; or "Green". Following this, we have arrived at a *'preferred set'* of comparators, that takes into account the ranking across each of these criteria. In addition, we have included "Total industries", as we consider it is beneficial to include a metric that captures productivity changes across the entire UK 'on average' (given the inherent subjectivity in comparator choice).[5] In our *'plausible range'* and *'PR24 focused range',* we use our *'preferred set'* of comparators.

We have also set out several sensitivities that test the robustness of our choice of comparators, by widening[6] / narrowing the set of comparators, based on the three criteria above. These correspond to our *'sensitivity analysis'* range. We also recognise that the mix of activities undertaken by water companies (and therefore appropriate selection of comparators) can vary somewhat over time. For example, if a water company expected to undertake significantly more asset construction or maintenance

[4] *Please see Chapter 7 for details of how this weighted average has been calculated.*

[5] *Our 'preferred set' of comparators is therefore as follows: (i) Total industries; (ii) Agriculture, forestry and fishing; (iii) Manufacturing; (iv) Chemicals; basic pharmaceutical products; (v) Manufacture of rubber and plastic products and other non-metallic mineral products; (vi) Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment; (vii) Wholesale and retail trade; repair of motor vehicles and motorcycles; and (vii) Transportation and storage. Please see Table 12 for the NACE I equivalents of each of these.*

[6] *This widened set of comparators corresponds to the 'preferred set' plus (in separate sensitivities): (i) "Mining and quarrying"; and (ii) "Construction".*

at PR24 than in the past, it may be appropriate to give that due consideration when assessing frontier shift under its Business Plan.

Results

Table 1 shows the lower and upper ends of each of our three ranges of estimates, as described above (and also sets out the time period and set of comparators that correspond to that particular estimate).

Table 1: Summary of estimates (total water value chain)

	Plausible range		PR24 focused range		Sensitivity analysis range	
	Low	**High**	**Low**	**High**	**Low**	**High**
Frontier shift estimate	0.3%	0.8%	0.3%	0.7%	0.1%	1.1%
Time period	2010-2019	1970-2007	2010-2019	Weighted average of: 1970-2007; and 1995-2019	2010-2019	1970-2007
Comparators	Preferred set	Preferred set	Preferred set	Preferred set	**Sensitivity 1**[7]	**Sensitivity 3**[8]

Source: Economic Insight analysis of EU KLEMS data

Retail

We have also assessed the scope for frontier shift specifically in relation to water retail, using the same broad approach (and the same time periods) as summarised above for the total water value chain. Again, we derive three ranges of estimates. Our analysis for retail suggests: (i) a *'plausible range'* of 0.3%-0.6%; (ii) a *'PR24 focused range'* of 0.4%-0.6%; and (iii) a *'sensitivity analysis range'* of -0.2%-1.2%. Overall, these ranges are highly similar to those for the total water value chain; but note that the upper ends of our *'plausible range'* and *'PR24 focused range'* are slightly lower for water retail. This is consistent with intuition, whereby we would characterise retail activities as being somewhat more 'vanilla'; with lower value add; lower capital intensity; and (therefore likely) lower scope for technological change that could, in turn, drive improved productivity.

[7] *This corresponds to our 'preferred set' plus "Mining and quarrying". Further details are provided in Section 5C.*

[8] *This corresponds to our 'preferred set' but with: (i) Criterion 3 strengthened; and (ii) highly aggregated sectors excluded. Further details are provided in Section 5C.*

1C. Recommendations

Recommendations to companies

In terms of how we recommend companies utilise our estimates in developing their PR24 business plans, this is as follows:

- The estimation of frontier shift is inherently uncertain. As such, companies have some discretion as to what evidence / approaches they place most weight on when determining what frontier shift to assume in their business plans for PR24. Our own analysis suggests frontier shift for the total water value chain could plausibly lie between 0.3% and 0.8% pa (0.3% and 0.6% for water retail); and so companies could select any figure within this range and it would be supportable, on the evidence. In determining 'where' in that range to select, companies should consider (and explain in their plans) the specific evidence / rationale in our report (or from elsewhere) they rely on.

- That said, with a focus specifically on the PR24 time period, it seems *likely* (both on the evidence and intuition, given the persistence of low productivity) that frontier shift will sit within a narrower range (which we find to be 0.3% to 0.7% for the total water value chain; and 0.4% to 0.6% for water retail). Companies should therefore consider with care the case for selecting figures outside of these narrower ranges (noting that, prior to PR14, frontier shift in the water industry was typically set around these levels by Ofwat).

- The fact that embodied technological change is only partially captured in our estimates may provide some basis for choosing numbers towards the higher end of our ranges. On the other hand, the fact that our raw estimates implicitly include efficiencies other than frontier shift means they are overstated, providing some basis for choosing numbers towards the lower end of our ranges.[9] Our recommendation is therefore that companies should: (i) generally adopt numbers at the mid-points of our ranges; or (ii) could deviate from that (i.e. selecting higher or lower numbers within our ranges) if that decision was informed by additional evidence relating to:

  - an assessment of the rate of technological change in the water industry, relative to the comparator sectors; and / or

  - additional evidence as to the scope for other efficiencies (e.g. economies of scale) in the water industry, relative to the comparator sectors.[10]

[9] *Noting that the overstatement of frontier shift due to catch-up is likely greater in magnitude than a potential understatement due to scale effects.*

[10] *Relatedly, and as noted previously in this executive summary, companies could further consider whether the comparator set itself might change, if (for example) the expected mix of activities they will undertake at PR24 is sufficiently different from the past.*

- We consider that (in principle) frontier shift gains should be applied to the totality of company costs (i.e. both base and enhancement), other than costs which are deemed outside of management control. In relation to enhancement costs, in order to avoid either omitting (or double-counting) a frontier shift challenge, companies should provide clear evidence as to how the frontier shift has been applied. If companies consider a frontier shift challenge has been implicitly included, they should explain why and provide evidence to support that. Where the challenge has been explicitly applied, they should state so and demonstrate this.

- Companies may want to consider whether, and to what extent, the possible use of Ofwat's innovation fund may affect the scope for frontier shift on a forward-looking basis. However, we note that the size of the fund (£200m)[11] relative to total industry totex set by Ofwat in its PR19 FD (£49.6bn)[12] is sufficiently small that it seems doubtful that this can materially affect productivity and thus, we do not recommend making an adjustment for this.

Wider recommendations for PR24

Below we set out recommendations for Ofwat and companies for PR24, in order to ensure that the most appropriate estimate of frontier shift is selected:

- Ensure that any choice of time period is based on a transparent assessment against the considerations captured within our criteria (specifically: internal consistency; use of complete business cycles; utilisation of data; and reflecting the structural break in productivity in the UK, post 2008). The UK's economic outlook should be reviewed as plans are finalised / regulatory determinations are made, to help ensure this is the case.

- In selecting comparators, undertake analysis to apply the evaluation criteria outlined in this report; critically assessing each comparator industry to objectively determine its applicability. This will also help inform how (or whether) to reflect any efficiencies other than frontier shift captured in the raw TFP data.

- Any updated productivity data (in particular, the EU KLEMS or ONS datasets) that is published between now and the determinations should, ideally, be utilised and frontier shift estimates updated prior to the determinations.

- Any further information / evidence relating the relative competitiveness of comparator sectors (published prior to the determinations) should be reviewed and taken into consideration.

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[11] *'Creating tomorrow, together: Our final methodology for PR24 Appendix 9 Setting expenditure allowances.' Ofwat (December 2022); page 38.*

[12] *'PR19 slow track draft determinations: Securing cost efficiency technical appendix.' Ofwat (December 2019); page 8.*

- Frontier shift estimates should be based on gross output TFP productivity, with little or no weight given to value added estimates.
- If frontier shift is estimated over a very long time period, the use of a geometric mean should be considered.
- In relation to embodied technological change, this matter could be further informed by the following:

  (i) Analyse historical TFP growth in the industry; and track the extent to which periods of higher technological change correlate with increased TFP growth. Then one could 'map forward' any anticipated technological change over PR24, to determine whether it is likely to be a relatively 'high', or 'low', period of technological change.

  (ii) Undertake a literature review regarding empirical estimates of embodied technological change. From our existing research, we have identified academic articles that estimate between 20%[13] and 60%[14] of TFP growth may represent embodied change. However, these estimates should be taken with certain caveats. Firstly, both studies rely upon data that is 40 years old (i.e. when productivity growth was much higher than it is now). Secondly, they take data from the US, whose economy has been consistently subject to higher levels of investment and greater productivity growth than the UK. Therefore, although these academic sources are informative in providing a starting point for quantifying the degree to which TFP may underestimate achievable frontier shift, their calculations should not be taken as a 'rule' for any adjustments required (further noting our finding that, in any event, TFP already includes *some* embodied technological change).

  (iii) For each chosen comparator, undertake a two-stage process to determine the importance of potentially excluded embodied technological change. Firstly, develop evidence as to the amount of embodied change that is likely reflected in the TFP data of the comparators. Secondly, examine the rate of technological change in the comparators, and compare this to the rate of technological change in the water industry. Where the rates are similar, the more appropriate it is to adjust for excluded embodied technological change. Conversely, where the rate of technological change is materially different in the water industry, relative to the comparators, adjustments for embodied change are more likely to result in an over or understatement of frontier shift. For example, where technological change in the water industry is slower than

[13] *'Growth Accounting When Technical Change is Embodied in Capital.' Hulten, C. (January 1992).*
[14] *'Embodied and disembodied technical change and the constant elasticity of substitution production function.' Uri, N. (December 1983).*

that for the comparators, an adjustment would likely result in an overstatement of frontier shift (and vice-versa).

- As a matter of urgency, the industry needs some way to scale the size of the efficiency challenge being set under the performance commitments at PR24. Without this, the totality of the efficiency challenge (both catch-up and frontier shift) cannot be determined; and a 'double-count' will likely occur. This is a material limitation under the current regulatory framework.

- Ofwat should adopt an internally consistent approach between that which is currently taken for real price effects, and what should be taken for frontier shift. Specifically, any frontier shift challenge should only account for ongoing efficiency gains specific to the water industry, that are not already implicitly captured within CPIH.

2 Context and aims

In this chapter we set out the context to, and aims of, our work. In turn we: (i) define frontier shift and explain how this relates to an overall measure of efficiency; (ii) illustrate how frontier shift challenges set at recent regulatory decisions have changed, relative to trends in productivity over time; (iii) review the approaches to frontier shift taken by Ofwat and the CMA at PR19; (iv) consider whether to adjust frontier shift for the innovation fund; and then (v) set out the aims of our study.

2A. Overview of frontier shift

In this report, when we refer to frontier shift, we are referring to the ongoing efficiency challenge that Ofwat applies to company costs. This challenge is designed to encourage companies to continue to make productivity improvements. It is applied in addition to the catch-up efficiency challenge, which is designed to encourage companies to 'catch-up' with the frontier efficient firm. The economic rationale for these two types of efficiency is explained further as follows:

- **Catch-up efficiency.** This is the efficiency improvement required for less efficient firms (i.e. those who are behind the efficiency frontier) to reach said efficiency frontier. For companies, catch-up is theoretically (primarily) achieved by management implementing the best operational practices. These often relate to appropriate responses to: (i) changes in technical efficiency (meaning how quickly companies are able to respond to material changes in input factors);[15] or (ii) changes in allocative efficiency (meaning the extent to which companies are able to vary their mix of inputs, in order to increase output).[16]

[15] *'The Luenberger productivity indicator in the water industry: An empirical analysis for England and Wales.' Molinos, M; Maziotis, A; Sala-Garrido, R; (September 2014).*

[16] *'Productive efficiency and allocative efficiency: why better water management may not solve the problem.' Allan, T; (March 1999).*

- **Frontier shift.** This relates to the change in the productivity frontier of an industry over time.[17] Frontier shift thus represents the efficiency savings that even the most efficient firms in an industry can make. By setting firms a frontier shift, Ofwat hopes to reflect the challenge firms face in non-regulated markets, where they are constantly required to make efficiency savings on an ongoing basis. The frontier is typically pushed out by strategic oversight; and capital investment, allowing more efficient new technology to be deployed and accumulated.[18]

  - Frontier shift is thus closely related to rates of technological change within industries, which is typically closely associated with rates of capital investment. Accordingly, one would intuitively expect frontier shift (and productivity more broadly) to vary significantly across industries, as is reflected in the data in practice.

  - The above link (between investment; leading to new technology; leading to productivity gains) also means that changes in frontier shift within an industry arising from increased spending (investment) are not instantaneous. For example, academic literature finds that there is usually a lag (approximately five years) following investment for productivity gains to be fully realised in the manufacturing industry. This reflects the time it takes for companies to make capital investments; deploy the related technology; and then learn the most effective way of using it.[19] The relevance of this to PR24 is that, to the extent that companies increase their capital investment (relative to the past), care must be taken not to assume this translates to immediately higher frontier shift. Moreover (and far more materially in this context), it remains problematic that, historically, the regulatory determined frontier shift challenge in the water industry has increased so significantly over time in a context of low investment (as highlighted in the recent House of Lords report).[20]

In principle, both catch-up and frontier shift efficiency can be delivered through either cost savings, or improvements in quality (or, indeed, any balance between / combination of the two). Accordingly, Figure 3 shows how one can think of efficiency (productivity) as a 'pie' with four constituent parts. As no market is perfectly competitive, all firms (in any industry) can likely make efficiency gains through some combination of both 'catch-up' and 'frontier shift'. For each of these, a firm can then choose[21] whether to achieve said gains through cost reductions or quality improvements (again, or any balance between the two). However, the whole pie can never be more than the sum of its constituent parts.

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17 *'Energy efficiency in Spanish wastewater treatment plants: A non-radial DEA approach.' Hernández-Sancho, F; Molinos-Senante, M; Sala-Garrido, R; (June 2011).*

18 *'U.S. Economic Growth at the Industry Level.' Jorgenson, D; Stiroh, K; (May 2000).*

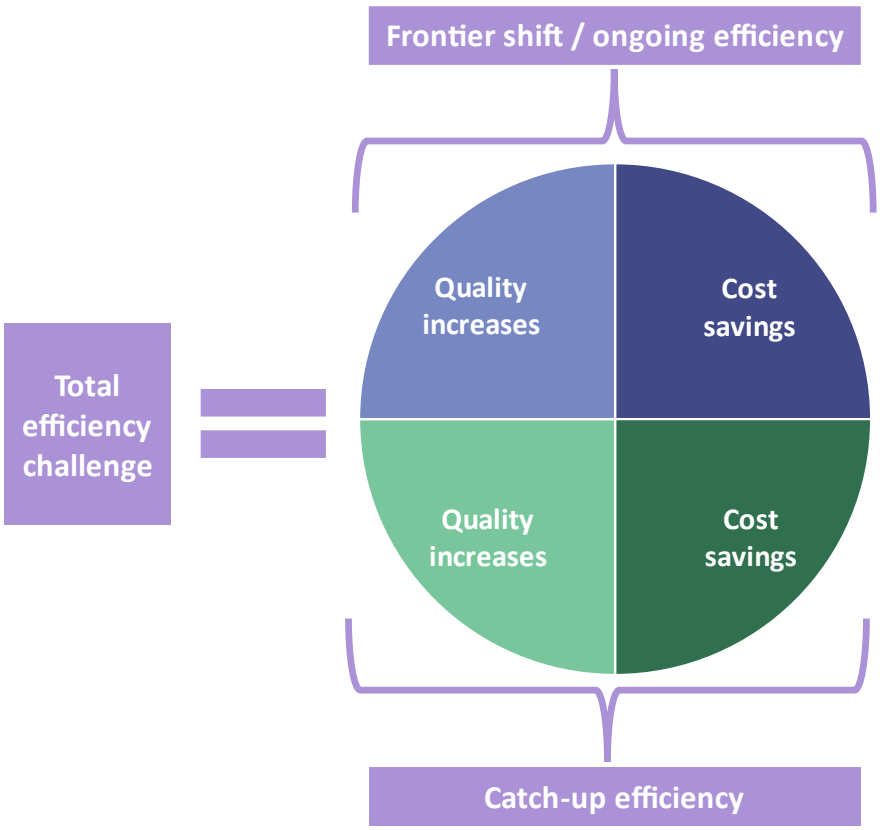
19 *'Linking investment spikes and productivity growth.' Geylani, P; Stefanour, S; (April 2012).*

20 *'The affluent and the effluent: cleaning up failures in water and sewage regulation.' House of Lords (March 2023).*

21 *In practice, competitive conditions in each market would determine the allocation of gains between cost and quality.*

The above discussion is pertinent to the setting of frontier shift in the water industry at PR24 (which is the focus of this report). Specifically, the key issue is that the *total* efficiency challenge companies are set (catch-up and frontier shift) also includes the efficiency gains they must make when tasked with delivering quality improvements (as per the performance commitments) out of base funding. We discuss this more fully in Section 3E.

Figure 3: Illustration of four components of efficiency gains



Source: Economic Insight

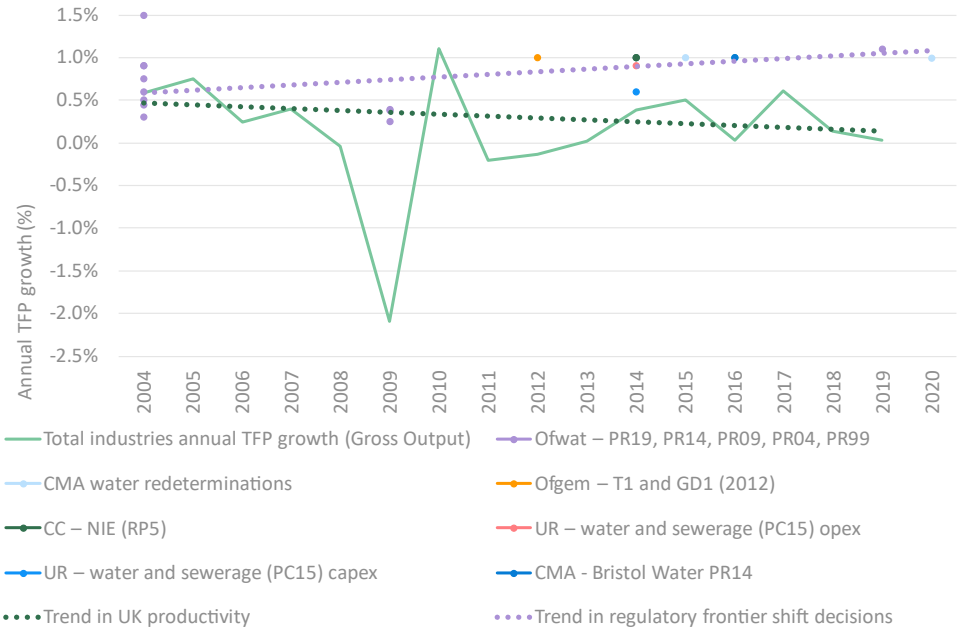
2B. Frontier shift and observed productivity

Whilst productivity in the UK has fallen over time, the frontier shift challenges set at more recent regulatory decisions in energy and water have risen. Figure 4 shows a *downward* trend in TFP growth for the UK, contrasting with an *upward* trend in the frontier shift challenge set by regulators, in both the water and energy sectors. Furthermore, regulatory decisions to set a 'higher' frontier shift actually coincide with a structural break (and marked decline) in UK productivity performance, following the 2008 financial crisis.

Over the last 20 years, frontier shift challenges have been as low as 0.25% (PR09 base opex), with the challenge only moving to around the 1% level at the time that the PR14; ED1; and PC15 decisions were made. It is also notable that older regulatory determinations are consistent with sectoral regulators taking the view that regulated industries are likely 'less productive' than the 'average' firm (as reflected in the UK's

overall TFP performance); whereas more recent determinations suggest regulators now consider these same industries are likely 'more productive' than the average firm. There is no intuitive explanation for this apparent change in expected relative performance.

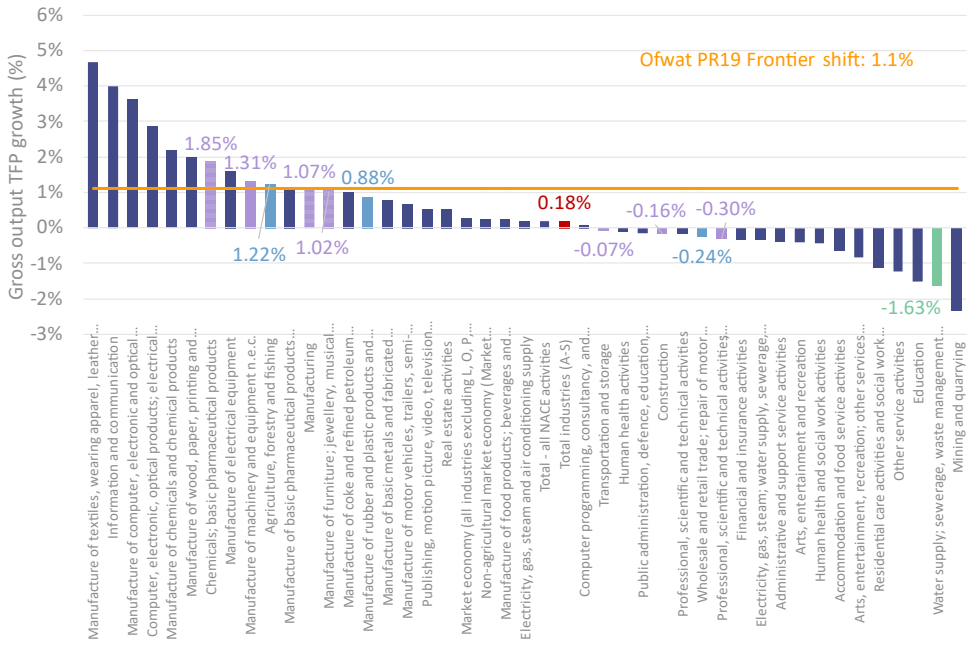
Figure 4: Falling UK productivity; increasing regulatory frontier shift decisions



Source: Economic Insight analysis

Specifically in relation to Ofwat's PR19 frontier shift challenge (1.1%), Figure 5 shows how this assumed frontier shift sits, relative to observed TFP growth of other sectors between 1995 and 2019. As can be seen, only 12 of 46 sectors experienced TFP growth of at least 1.1% (and many of these, as one would expect, relate to high-tech industries, such as telecoms; chemicals; and computing). Furthermore, Figure 5 shows (in red) that average annual TFP growth for "Total industries" between 1995 and 2019 was 0.18% (which is significantly lower than Ofwat's PR19 challenge of 1.1%). We provide further examples in Annex 1. Annex 1 also provides additional details of the colour coding in Figure 5, which is used to identify our comparator choices, as explained in Chapter 5.

Figure 5: Sector level gross output TFP growth (1995 to 2019)



Source: Economic Insight analysis of EU KLEMS data

Notes: We have not included "Telecommunications" in this chart in order to improve readability, as its average TFP growth is 12.9%.

Put another way, Ofwat's position suggests that the water industry should have productivity growth well above most other industries in the UK. One must therefore consider how plausible that implied relative performance is.

Specifically, one might expect industries with very high TFP to have certain characteristics. For example, 'tech industries' tend to have high productivity (i.e. because, by definition, they have high rates of technological change / and / or high utilisation of technology, which drives greater productivity growth than the UK industry average). Consistent with this, some of the industries that outperform most in the data are: computing; communications; and electrical equipment sectors (again, as shown in Figure 5). It is intuitively questionable as to whether the water industry could be similarly characterised.

In the above context, we note that in its PR24 Draft and Final Methodologies, Ofwat specified that it plans to set a *"stretching"* frontier shift challenge at PR24.[22]

2C. Treatment of frontier shift at PR19

In the following two sections, we consider the approaches taken by Ofwat and the CMA at PR19 in arriving at decisions on: (i) an overall level of frontier shift; and (ii) the scope of frontier shift, i.e. the costs to which it should be applied.

[22] *'Creating tomorrow, together: Our final methodology for PR24 Appendix 9 Setting expenditure allowances.' Ofwat (December 2022); page 35.*

Level of frontier shift

At PR19, Ofwat and the CMA set the following frontier shift challenges:

- Ofwat Final Determinations: 1.1% (down from 1.5% in its Draft Determinations).
- CMA Redeterminations: 1.0%.

In its FD, Ofwat described its choice of a 1.1% frontier shift as being a *"stretching but achievable challenge for water companies."*[23] The CMA similarly characterised its choice of a 1.0% frontier shift, stating that it wanted to "*to ensure our estimate remained achievable but stretching."*[24] In selecting these values, both Ofwat and the CMA chose estimates from the top of their derived ranges (0.6%-1.2% and 0.3%-1.2%, respectively).

In setting their respective challenges, Ofwat and the CMA considered the following:

- **Embodied change**. Both Ofwat and the CMA considered that, since evidence suggests that TFP estimates do not fully capture embodied technological change, frontier shift estimates based on TFP would be understated. We discuss the embodied change issue in Sections 3C and 6B.
- **Totex framework**. Ofwat commissioned a report by KPMG, which claimed that the recent addition of a totex approach to water regulation could unlock additional ongoing productivity gains of 0.2% to 1.2% pa (i.e. *'over and above'* the above-mentioned range).[25]
- **Relative productivity in water**. The CMA suggested that, despite low levels of UK productivity growth since the financial crisis, the water sector may be less affected by this than other sectors – we consider this argument in Section 4E.

Scope of frontier shift

In addition to determining the level of frontier shift, regulators must determine the 'scope' of costs to which it is applied. At PR19, Ofwat and the CMA applied a frontier shift challenge to cost categories as follows:

- **Modelled wholesale costs**. Frontier shift was applied to all of these costs.

[23] *'PR19 slow track draft determinations: Securing cost efficiency technical appendix.' Ofwat (December 2019); page 177.*
[24] *'PR19 slow track draft determinations: Securing cost efficiency technical appendix.' Ofwat (December 2019); page 177.*
[25] *'Innovation and efficiency gains from the totex and outcomes framework.' KPMG (June 2018).*

- **Unmodelled wholesale costs**. In its FD, Ofwat also applied frontier shift to all of these costs. In contrast, the CMA did not apply frontier shift to unmodelled wholesale costs that it consider to be mostly outside of management control (e.g. business rates and abstraction charges).[26]

- **Enhancement costs**. Ofwat applied frontier shift to a selection of these costs, specifically those that corresponded to larger and more common work programmes across companies. This was on the basis that these had greater potential for ongoing efficiency gains than smaller, less homogenous, programmes. The CMA adjusted this approach and applied frontier shift to all enhancement costs, as it considered that the frontier shift challenge was derived using TFP estimates from comparator sectors; and these included productivity gains made from all inputs, including enhancement expenditure. The CMA also undertook a review of companies' business plans to determine the extent to which ongoing efficiency gains had already been accounted for within enhancement. This was in order to prevent the risk of a double-count. The CMA considered that evidence in business plans was often inconsistent and unclear, noting that *"in the future, there may be a benefit in clarifying the basis for the reporting of these figures more explicitly, in order to avoid factual disputes of this nature (such as double-counting)."*[27]

- **Retail**. In its FD, Ofwat also considered applying frontier shift to retail costs, but chose not to (since these were partly based on forward-looking costs that *"reflect significant efficiency improvements on historical expenditure")*.[28]

2D. Whether to adjust for innovation funding

The question of whether to adjust frontier shift estimates for innovation funding has been raised by Ofwat in its PR24 Draft and Final Methodologies. Specifically, Ofwat has said that it will consider *"efficiency improvements driven by the £200 million innovation fund"*[29] when setting a frontier shift estimate at PR24.

At RIIO-GD2, Ofgem's application of an innovation uplift to its frontier shift challenge innovation fund was a key part of the appeals to the CMA. GEMA initially applied an upwards adjustment of 0.2% to *"reflect the extra innovation funding companies received from consumers."*[30] However, the CMA subsequently removed this uplift at appeal.

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26 *'Anglian Water Services Limited, Bristol Water plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations Final report.' CMA (March 2021); paragraphs 4.628-4.629.*

27 *'Anglian Water Services Limited, Bristol Water plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations Final report.' CMA (March 2021); paragraph 5.742.*

28 *'PR19 slow track draft determinations: Securing cost efficiency technical appendix.' Ofwat (December 2019); page 177.*

29 *'Creating tomorrow, together: Our final methodology for PR24 Appendix 9 Setting expenditure allowances.' Ofwat (December 2022); page 38.*

30 *'Cadent Gas Limited, National Grid Electricity Transmission plc, National Grid Gas plc, Northern Gas Networks Limited, Scottish Hydro Electric Transmission plc, Southern Gas Networks plc and Scotland Gas Networks plc, SP Transmission plc, Wales & West Utilities Limited vs the Gas and Electricity Markets Authority Final determination Volume 2B: Joined Grounds B, C and D.' CMA (October 2021); paragraph 7.4.*

In our view, the key issues pertinent to this are as follows:

- **Materiality**. If the overall size of innovation funding is small, relative to overall industry costs, its scope to affect productivity will be limited (and vice-versa).

- **The proportion of innovation funding that is intended to deliver efficiencies for companies (as opposed to supporting positive externalities)**. At RIIO-GD2, companies submitted evidence to show that *"fewer than 50% of projects were primarily focused on cost reduction,"*[31] with much of the funding focused on achieving positive externalities (e.g. environmental benefits). Put simply, if the funding is not actually focused on delivering company efficiency savings, it is irrelevant to frontier shift.

- **Existing R&D rates in the water industry relative to comparator sectors**. If existing rates of R&D in water (absent the innovation fund) are significantly lower than in comparator sectors, then TFP estimates from comparator sectors would display higher productivity gains than those that are achievable for water. As such, if the total innovation funding only increases the rate of innovation in the water industry, up to a level that is equivalent to comparator industries, then this would suggest that all of the potential ongoing efficiency gains resulting from the innovation funding are already captured in TFP estimates – therefore pointing away from any innovation uplift. This occurred at RIIO-GD2, with GEMA assuming that the innovation funding was entirely incremental to R&D in other sectors (i.e. that existing R&D rates in the energy sector were equivalent to those in comparator sectors). However, evidence presented to the CMA showed that existing R&D rates were in fact lower in energy than in comparator sectors.

- **The extent to which business plans already account for efficiency benefits from innovation funding.** In order to prevent a double-count of ongoing efficiency gains, an adjustment for innovation funding should only be applied if companies' business plans do not already include these gains. We note that, at RIIO-GD2, the CMA considered that GEMA had double-counted these benefits.

We now briefly consider the above in relation to the water industry at PR24. Taken together, these points suggest that an adjustment to frontier shift for the innovation fund would be inappropriate.

- The total size of the innovation fund (£200m)[32] relative to total industry totex set by Ofwat in its PR19 FD (£49.6bn)[33] is approximately 0.4%. As such, it is doubtful that the fund can materially affect productivity.

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31 *'Cadent Gas Limited, National Grid Electricity Transmission plc, National Grid Gas plc, Northern Gas Networks Limited, Scottish Hydro Electric Transmission plc, Southern Gas Networks plc and Scotland Gas Networks plc, SP Transmission plc, Wales & West Utilities Limited vs the Gas and Electricity Markets Authority Final determination Volume 2B: Joined Grounds B, C and D.' CMA (October 2021); paragraph 7.805.*

32 *'Creating tomorrow, together: Our final methodology for PR24 Appendix 9 Setting expenditure allowances.' Ofwat (December 2022); page 38.*

33 *'PR19 slow track draft determinations: Securing cost efficiency technical appendix.' Ofwat (December 2019); page 8.*

- Ofwat has stated that the: *"overarching objective of the Fund is that the sector can better meet the needs of, and create long-term value for, customers, society and the environment through innovation."*[34] As such, the proportion of innovation funding provided to water economies that is intended for efficiency gains, relative to positive externalities, is unclear.

- We have reviewed competitions run as part of the innovation fund, and the extent to which they directly address company cost reductions (rather than externalities, e.g. environmental benefits) is unclear.[35]

2E. Aims of our study

In the above context, a consortium of water companies[36] commissioned Economic Insight to provide an independent report on the scope for frontier shift at PR24. The primary aim of this study is to reach our own independent and robust view on the appropriate range for frontier shift at PR24. In order to do this, we:

  - review data on recent economic conditions, so as to determine the appropriate time period for our analysis; and

  - provide a set of criteria that we apply in order to reach a view on an appropriate set of comparable sectors to the water industry.

We then build on the analysis of Ofwat and the CMA, by using more recent versions of the EU KLEMS and ONS productivity datasets to arrive at our frontier shift estimates.

Further to our overarching objective, our work also aims to:

- Provide clarity as to the economics theory relevant to measuring frontier shift; relatedly, 'what' the existing productivity datasets measure; and hence, 'how' they should be interpreted.

- Identify the key conceptual considerations in determining appropriate methods for estimating frontier shift in practice.

- Set out clear criteria to inform the 'in practice' choices that must be made when applying said methodology.

- Provide clarity as to 'what' the total efficiency challenge is under the regulatory model for the water industry (and 'how' this is set). Here, the key issue is how one takes into account the efficiency challenge associated with improving outcomes out of base funding.

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[34] *Please see: https://waterinnovation.challenges.org/ofwat-innovation-fund/about-the-fund/.*

[35] *For instance the "Innovation in Water Challenge"; "Water Breakthrough Challenge"; and "Water Breakthrough Challenge 2". Please see: https://waterinnovation.challenges.org/past-competitions/.*

[36] *Affinity Water; Anglian Water; Bristol Water; Northumbrian Water; Severn Trent Water; South East Water; South Staffordshire Water; South West Water; Southern Water; Thames Water; United Utilities; Welsh Water; Wessex Water; and Yorkshire Water.*

3 Total factor productivity

In this chapter we: (i) provide an overview of total factor productivity (the metric used at PR19 to determine the frontier shift); (ii) set out how it is measured; (iii) explain the difference between TFP and frontier shift (and the key issues in inferring the latter from the former); and (iv) explain how the performance commitments set in the water industry also form part of the overall efficiency challenge, and the implications of this for frontier shift.

3A. Overview

Productivity gains made from ongoing efficiency (frontier shift) are most frequently assessed through TFP analysis. TFP is a measure that '*captures changes in performance attributable to increased physical production of outputs relative to inputs*'.[37] Put simply, TFP growth measures the change in outputs that cannot be explained by changes in the quantity of inputs used. It is chosen over other measures, such as labour productivity, because it captures all the measurable factors of production that it is possible to include. Inputs are measured as capital and labour, whilst output is usually a measure of aggregate economic output. TFP thus represents the change in output that cannot be explained by changes in the quantity of capital and labour.[38] In the PR19 FD and CMA redeterminations, the EU KLEMS dataset (which provides a measure of TFP) was used to arrive at estimates for frontier shift.

In addition to TFP data, multifactor productivity (MFP) data is available from the ONS, which differs slightly to TFP – we discuss this in more detail in Section 3B and Annex 2. In this report, our frontier shift ranges are based on EU KLEMS TFP data,[39] and so we do not use ONS MFP estimates to inform any of our frontier shift estimates. Therefore, throughout the remainder of this report, whenever we refer to TFP we are also referring to MFP.

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37 '*Regulatory Price Performance, Excess Cost Indexes and Profitability: How Effective is Price Cap Regulation in the Water Industry?*' *Maziotis, A; Saal, D; Thanassoulis, E (September 2009) page 5.*

38 *And so, TFP growth is considered to comprise of intangible factors, such as technological change; R&D; and synergies.*

39 *This comprises TFP data from both the NACE II (1995-2019) and NACE I databases (1970-2007). We note that an updated version of the EU KLEMS NACE II database was released in February 2023. This database includes an extra year of data but, in addition, compared to the previous iteration of this database, much of the data has changed for the same years and the same comparators. We have raised a query with EU KLEMS as to exactly what has driven this change.*

3B. Measuring TFP in practice

TFP can be assessed using two different methodologies: (i) value added (often labelled as 'VA'); and (ii) gross output (often labelled as 'GO').[40] These methodologies produce different productivity values. Therefore, when selecting which to use, one must assess the advantages and disadvantages of each, relative to the objectives at hand. Below, we provide an overview of each of these metrics.

- **Value added TFP**. The value added approach excludes intermediate outputs (materials, energy and services used up in the process of production), meaning that value added productivity measures the rate of change of real value added, compared to the rate of change of primary inputs (i.e. labour and capital). In practice, this is the difference between prices and costs.
  - Advantages: Most academic literature expresses the view that TFP is easier to calculate accurately using this method.[41] The rationale is that a value added approach (when compared to a gross output methodology) avoids the risk of double-counting intermediate outputs, which may vary greatly by industry and can be difficult to quantify.[42] A value added method can also account for differences in the quality of inputs, through its inclusion of prices.[43]
  - Disadvantages: This method can provide a distorted view of the impact of technology, as it removes the effect of changes in the prices of raw materials. In general, TFP estimates are 'higher' when a value added methodology is used. This is because the exclusion of intermediate goods and services can create an upward bias. Research has found that the value added methodology amplifies the size of TFP by between two and three times for most industries.[44] Whilst, in the short-term, this magnification factor can be approximated by the share of primary inputs within total inputs, this does not work over the longer term, where the share of primary inputs can vary.[45]
- **Gross output TFP**. The gross output approach includes intermediate outputs (materials; energy; and services, used up in the process of production). It measures the difference between the rate of change in the volume of outputs and the weighted average rate of growth of all combined inputs.

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40 *In this report, these labels may be used in equations and graphs, but not in the main body text.*

41 *'Productivity measurements in Indian manufacturing: A comparison of alternative methods.' Kathuria.V; (2011).*

42 *'The quadratic approximation lemma and decompositions of superlative indexes.' Diewert, W E; (December 2002).*

43 *'Sources of output growth in Bangladesh food processing industries: a decomposition analysis.' Salim, R A; Kalirajan, K P. (September 1999).*

44 *'On the Relationship between Gross Output-based TFP Growth and Value Added-based TFP Growth: An Illustration Using Data from Australian Industries.' Calver, M; (2015).*

45 *'On the Relationship between Gross Output-based TFP Growth and Value Added-based TFP Growth: An Illustration Using Data from Australian Industries.' Calver, M; (2015).*

- Advantages: The advantage of this method is that it can separate primary inputs from intermediate inputs.[46] As above, primary inputs are defined as capital and labour, whilst intermediate inputs are energy; materials; and services. In practice, this allows the model to separate components like fuel and raw materials, from labour and capital. According to Norsworthy and Jang (1992), this offers an advantage over the value added methodology, particularly when there is rapid change in intermediate input prices, such as during the 1970s energy crisis.[47]
- Disadvantages: It is more complicated to calculate than the value added approach; and the data required to calculate gross output accurately is harder to collect.

In practice, TFP data is more frequently presented using the value added methodology, given that is easier to calculate. Specifically, both the EU KLEMS and ONS datasets use a value added methodology.

The EU KLEMS dataset also presents gross output figures (which, in the case of the UK, are based on the value added measures produced by the ONS, which are then adjusted to gross output). The use of gross output is aligned with Ofwat's position at PR19, where Europe Economics stated that gross output is a more accurate measure of frontier shift than value added, since *"Ofwat intend to apply the frontier shift estimates to totex or botex, both of which include expenditure on intermediate input"* and *"[a] gross output measure of TFP is also less sensitive to changes in the degree of outsourcing over time. Therefore, for sectors in which outsourcing is important, the gross output TFP measure is typically preferable."*[48] We also note that, in the EU KLEMS database, the water industry exhibits an average ratio of 0.46 between intermediate inputs and gross output (between 2015 and 2019),[49] relative to a median across all sectors of 0.48 – implying that intermediate inputs are important for the water sector.

In light of the above, we consider that **the gross output approach more appropriately reflects the scope for achievable frontier shift in the water industry**, than the value added approach.

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46 *'Productivity measurements in Indian manufacturing: A comparison of alternative methods.' Kathuria.V; (2011).*

47 *'Productivity measurements in Indian manufacturing: A comparison of alternative methods.' Kathuria.V; (2011).*

48 *'Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations.' Europe Economics (December 2019); page 76.*

49 *Data on the intermediate inputs was from the tab "II_CP", and gross output from the tab "GO_CP", both available from the file "National Accounts" for the UK here: https://euklems-intanprod-llee.luiss.it/download/.*

3C. Total factor productivity vs Frontier shift

Whilst it is established practice for TFP metrics to be used to derive estimates of ongoing efficiency (i.e. the frontier shift challenge), it is important to note the differences between the two measures. Whilst frontier shift represents the efficiency improvements that it is possible for even the most efficient firms to make over a period of time, (as above) TFP merely measures the change in the quantity of outputs relative to a change in the quantity of inputs (i.e. the change in outputs that cannot be explained by a change in inputs). Due to TFP's broader definition, there is debate over what is captured within the metric; and the most appropriate way to interpret and apply it, for regulatory price control setting purposes.

The main issues are: (i) TFP captures other efficiency savings that can be achieved, beyond just frontier shift; (ii) the potential understatement of frontier shift due to embodied change; (iii) the fact that the overall TFP estimate is highly sensitive to the choice of time period over which comparators are assessed. We discuss (i) and (ii) in more detail below; and we address issue (iii) in Chapter 4.

TFP captures multiple efficiency savings

As set out in the proceeding section, TFP growth measures the change in the ratio of outputs to inputs. This means that it is a measure of *all* efficiency improvements that have been made. Although ongoing efficiency (which is what the frontier shift challenge is intended to represent) is one way that a firm could achieve TFP growth, it is also possible to achieve growth through other efficiency improvements. We set out these efficiencies below.

- **Catch-up efficiency.** Specifically, TFP estimates also include catch-up gains, which are distinct from frontier shift gains, as explained in Section 2A. Specifically, if a firm, or firms, within an industry are not already operating at the efficiency frontier, TFP growth can be achieved via a firm 'catching-up' to the frontier. Catch-up efficiency will be present for <u>all</u> industries to some extent, as none are *perfectly* efficient (and no market is perfectly competitive), meaning that there will always be some firms that are operating behind the frontier.

- **Economies of scale**. These occur in scenarios where unit costs rise or fall, depending on whether a firm's output volume is increasing or decreasing. If an industry benefits from economies of scale, then an increase in inputs would lead to a more than proportionate increase in outputs, as the unit costs of producing the output would fall. This would show an improvement in TFP growth. However, it would not be caused by an outward shift in the production frontier (i.e. it would not be equivalent to frontier shift).

Following from the above, when using TFP estimates to determine the appropriate frontier shift challenge, it is important to consider these issues; and how they can be mitigated (e.g. through careful comparator selection). In Table 2, we summarise the

implications for inferring frontier shift from TFP, arising from the above, and the potential mitigation options.

Table 2: Impact of efficiencies included in TFP estimates and available mitigations

Efficiency	Impact	Rationale	Potential mitigation
Catch-up	TFP will overstate frontier shift	This is because no sectors are perfectly competitive. This means that in any industry (used as a comparator) there are always some firms that operate behind the efficient frontier, so their TFP figures will contain a degree of catch-up.	To mitigate this as best as possible, comparators can be selected that operate in as 'competitive' markets as possible, such that fewer firms are a long way from the efficiency frontier.
Economies of scale	Symmetrical	Economies of scale will either over or understate frontier shift, depending on whether comparators benefit from greater, or smaller, scale effects (relative to the water industry), respectively.	To best control for this, comparators can be chosen which have similar: (i) proportions of fixed costs to the water industry (as there is generally a relationship between the proportion of fixed costs and achievable scale effects); and (ii) output growth rates (as scale effects may vary over time).

Source: Economic Insight analysis

The potential understatement of frontier shift due to embodied change

When measuring potential frontier shift, it is important that both embodied and disembodied technological change are included, in order that the full scope for productivity gains is captured:

- **Embodied** technological change relates to productivity gains generated by improvements in the design and quality of new capital equipment, and intermediate products, compared to using older iterations of the same equipment (i.e. embodied change captures the use of *new* technology and assets).
- **Disembodied** technological change relates to gains made without improvements arising from the use of new equipment (i.e. disembodied change captures gains from the use of *existing* technology and assets).

TFP estimates by definition *include* disembodied change, meaning that the key considerations here relate to embodied change. There are two main questions when considering embodied change in relation to a frontier shift challenge for the water industry, as derived from TFP data. Namely:

  - what is the amount of embodied change that is included in / excluded from TFP?; and

– what is the scope for the water industry to make TFP gains from embodied technological change, relative to any comparators used to inform the frontier shift challenge?

Below, we discuss each in turn.

The amount of embodied change that is included in / excluded from TFP

A TFP measure that *excludes* embodied change in effect has an input measure that includes quality adjustments that reflect the benefit of new technologies, but which are not reflected in the change in outputs. As a result, the *'true'* productivity gains for that sector would be understated. The amount of embodied change that is *include*d in TFP is, however, unclear (and is the subject of considerable debate in the academic literature). It is *generally* considered that TFP does not *fully* capture embodied technological change; but, as it is difficult to entirely account for quality changes in the inputs, it is likely that *some* embodied change will still be included within TFP. It is also likely that the relative share of embodied change that is captured in TFP varies considerably by sector. Figure 6 shows how gross output TFP growth in the EU KLEMS database (both NACE I and NACE II) has changed over time for the UK as a whole. As can be seen, productivity growth is highly volatile, with frequent peaks and troughs. If TFP included *only* disembodied change, then the entirety of these movements would be due to shifts in the way that companies use *existing* infrastructure / assets. Therefore, the processes used by companies when producing outputs based on their current inputs would need to improve and then worsen substantially (often within the space of just a few years).

Figure 6: TFP growth data - EU KLEMS NACE I and NACE II databases

Source: Economic Insight analysis of EU KLEMS data

We consider the above is unlikely to be the case, given that this would require companies to: acquire knowledge / establish best practices / make technological

progress, relating to their use of *existing inputs,* and then suddenly *'go backwards'.* We consider it more plausible that the large observable movements in TFP at the UK level are consistent with the data reflecting embodied technological change (at least to some degree). Indeed, this point has also recently been made by the Bundesbank, when analysing productivity across the EU:

> *"The long-term development of TFP is sometimes also seen as an indicator of disembodied technological progress. In the short term, though, it is difficult to make such an interpretation. Even in the case of severe economic downturns, decreases in technological progress* [from existing technology / assets] *can, if at all, only be regarded to a very limited extent as a plausible explanation for calculated TFP declines. Furthermore, due to its residual character, the contribution of TFP can also pick up other influences on labour productivity. Against this background, there is good reason to interpret TFP more broadly and to view it as a metric of production efficiency"*[50] [emphasis added].

Specifically, the Bundesbank is proposing that technological progress / decline from the utilisation of *existing* assets (i.e. disembodied change) can only explain a small part of the extreme changes in TFP across Europe. As a result, technological progress / decline from the utilisation of *new* assets (i.e. embodied change) must explain the majority of these changes.

The academic literature also makes the above point, and highlights the complexity in determining precisely 'what' TFP measures. Hulten (2000) provides the following helpful characterisation:

Firstly, on the intuition for why one might *not* think TFP fully captures embodied technological change, the author refers to the Solow Paradox. This refers to the 'new economy' critique of TFP statistics, which relates to various arguments made that the slowdown in productivity seen in the USA in the late 1960s and early 1970s was at odds with perceived benefits from technological change that occurred at that time (e.g. the computing revolution). In relation to this, Robert Solow in 1987 famously argued that: *"[y]ou can see the computer age everywhere but in the productivity statistics."*[51] In his paper, Hulten summarises the point more broadly as: *"one might well say that we see new technology everywhere but in the productivity statistics."*[52]

Secondly, and on the other hand, Hulten explains the counterpoint: *"However, there is another 'new economy' paradox that has been largely overlooked: if the missed quality change* [arising from new technology] *is of the magnitude suggested above* [an upward bias of 0.6 percentage points in CPI per year to account for quality improvements], *the quality of the goods in past centuries – and the implied standard of living – must have been much lower than implied by official (and allegedly quality-based) statistics. Indeed, taken to its logical conclusion… quality adjusted average income in 1774…* [would be] *dubiously*

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50 *'The slowdown in euro area productivity growth,' Deutsche Bundesbank Monthly Report (January 2021); page 20.*
51 *'Total factor productivity: a short biography,' Hulten, C; NBER (January 2000); page 2.*
52 *'Total factor productivity: a short biography,' Hulten, C; NBER (January 2000); page 3.*

small."[53] Put simply, Hulten suggests that growth in average income has been so significant over time that, if this somehow completely excludes embodied change, the starting point (for average income) seems implausible.

He then summarises the above-mentioned two points as follows: *"In other words, conventional estimates of productivity growth are either much too large or much too small, depending on one's view of the matter. The truth undoubtably lies somewhere between the two extremes."*[54]

Further, as was detailed in Section 4B, economic growth and TFP are shown to be highly correlated. This is further consistent with embodied technological change being captured (to some degree) in the TFP data. The intuition for this is as follows. Firstly, embodied technological change (by definition) requires investment in new technology (i.e. investing in new assets). Secondly, therefore, its impact on productivity is likely time variant; and will be higher in periods of greater investment and lower when the opposite is true. Consequently, if TFP *fully* excluded embodied technological change, one would arguably not expect such a close correlation between TFP and GDP % growth (i.e. because an important 'time varying' driver was being omitted, which would give rise to a poorer fit between the variables). We recognise that this is a matter of degree.

Consistent with the above discussion, an overview of the EU KLEMS dataset sets out the following, *"[u]nder strict neo-classical assumptions, TFP growth measures disembodied technological change. In practice, TFP is derived as a residual and includes a host of effects such as improvements in allocative and technical efficiency, changes in returns to scale and mark-ups and technological change proper. All these effects can be broadly summarised as "improvements in efficiency", as they improve the productivity with which inputs are being used in the production process. In addition, being a residual measure, TFP growth also includes measurement errors and the effects from unmeasured output and inputs"*[55] [emphasis added]. In effect, the description implies that EU KLEMS TFP (and ONS MFP) estimates *mainly* (but not *exclusively*) reflect disembodied technological change.

Recognising the importance, but complexity, of this issue, we sought views from the ONS as to the appropriate interpretation of the data (noting that EU KLEMS draws on the ONS' data). In response, the ONS told us that: *"whilst multifactor productivity should measure just the disembodied change, we do think that there is likely some embodied change in the measure."*

In recent decisions, Ofwat, Ofgem and the CMA have all stated that, in their view, TFP largely excludes embodied change. The CMA took the view that the EU KLEMS TFP data "*did not seek to measure productivity growth resulting from changes in embodied technical change*".[56]

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53 *'Total factor productivity: a short biography.' Hulten, C; NBER (January 2000); page 3.*
54 *'Total factor productivity: a short biography.' Hulten, C; NBER (January 2000); page 4.*
55 *'An overview of the EU KLEMS Growth and Productivity Accounts.' European Commission (October 2007).*
56 *'Anglian Water Services Limited, Bristol Water plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations Final report.' CMA (March 2021); paragraph 4.553.*

From the above discussion, we summarise that the question of the extent to which embodied technological change is included in the TFP data has no clear cut or easy answer. However, for the purpose of determining the appropriate approach to inferring frontier shift from TFP data, some progress can, nonetheless, be made.

Recall that (as was discussed in Section 2B) gross output TFP estimates draw on inputs from labour, capital and intermediate outputs (with value added measures using just labour and capital). Quality adjustments are then applied to capital assets and intermediate inputs, in order to try to remove the effect of quality changes over time from these inputs (i.e. implying TFP would measure disembodied change).[57] However, there is likely a margin of error in this approach, such that not all of the 'quality' is removed (i.e. some embodied technological driven change remains). From this, we consider that TFP data for comparator sectors that use relatively more capital (and intermediate inputs), is likely to include a greater amount of embodied change.

Following from the above, rather than assume a 'blanket' adjustment for embodied change should be applied to any frontier shift derived from TFP data, we consider it more appropriate to consider the *specific comparator industries* being used. In Section 6B, we have therefore undertaken an initial assessment of the comparator sectors proposed under our analysis, in order to provide some indication of the extent to which embodied change may be included in their TFP data (relative to industries 'on average' in the UK).

This type of analysis provides a useful first step in determining 'how appropriate' an adjustment may be. However, it is objectively extremely challenging to determine precisely 'how much' of any comparator industries' embodied technological related productivity gains are captured in the TFP data.

The applicability of embodied change from comparator sectors to the water industry

Notwithstanding the inherent challenge under the first question above of identifying 'how much' of an industry's TFP is embodied technological change related, there is a second question as to the *relevance* of that to determining frontier shift for the water industry. This turns on one's view on the scope for embodied change in the water industry (and whether that is higher, or lower, than the comparator sectors of relevance). We explain this further in the following.

Setting aside the measurement challenge above, suppose one came to the view that a comparator industry could achieve embodied technological change related productivity gains of 0.3% pa, but only 0.1% of that was included in its TFP data (and suppose its annual average TFP was 0.5%). At face value, this would imply that, in

[57] *This adjustment is not applied to labour in the same way. Specifically, the labour input measure in the ONS MFP dataset is called the "Quality-adjusted labour input" (with further details provided in Annex 2). However, we note that the quality adjustment is different in this situation as it is intended to adjust the number of hours worked by employees, based on the factors listed above (i.e. their "quality"). Therefore, for this "quality" to increase over time, it would be necessary to adjust the mix of employees. In contrast to this, embodied change relates to changes in the quality of the same inputs over time, i.e. without changing the mix of inputs used.*

inferring a frontier shift challenge for the water industry from the comparator TFP data, one would need to make an upwards adjustment of 0.2% for (excluded) embodied technological change (i.e. 0.3% of embodied change related gains, less the 0.1% of that included in the TFP data = 0.2%). However, this is not necessarily correct. For example:

- If, in fact, the water industry could achieve *higher* embodied technological change related gains than the comparator of (say) 0.4% pa, the above adjustment would be too small.

- If, alternatively, the water industry could achieve *lower* embodied related technological change related gains than the comparator of (say) 0.1%, the above adjustment would be too large.

Thus, having come to a view on the 'extent' of embodied change captured in the comparator TFP data in the first place, one must secondly also consider the scope for the water industry to make embodied technological related gains on a forward-looking basis (relative to said comparators).

In Section 6B, we therefore undertake an initial assessment of the likely extent to which comparator sectors are similar to the water industry, in terms of their technological progress. We then use this to arrive at a high-level view of the extent to which any excluded embodied change, from the TFP estimates of our chosen comparators, is applicable to the water industry.

As per the first question, there is no straightforward way of 'quantifying' the forward-looking scope for embodied technological change in the water industry, relative to the comparators used when inferring frontier shift. However, as a general observation, we note that the water industry is characterised by high value capital assets that last for a long time, which are then replaced at the end of their lifecycle by (broadly) similar infrastructure assets. In other words, it is not, at first blush, an industry in which one would expect rapid technological change (i.e. one would not expect high embodied technological related gains, relative to other industries).

Summary of our views

We find that it is appropriate to consider applying an adjustment to frontier shift, to reflect the fact that embodied technological related change may not be *fully* captured in the TFP data. However, in light of the evidence, we caution against any 'broad brush' mechanistic upwards adjustment. Rather, an appropriate approach would be as follows:

- Firstly, with respect to the specific comparators used to infer frontier shift, consider the scope for embodied change to be excluded from the TFP data. More embodied change is likely captured in TFP for industries with higher capital intensity and more intermediate inputs.

- Secondly, come to a view on the likely scope for technological change in the water industry, relative to any comparators used above.

- Thirdly, take the findings from the above two steps into account when determining 'where' in the range of frontier shift estimate to select (rather than making any formal adjustment).

3D. CPIH will capture productivity gains to some degree

A further important consideration is that CPIH itself (which is used to index the RCV under the regulatory framework) must logically capture productivity gains. That is to say, CPIH is a broad measure of consumer inflation faced in the UK. The main drivers of general movements in consumer prices will be: (i) changes in underlying costs incurred in producing goods and services; (ii) changes in the demand and supply of said goods and services; and (iii) efficiency savings achieved by firms producing those goods and services.

The above is problematic to the extent that it may contradict Ofwat's approach to compensating companies for inflation at PR24. That is to say, at PR19, Ofwat's position was that CPIH likely compensated companies for input costs changes; and so the regulator only provided separate allowances for movements in input costs (real price effects) to the extent that those differed from CPIH. Under that logic, however, the same lens should be applied to frontier shift. That is to say, Ofwat should only set a challenge relating to frontier shift to the extent that the 'industry specific' frontier shift differs from the productivity gains already implicitly captured within CPIH.

It is therefore important that, at PR24, Ofwat applies an internally consistent approach between compensating companies for input cost inflation and the setting of a productivity (frontier shift) challenge. Absent this, there is scope to apply an inappropriately high frontier shift for companies, as productivity gains are effectively double-counted. We have not, within the scope of this report, sought to estimate the frontier shift challenge implicit in CPIH.

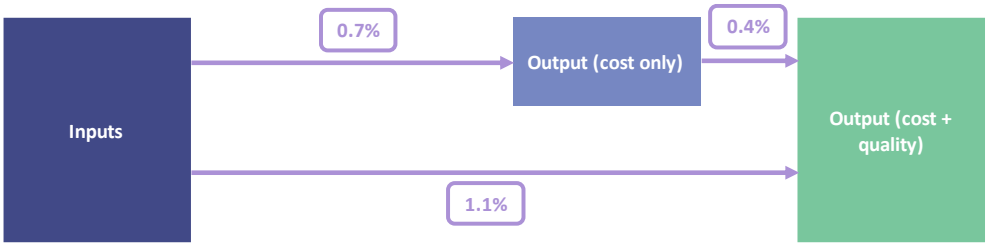
3E. Ofwat's performance commitments represent efficiency improvements

We note that the above consideration of quality-adjusted output is separable from the central, and more material, issue here: which is that the total of any efficiency estimates must be allocated between cost reductions and quality improvements, in order to avoid a double-count.

Ofwat sets companies performance targets to encourage firms to improve the quality of their output over time. As set out in the preceding chapter (see Section 2A), efficiency savings (both ongoing, and catch-up) can be achieved through a combination of both cost savings, and/or quality improvements. Therefore, Ofwat's performance commitments (quality improvement targets) represent an efficiency challenge, *in addition* to the efficiency challenge (both ongoing, and catch-up) as applied to costs. Put another way, as Ofwat is asking companies to achieve quality improvements out of base funding, the regulator is, by definition, requiring them to be achieved through efficiency. Thus, the performance targets themselves represent a mix of catch-up and ongoing efficiency for most companies (but for the 'frontier' company, implicitly only represent an ongoing / frontier shift challenge).

The consequence of this is that we need to calculate a 'cost-quality measure' of frontier shift, in order to avoid an overstatement of the appropriate level of frontier shift to apply to costs at PR24. That is, once the scope of total frontier shift water companies can make over the period has been determined (using TFP estimated from comparators), one needs to then determine what share of this will be delivered through quality improvements; and apply only the residual/remainder (should there be any) to cost reductions. Below, we present an illustrative example to help further explain the issue.

Figure 7: Illustrative example of cost-quality measure of frontier shift



Source: Economic Insight

With reference to Figure 7, suppose that Ofwat determined (as per PR19) that the total frontier shift challenge should be 1.1%. As explained previously, under the comparator method used to derive this, the 1.1% represents total gains that said comparator firms realised through various combinations of cost reductions and quality / output increases. Therefore, in order to avoid a double-count, it would be necessary to:

- Determine the total efficiency challenge implicit in the performance commitments set at PR24 (i.e. the improvements companies are being asked to make out of base costs).
- Determine what proportion of the above is frontier shift, as opposed to catch-up.
- And then only apply the residual / remaining amount of frontier shift to company base costs (and likewise, only apply the residual amount of catch-up to company base costs).

In the above example, suppose that the performance commitments translated to a frontier shift efficiency requirement of 0.4%; this would leave 0.7% of frontier shift to be allocated to reducing base costs (assuming 1.1% was the appropriate overall target for frontier shift). In this example, clearly the application of the entirety of the 1.1% frontier shift challenge to costs would be a double-count, as companies would (in addition) be required to make a further frontier shift saving of 0.4% under their performance commitments.

There are two methodological steps required in order to address this issue:

- the overall % efficiency challenge implicit in performance commitments must be estimated; and
- this must then be split between catch-up and frontier shift.

In principle, an appropriate way to measure the former would be as follows:

$$QE = \frac{(PCL - PL) * MCe}{Base\ totex}$$

Where:

- QE is the total % efficiency challenge a company is implicitly set under a performance commitment;
- (PCL – PL) is the difference between the target performance commitment level and a company's current actual outcomes performance; and
- MCe is an estimate of the efficient marginal cost of making the improvement.

Whilst, in principle, the above approach is straightforward, in practice in the water industry (under the current regulatory framework) it may be challenging. The main challenge relates to the estimation of marginal costs, which may be inherently difficult for so long as performance commitments are relatively 'narrow' (i.e. multiple, specific metrics) in a network industry, with a high degree of joint and common costs.

Notwithstanding the above practical considerations, the materiality of the issue should not be ignored at PR24. Indeed, it is plausible that the scale of efficiency savings implicit in the targeted quality improvements (performance commitments) are so large that there is no residual left over for cost efficiencies.

The allocation of any efficiency gains that companies are required to make under their performance commitments (once estimated as above) between catch-up and frontier shift is more straightforward, in that several practical methods likely exist. For example, one could simply take the 'benchmark firm' (or firms) as under Ofwat's base cost assessment, and then say that the totality of their required outcomes performance improvement (under their performance commitments) is the frontier shift element.

4 Time periods for analysis

In this chapter, we set out our choice of time periods for our analysis and rationale for selecting them. Specifically, we present: (i) the key considerations that need to be taken into account when determining time periods; (ii) recent evidence regarding the UK's economic performance; (iii) our resultant choice of time periods; (iv) a comparison with Ofwat's approach at PR19; and (v) a discussion of the relevance of lower recent productivity to the water industry.

4A. Key considerations

As economic performance and productivity are highly correlated, estimates of frontier shift are sensitive to the time period over which any comparator industry's TFP is assessed. When considering which time period(s) to use, there are several considerations that need to be taken into account. These are as follows:

- **Internal consistency**. It is important that the time period used to determine frontier shift is consistent with the time period (and assumed economic context) used to inform other key components of the price control (e.g. equity returns, given their correlation with productivity and growth). Therefore, this should be something that Ofwat considers when choosing the period for the purpose of deriving frontier shift estimates at PR24. In its Draft Methodology, Ofwat states "*while the water sector showed relatively strong productivity post privatisation with growth of 3 to 4% per year between 1994 and 2000, it appears to have stagnated since 2011 with weak growth since then*".[58] One interpretation of this is that Ofwat will favour pre-crisis time periods for its frontier shift analysis. If Ofwat does take this approach, however, it raises questions as to why (for the purpose of determining the cost of equity, for example) it would also not need to place similar weight on said time period.

[58] *'Creating tomorrow, together Consulting on our methodology for PR24.' Ofwat (July 2022); page 68.*

- **The structural break arising from the financial crisis**. The 2008 financial crisis coincides with a structural break in UK productivity (and consequently GDP growth) performance, worsening it substantially. Section 4B demonstrates that post financial crisis growth has not returned to pre-crisis levels. Until recently, data has not been available to assess a full business cycle affected by the financial crisis. However, following the publication of additional data, trough-to-trough analysis (using annual GDP growth data from the ONS and World Bank) now indicates a business cycle from 2010 until 2020 (shown in Figure 11 and Figure 12 below). When determining frontier shift on a forward-looking basis, it seems appropriate to place increasing weight on more recent time periods, given the clear persistence of depressed productivity performance in the UK (i.e. this is not a water industry specific issue). That we now have a full business cycle's worth of data post-crisis makes this more practical than previously.

- **The inclusion of full business cycles**. Because productivity is shown to be pro-cyclical, ideally the high and low periods of business cycles should be included within any time period used to estimate frontier shift. We have used estimates by the Economic Cycle Research Institute (ECRI) to determine the UK business cycles, in addition to the above-mentioned trough-to-trough analysis.

- **The utilisation of the data available**. Maximising the number of observations used in estimating frontier shift reduces the risk of outliers affecting the results.

The above points require (to some degree) trade-offs to be made when determining the estimation time period. Therefore, to understand which factors to prioritise, one must be clear on the question one is seeking to answer. In this case: *'what is the scope for frontier shift specifically over PR24?'*. As productivity and economic performance are well correlated, it is important to begin addressing this question by understanding the UK's likely economic outlook over the PR24 period, which we turn to below.

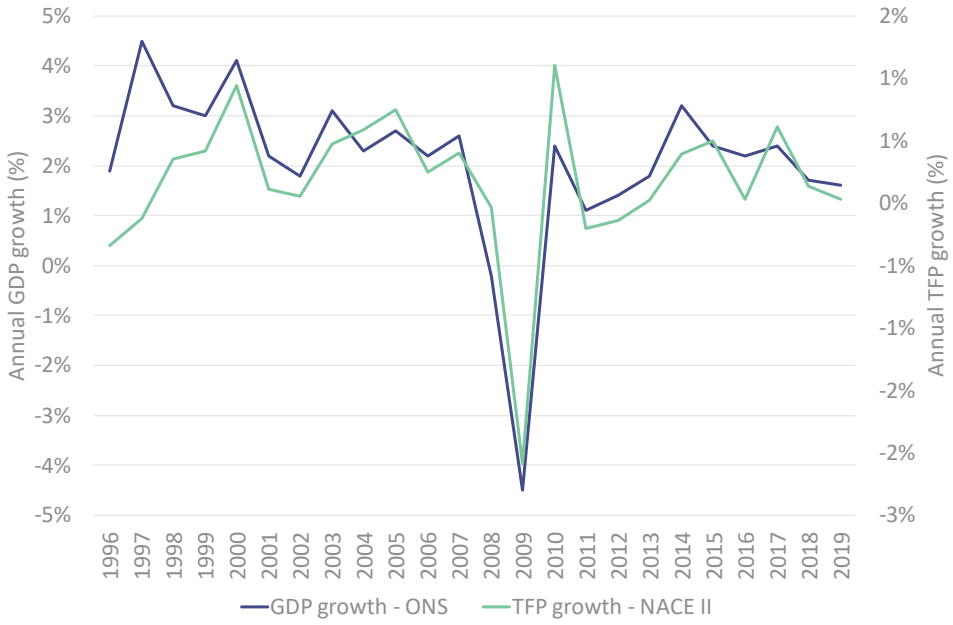
4B. Recent evidence of the UK economic situation

When choosing a historical period over which to estimate the frontier shift challenge using comparator data, it is important that this period shares similar characteristics with those forecast for PR24. Here, and as we show further below, a key point is the strong correlation between growth and productivity (as expected under economics theory and shown in previous empirical studies) in the UK. Consequently, if economic forecasts for the UK over the PR24 period are generally consistent with a continuation of low growth and productivity; then it would be appropriate to use an estimation period for TFP (frontier shift) that shares those characteristics. Put another way, it would seem 'odd' to use a period where growth and productivity were much higher.

Correlation between productivity and growth

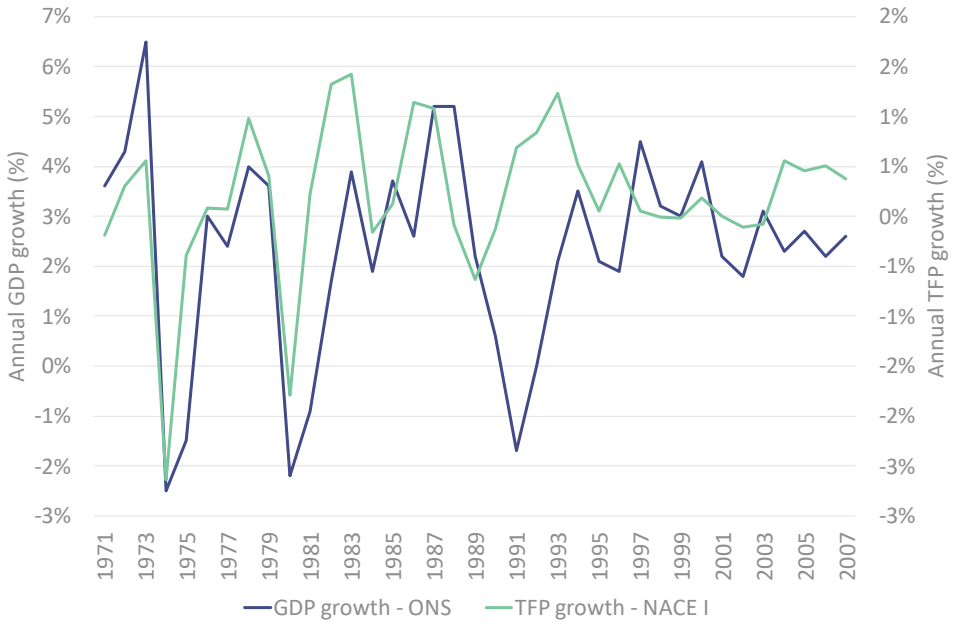
Figure 8, Figure 9 and Figure 10 show economic growth and productivity are strongly correlated with one another. This is the case whether using the TFP gross output growth data from EU KLEMS (NACE I and NACE II), or value added MFP growth data from the ONS.

Figure 8: Relationship between economic growth and productivity - NACE II TFP growth



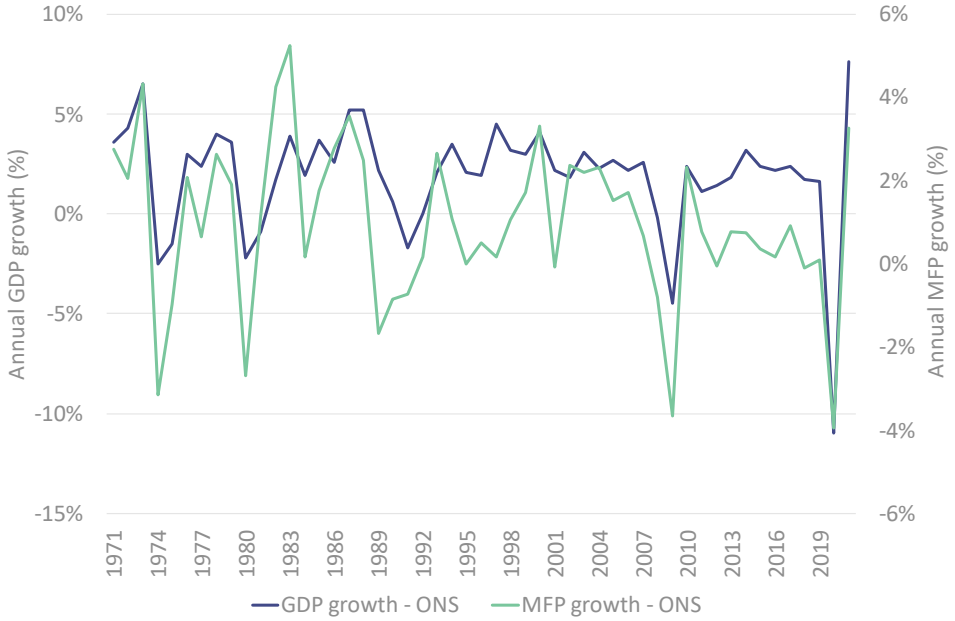
Source: Economic Insight analysis of ONS and EU KLEMS data

Figure 9: Relationship between economic growth and productivity - NACE I TFP growth



Source: Economic Insight analysis of ONS and EU KLEMS data

Figure 10: Relationship between economic growth and productivity – ONS MFP growth



Source: Economic Insight analysis of ONS and ONS MFP data

UK economic outlook

The UK economic outlook is fragile and uncertain, both over the immediate term and PR24. The economy is currently characterised by: significant levels of public debt;[59] high inflation;[60] rising interest rates;[61] low rates of business investment;[62] low to falling GDP growth;[63] relatively high levels of taxation (by historical standards);[64] and high rates of business closures.[65]

In Table 3, we have summarised published forecasts for UK real GDP growth over time from credible sources. However, limited inferences can be drawn from this as regards

[59] *The ONS states that: (i) "Public sector net debt excluding public sector banks (PSND ex) was £2,503.6 billion at the end of December 2022, which was an increase of £132.7 billion compared with December last year"; and (ii) "The extra funding required by government over the course of the coronavirus (COVID-19) pandemic, combined with reduced cash receipts and a fall in gross domestic product (GDP), have all helped to push public sector net debt at the end of December 2022 to 99.5% of GDP." Please see: https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/publicsectorfinance/bulletins/publicsectorfinances/december2022#debt.*

[60] *Please see: https://www.ons.gov.uk/economy/inflationandpriceindices/bulletins/consumerpriceinflation/december2022#consumer-price-inflation-rates; Figure 1.*

[61] *Please see: https://www.bankofengland.co.uk/boeapps/database/Bank-Rate.asp.*

[62] *The ONS has found that: "Business investment in Quarter 3 (July to Sept) 2022 remains below pre-coronavirus (COVID-19) levels at negative 8.1%". Please see: https://www.ons.gov.uk/economy/grossdomesticproductgdp/bulletins/businessinvestment/julytoseptember2022revisedresults#business-investment-growth-revised-down-as-levels-increase.*

[63] *Please see Table 3.*

[64] *The upper band of the 2022-23 basic income tax rate is 9% greater than in 2007-2009; and 35% greater than in 1999-2000. Please see: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1086426/Table-a2.ods.*

[65] *The ONS has found that: "The number of closures in Quarter 4 2022 is the second highest Quarter 4 figure since the start of the series in 2017, with only Quarter 4 2021 at a higher level. It is also the sixth quarter in a row where there have been more closures than creations." Please see: https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/bulletins/businessdemographyquarterlyexperimentalstatisticsuk/octobertodecember2022#business-closures.*

PR24, as only the OBR and Bank of England have published forecasts for 2025 or later. We also note that the OBR has a materially more optimistic forecast then the Bank; which again, indicates that caution should be exercised in interpretating these projections.

Table 3: Annual real GDP growth forecasts

Agency	Date of forecast	2023	2024	2025	2026	2027
HM Treasury	January 2023	-0.9%				
IMF	January 2023	-0.6%	0.9%			
OECD	November 2022	-0.4%	0.2%			
OBR	November 2022	-0.6%	1.2%	2.5%	2.6%	2.2%
Bank of England	November 2022	-1.5% (1.0%)	-1.0% (1.5%)	0.5% (2.0%)		
Average		**-0.8%**	**0.3%**	**1.5%**	**2.6%**	**2.2%**

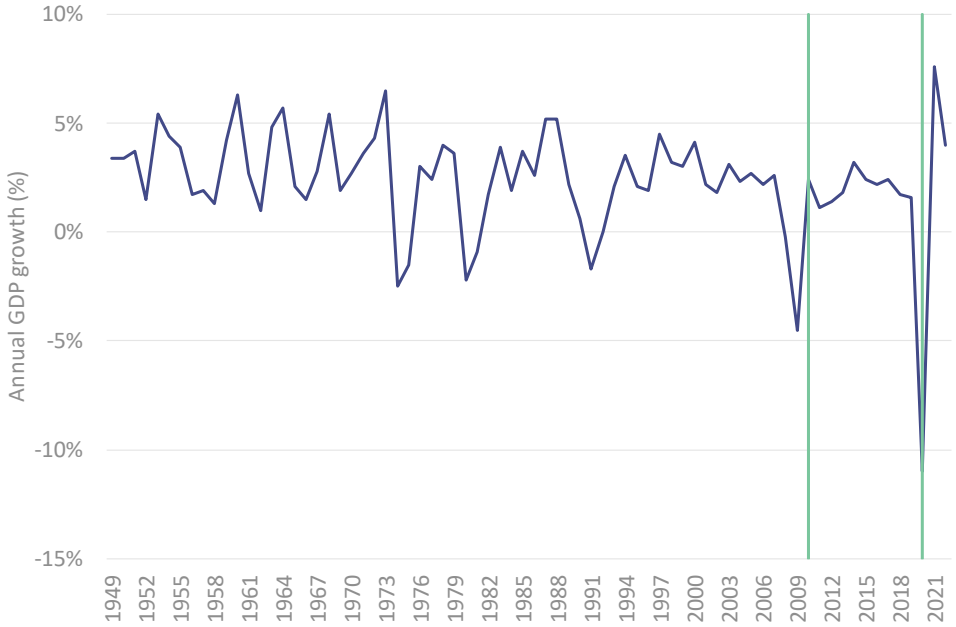
Source: (i) 'Forecasts for the UK economy: a comparison of independent forecasts.' HM Treasury (January 2023); (ii) 'WORLD ECONOMIC OUTLOOK UPDATE.' IMF (January 2023); (iii) 'Economic Outlook.' OECD (November 2022); (vi) 'Economic and fiscal outlook.' OBR (November 2022), Table A.3; and (v) 'Monetary Policy Report.' Bank of England (November 2022), Table 1.D.
Notes: (i) Figures for the OBR are provided on a financial year basis, which we have converted to calendar year by calculating a weighted average of the two calendar years based on the number of months in each; and (ii) world GDP figures are shown in brackets for the Bank of England forecasts.

As more forecast data becomes available, it will be helpful to see if a clearer view of economic performance for the UK emerges. At this point, we would merely highlight the long persistence of low productivity performance (15-years), which is common across the majority of UK sectors.

The most recent business cycle

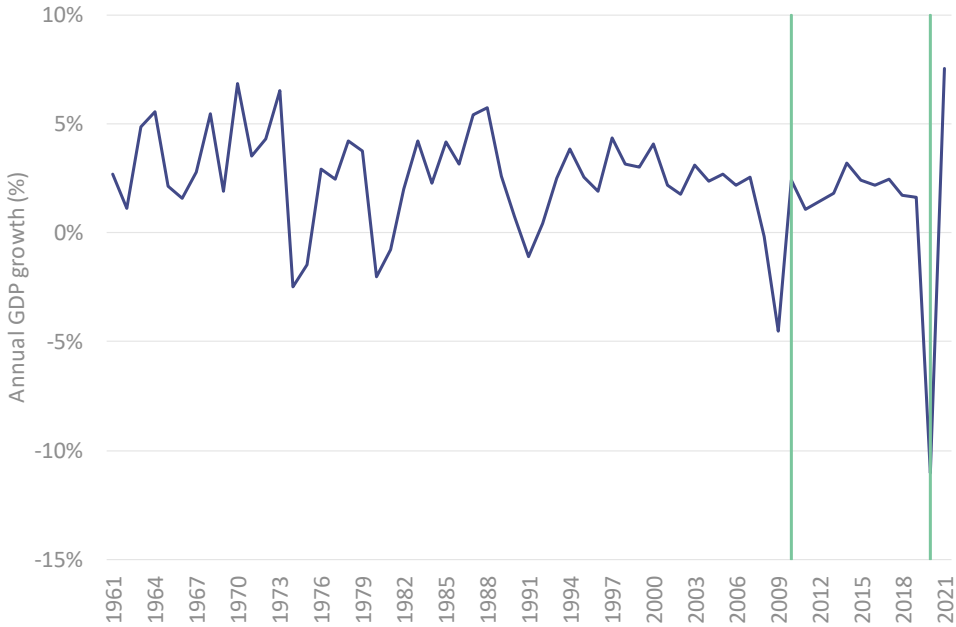
When Ofwat determined its frontier shift estimates for PR19, the UK economy was in the middle of a business cycle. Therefore, the regulator did not have a full view of TFP estimates for the most recent business cycle. However, we consider that this is no longer the case. Figure 11 and Figure 12 show UK annual GDP growth, based on data published by the ONS and World Bank, respectively. These cover the periods 1949-2022, and 1961-2021, respectively. Using trough-to-trough analysis, these figures both suggest that the most recent economic cycle is now 2010-2020 (with 2010 corresponding to the year after the end of the previous business cycle in 2009), meaning that this is now an important time period to consider for estimating frontier shift at PR24.

Figure 11: Recent business cycle based upon ONS annual GDP growth



Source: Economic Insight analysis of ONS data

Figure 12: Recent business cycles based upon World Bank annual GDP growth



Source: Economic Insight analysis of World Bank data

Further to the above, the ECRI has published the peak and trough dates for business cycles across 21 different countries, including the UK, since the 1970s. These dates are broadly consistent with the trough-to-trough analysis from Figure 11 and Figure 12, indicating that the most recent business cycle now corresponds to 2010-2020. These are reported in Table 4.

Table 4: ECRI UK business cycle peak and trough dates, 1974 - 2020

Business Cycle	Peak / Trough	Dates
1974-1975	Peak	September 1974
	Trough	August 1975
1975-1981	Peak	June 1979
	Trough	May 1981
1981-1992	Peak	May 1990
	Trough	March 1992
1992-2010	Peak	August 2008
	Trough	January 2010
2010-2020	**Peak**	**October 2019**
	Trough	**April 2020**

Source: Economic Insight analysis of 'Business Cycle Peak and Trough Dates, 22 Countries, 1948-2020.' (ECRI) (last accessed 9 February 2023).

4C. Our choice of time periods

Based on the evidence presented in this chapter, we consider that the frontier shift challenge at PR24 should be set mindful of: (i) the latest official UK economy forecasts, which are that economic conditions are likely to remain poor; and (ii) the now more than decade long persistence of low productivity. Both of these imply that one should take care not to attach undue weight to earlier time periods in which growth and productivity were (substantially) higher, given the aim to determine frontier shift over PR24. Nonetheless, we also consider that it is helpful to include data from periods that allow us to show what frontier shift *could* be, if the structural break in productivity from the financial crisis unwinds (to some degree) over the course of PR24, i.e. that incorporate data from before the financial crisis.

As such, we consider that the following represent 'plausible' time periods for our analysis:

- **Time Period 1: 2010-2019 (EU KLEMS NACE II)**. This covers the majority of the most recent business cycle (which we consider to be 2010-2020), noting that data on TFP estimates is unavailable in 2020 within the NACE II database. As a result, we consider that our frontier shift estimates using this period may, in fact, be biased upwards, given that the final year of poor economic performance in the UK is not captured in this period.

- **Time period 2: 1995-2019 (EU KLEMS NACE II)**. This covers the whole period for which data is available in the NACE II database, in addition to the majority of the two most recent business cycles (which we consider to be 1992-2009; and 2010-2020); noting, as above, that data is unavailable in 2020, or before 1995, in the NACE II database.

- **Time period 3: 1970-2007 (EU KLEMS NACE I)**. This covers the whole period for which data is available in the NACE I database, in addition to the vast majority of the four business cycles before the financial crisis (which we consider to be 1970-1974; 1975-1980; 1981-1991; and 1992-2009); noting that data is unavailable beyond 2007 in the NACE I database.

In Chapter 7, we set out the headline results of our analysis (with full results in Annex 3), in which we define three different ranges for our frontier shift estimates:

- **Plausible range**. This includes the following time periods: (i) **Time Period 1: 2010-2019 (EU KLEMS NACE II)**; (ii) **Time Period 2: 1995-2019 (EU KLEMS NACE II)**; and (iii) **Time period 3: 1970-2007 (EU KLEMS NACE I)**.

- **PR24 focused range**. This includes the time periods: (i) **Time Period 1: 2010-2019 (EU KLEMS NACE II)**; and (ii) a weighted average of **Time Period 2: 1995-2019 (EU KLEMS NACE II)** and **Time period 3: 1970-2007 (EU KLEMS NACE I)**.

- **Sensitivity analysis range**. This includes the three time periods listed in the *'plausible range'* above, but also the **1992-2007 (EU KLEMS NACE I)** time period.

4D. Comparison with Ofwat

Our choice of time periods for the EU KLEMS analysis are *relatively* similar to those adopted by Ofwat at PR19, as summarised in Table 5.

Table 5: Comparison of time periods between Ofwat's and our approach

Ofwat's time periods (used at PR19)	Our closest comparable period	Reason for Ofwat choice
1971-2007 (NACE I)	1970-2007 (NACE I)	To use the entire period for which NACE I data is available.[66]
1990-2007 (NACE I)	1992-2007 (NACE I)	To use data from the entirety of the previous business cycle before the financial crisis.[67]
1980-1989 (NACE I)	N/A	To use data from the whole of a business cycle.
1980-2007 (NACE I)	N/A	To use data from the entirety of the previous two business cycles before the financial crisis.
1999-2014 (NACE II)	1995-2019 (NACE II)	To use data for the entire period for which NACE II was available.[68]
1999-2007 (NACE II)	N/A	To use all NACE II data from the pre-crisis period.
2010-2014 (NACE II)	2010-2019 (NACE II)	To use all data from the post-crisis period.[69]

Source: 'Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations.' Europe Economics (2019); page 75.

[66] *We note that the 1971-2007 (NACE I) and 1970-2007 (NACE I) periods used by Ofwat and us (respectively) are identical. The difference arises as Ofwat has recorded 1971 as the start of the range as this is the first year for which a growth rate is used in the TFP estimates over the range, whereas we have recorded 1970 as the start as this is the first year of data that is used in the TFP estimates over this range (with 1970 data forming part of the calculation for the 1971 growth rate).*

[67] *We note that this differs slightly from the approach taken by Ofwat, in which 1990 was taken as the start of the business cycle. This is because we consider the evidence presented above suggests 1992 as the appropriate starting year to use. Nonetheless, we note that this has a minimal impact on our results.*

[68] *We note that Ofwat's approach only used data from 1999 as TFP data from 1995-1998 was not available in the 2017 version of the EU KLEMS NACE II dataset used by Ofwat.*

[69] *We note that Ofwat's approach only used data until 2014 as this was the latest year that TFP data was available in the 2017 version of the EU KLEMS NACE II dataset used by Ofwat.*

The main differences between our choice of time periods and Ofwat's are:

- **The exclusion of pre-crisis data**. Ofwat chose to use "1999-2007 (NACE II)" as one of its periods of analysis, on the basis that this captured (only) the pre-crisis period. However, we disagree with this approach, as we do not think it appropriate to 'remove' over a decade's worth of the most recent data (which is available in the NACE II database). This is especially because the more recent data likely provides a better indication of productivity potential over PR24, given the economic outlook detailed in Section 4B. We therefore do not think that weight should be attached to a time period that is *entirely* 'pre-crisis' (particularly now that more recent data exists, which also captures an entire business cycle), at the expense of periods that include 'post-crisis' data.

- **The use of historic data**. Ofwat also chose to use "1980-1989" as one of its periods of analysis, on the basis that this corresponded to a whole business cycle, prior to the one that ended in 2009. However, we consider that data from so long ago is increasingly unlikely to be representative of PR24. Again, given the increased availability of more recent data, we do not think that weight should be given to this time period *at the exclusion* of said recent data.

4E. Relevance of lower recent productivity

As we have discussed above, in its PR19 redeterminations, the CMA considered that the water industry may be less affected by the low levels of UK-wide productivity since the financial crisis. Specifically, the CMA noted that the range over the period it considered (1990 to 2007), produced higher results than more recent figures (e.g. 2008 to 2014), and that *"[t]here is substantial uncertainty as to whether the UK's productivity growth will rebound"*. However, it also felt that *"the water sector will be less affected by many of the factors which led more recent UK-wide productivity growth to be lower than the long-term average"*.[70] The CMA used this as part of its rationale for setting a frontier shift challenge towards the upper end of its range (i.e. implicitly attaching less weight to more recent data, during which productivity was depressed).

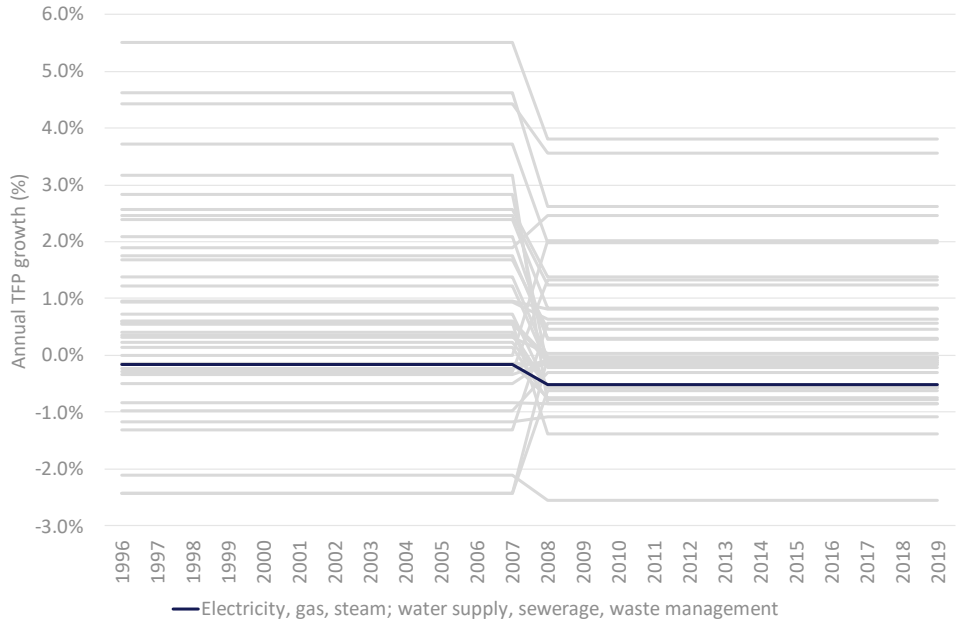
From an 'in principle' perspective, the points raised by Ofwat and the CMA do not seem unreasonable. That is to say, we can see that 'in principle' there could be factors that explain reduced productivity observed for some industries, following the financial crisis, that are less applicable to the water industry. However, in practice, the data and evidence is not, in fact, supportive of the position taken by Ofwat and the CMA.

The question of 'how relevant' post financial crisis data is to water can be considered in the context of examining productivity across UK industries pre and post-crisis. As such,

[70] *'Anglian Water Services Limited, Bristol Water plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations Final report.' CMA (March 2021); paragraphs 4.616.*

Figure 13 shows average annual TFP growth for industries in the EU KLEMS NACE II database[71] for the years up to 2007 (inclusive), and from 2008 (inclusive).

Figure 13: Average pre-and post-crisis TFP growth in UK industries



Source: Economic Insight analysis of EU KLEMS data

Following from the above, as regards the arguments put by Ofwat and the CMA, we would note:

- Firstly, the consistency of the reduction in productivity across multiple industries in the UK calls into question the plausibility of 'water being different'. That is to say, whilst (in principle) the characteristics of industries can vary, such that some might have been more / less affected by the factors that led to a downturn in productivity post-2008, in practice, we consistently observe a clear reduction in productivity across industries following the crisis. Thus, the Ofwat / CMA position would seem to require that 'water alone' was unaffected (or less affected).

- Secondly, in practice the data does, in fact, show a reduction in productivity in the water industry post financial crisis (see blue line in the above figure). Therefore, in practice, for the Ofwat / CMA position to hold, one would further need to believe that the reasons for this occurring in water were 'different' (i.e. unrelated to the wider UK productivity downturn) to those in other industries, and occurred at the same time, 'only by coincidence'. This is questionable.

[71] *This is with the exception of: (i) Mining and quarrying; and (ii) Telecommunications. Average productivity in each of these sectors are significantly lower and greater, respectively, than the vast majority of other sectors. Therefore, they have been excluded to improve readability.*

- Thirdly, suppose the first two points above held (i.e. water alone was unaffected by the downturn; and the observed downturn in water was thus coincidental). Even if that were the case, for one to still take the view that lower productivity in water would not persist at PR24, it would also be necessary to believe that the 'reasons' for that low productivity in water (i.e. reasons other than those explaining the wider downturn in productivity in the UK, which are coincidental) would themselves not persist going forward. As this has not been established, the fact that water productivity has, in fact, been low, remains entirely relevant to an assessment of frontier shift at PR24 and means it is important to include data over a time horizon that accurately reflects that.

5 Comparator selection

In this chapter we provide an assessment of the comparators we consider relevant to informing the scope for TFP growth (and therefore frontier shift) in the water industry. In turn, we: (i) set out precedent from recent water industry decisions on comparator choice; (ii) detail a set of criteria that we use when considering comparator choice; (iii) present our choice of comparators; and (iv) discuss Ofwat's previous choice of comparators relative to our own.

5A. Precedent on comparator choice

During PR19 and the subsequent redeterminations Ofwat and the CMA broadly agreed on the industries that represent appropriate comparators to the water industry, for the purpose of assessing frontier shift. The industries considered were:[72]

- total manufacturing;
- construction;
- chemicals and chemical products;
- other manufacturing; repair and installation of machinery and equipment;
- transport and storage; and
- machinery and equipment n.e.c; and
- professional, scientific, technical, administrative and support service activities.[73]

Alongside the above comparators, Ofwat also reviewed a wider set of industries that included those assessed by various economics consultancies on behalf of water companies, which we have therefore also considered below.[74] Furthermore, in its Draft

[72] *We note that the names of these comparators have changed between the previous iteration of the EU KLEMS NACE II database, and the most up-to-date version. Please see Table 6 for the updated names of the comparators used by Ofwat.*

[73] *(i) 'Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations.' Europe Economics (December 2019); Table 3.9; page 71.; and (ii) 'Anglian Water Services Limited, Bristol Water plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations: Final Report.' CMA (March 2021); Table 4-16; page 243.*

[74] *'Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations.' Europe Economics (December 2019); Table 3.8, page 71.*

Determination for the 2021-27 price control, UREGNI considered: "Manufacturing"; "Electricity, gas, steam and air conditioning supply"; "Transportation and storage"; "Financial and insurance activities"; and "Professional, scientific and technical activities; and administrative and support service activities".[75]

5B. Criteria

When exploring which comparators to consider for our analysis, our selection process has been consistent with best practice. This states that comparators should conform to three key criteria.

- **Criterion 1: Similarity of activities being undertaken.** To ensure that the parallels drawn between the comparators and the water industry are reasonable, it is important both undertake common (similar) activities. When activities are common between firms, one would expect productivity gains to be similar. Similar activities we have considered include: extraction and processing of a resource; operation and maintenance of a complex network; and the construction of major infrastructure.

- **Criterion 2: Competitiveness of industry.** Using comparators that operate in competitive industries means that TFP growth is more likely to have been primarily driven by frontier shift; and will be less driven by catch-up efficiency. Thus, by focusing on industries that are 'more competitive', this should allow us to somewhat mitigate (but not remove entirely) the overstatement of frontier shift that arises from 'catch-up' efficiency being included in any TFP figures.

- **Criterion 3: Extent of scale effects.** Because TFP also includes productivity gains achieved through economies of scale, it is important that comparators have a similar scope for scale-related gains to the water industry. This is to ensure that TFP estimates more accurately reflect achievable frontier shift. As was detailed above in Table 2, there are two ways in which the comparator choice can be used to mitigate against this:

  – We would expect there to be a high correlation between the extent of fixed costs in an industry and the extent of scale effects. Hence, having a similar proportion of fixed costs to the water industry is an important consideration when selecting comparators. Selecting industries with very different proportions of fixed costs to the water industry could either over, or understate the scope for frontier shift.

[75] *'Water & Sewerage Services Price Control 2021-27. Draft determination - Annex K Opex and Capex Frontier Shift.' UREGNI (September 2020); Table 3.1; page 20.*

- Efficiencies arising from scale effects vary over time, in part because they vary with growth rates. For example, for a given level of fixed cost, a faster growing firm benefits more from economies of scale than a slower growing firm. Hence, comparators that exhibit similar growth rates over time to the water industry further allow us to ensure that scale-related gains are likely to be similar over the relevant time period.

We have sought to apply our evaluation criteria transparently, so as to arrive at an objective view as to the appropriate comparators. In the following passages, we set out how we have applied these in practice. Note, before assessing any comparators against our set of criteria, we first filtered all the industries (in both the EU KLEMS and ONS databases) down to a set that contained just: (i) those previously considered by Ofwat and the CMA or by UREGNI;[76] and (ii) any further industries that we consider could share similar characteristics to the water industry.[77] We note that the application of this criteria applies to the NACE II industries, with the NACE I equivalents available in Table 12.

Criterion 1: Similarity of activities being undertaken

For Criterion 1, we undertook a qualitative assessment of the extent to which we considered the industry to share similar activities to those of water companies. For those comparators we assessed, our ranking system was as follows:

- **Green**. These correspond to industries that we consider to be either identical (or almost) to the water industry. This includes: (i) the water sector itself, "Water supply; sewerage, waste management and remediation activities"; (ii) the energy sector, "Electricity, gas, steam and air conditioning supply"; and (iii) the combination of these two sectors, "Electricity, gas, steam; water supply, sewerage, waste management".

- **Amber**. These correspond to the vast majority of industries assessed, as we consider most of these industries to share some activities with water, but only to a degree. For instance, "Mining and quarrying" includes activities related to the extraction and processing of a natural resource (as would be done for water, and also the treatment of wastewater), in addition to the operation and maintenance of a complex network of mines / quarries (i.e. it has network elements, like the water industry). However, it does not involve the delivery or transport of the product to end customers in a downstream market (i.e. the retail element of the water industry).

[76] *'Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations.' Europe Economics (December 2019); Table 3.8, page 71.*

[77] *We also note that we have only included industries for which TFP data is available in the NACE II database, e.g. we have not assessed "Wholesale and retail trade and repair of motor vehicles and motorcycles".*

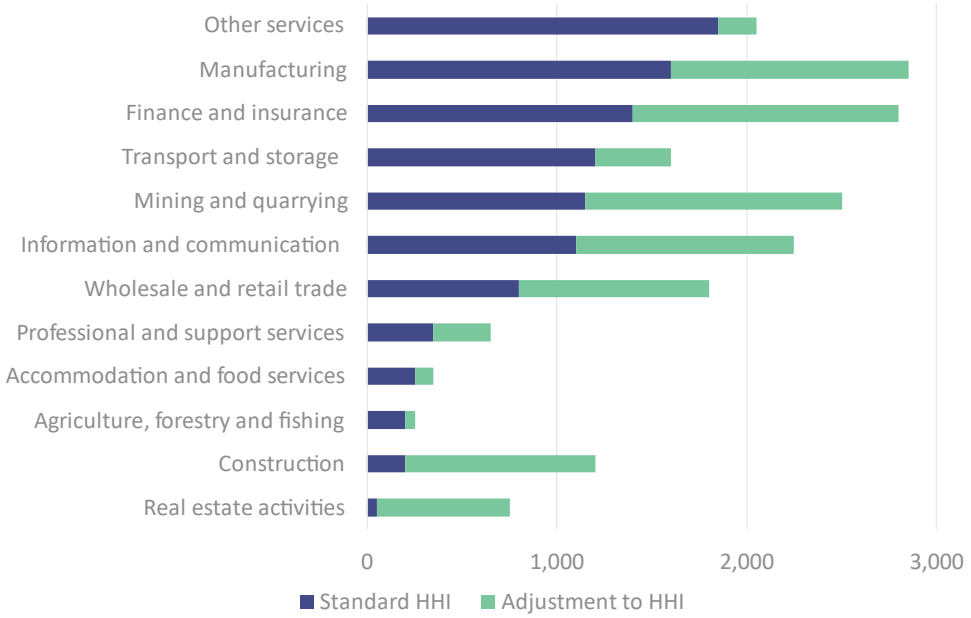
- **Red**. These are sectors that we consider to be very different to the water industry. For instance, we consider neither "Financial and insurance activities" nor "Real estate activities" to share similar activities to the water industry as a whole (i.e. the total water value chain).[78] These are only included in our assessment because they were considered by Ofwat at PR19.

Criterion 2: Competitiveness of industry

For Criterion 2, we assigned any regulated or public sector industry as "Red". This is because they can be assumed to not operate in competitive markets, and so any TFP estimates may include a significant catch-up element, in addition to frontier shift.

To inform the relative competitiveness of other industries, we used the Herfindahl-Hirschman Index (HHI) metric of market concentration, as published by the CMA in its State of Competition report from April 2022.[79] Figure 14 shows this. The adjusted figures also reported in the chart account for the effect of common ownership and international trade, which the CMA considers affect competition, but are not included in the standard HHI measure.[80]

Figure 14: Standard and adjusted HHI across UK SIC sectors



Source: 'The State of UK Competition.' CMA (29 April 2022).
Notes: The sector names in the chart differ slightly to those used in the EU KLEMS database, e.g. (i). "Transport and storage" in the above is equivalent to "Transportation and storage" in EU KLEMS NACE II; (ii) "Manufacturing" is equivalent to "Total Manufacturing" in EU KLEMS NACE I; and (ii) "Professional and support services" corresponds to "Professional, scientific and technical activities; administrative and support service activities" in the EU KLEMS database.

78 *We note, however, that we consider "Financial and insurance activities" nor "Real estate activities" to share similar activities to water retail, which we discuss in more detail in Chapter 8.*
79 *'The State of UK Competition.' CMA (April 2022); Figure 3.5; page 73.*
80 *'The State of UK Competition.' CMA (April 2022); paragraph 3.1.*

We assigned "Green" and "Amber" in the following way: (i) "Green" where the adjusted HHI is less than 1,000; and (ii) "Amber" where the adjusted HHI is greater than 1,000. We note the CMA states that *"[p]roduct markets with HHIs of more than 1,000 are generally considered to be concentrated, and those with HHIs of more than 2,000 to be highly concentrated"*.[81] Consistent with the CMA's 'highly concentrated' distinction (and as detailed later in this chapter), we also include a sensitivity in which we remove all comparators that have an adjusted HHI that is greater than 2,000. As is shown in Annex 3, the impact of this change is limited.

We note that Figure 14 is based on the industries listed in the ONS dataset, rather than in the EU KLEMS dataset. In some cases the ONS industries are more aggregated than those in the EU KLEMS dataset. For example, "Transport and Storage" is broken down into further sectors in the EU KLEMS database, such as: (i) "Land transport and transport via pipelines"; and (ii) "Water transport". Given the EU KLEMS data structure, we apply the Criterion 2 rating (as applied to the aggregated sector from the ONS data) to all of its constituent disaggregated sectors in the EU KLEMS dataset. For example, both "Land transport and transport via pipelines" and "Water transport" would be rated as "Amber" as "Transport and storage" is rated as "Amber".

Criterion 3: Extent of scale effects

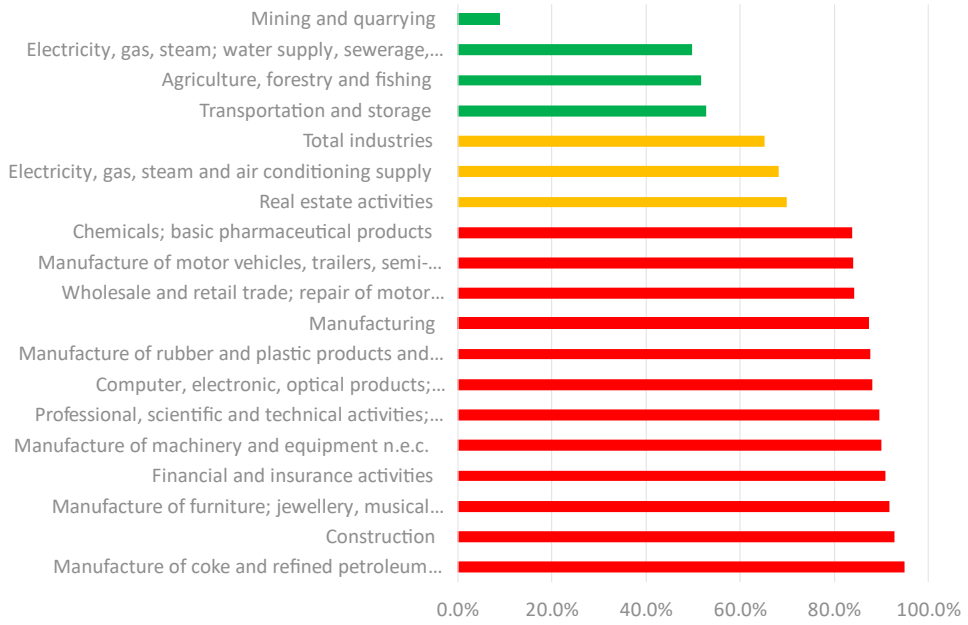
For Criterion 3, we calculated scale-related metrics across industries using EU KLEMS data, in order to determine which are most similar to water, splitting the criterion into three sub-criteria:[82]

- **For Criterion 3a,** we calculated the average capital stock / gross output ratio between 2015 and 2019, and compared this to the average for "Water supply; sewerage, waste management and remediation activities". We include this criterion on the basis that, where the average ratios are similar, this suggests that the comparator sector is similar to the water industry in terms of its capital intensity, and hence proportion of costs that are fixed. We then assigned the three-colour scale in the following way: (i) "Green" where the absolute divergence between the averages is less than 60.0%; (ii) "Amber" where the absolute divergence is between 60.0% and 80.0%; and (iii) "Red" where the absolute divergence is greater than 80.0%. Figure 15 shows the absolute divergence from the water sector.

[81] *'The State of UK Competition.' CMA (April 2022); paragraph 2.10.*

[82] *Data on the capital stock was taken from the tab "K_GFCF", available from the file "Capital" for the UK here: https://euklems-intanprod-llee.luiss.it/download/. Data on gross output was taken from the tab "GO_CP", available from the file "National Accounts" for the UK here: https://euklems-intanprod-llee.luiss.it/download/.*

Figure 15: Absolute divergence in average capital stock-gross output ratio (2015-2019)

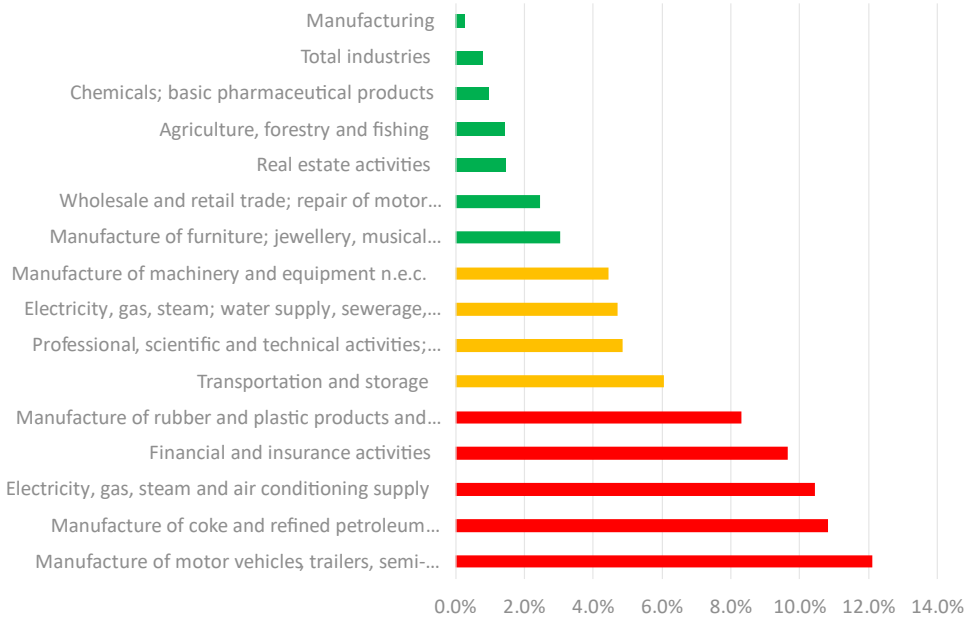


Source: Economic Insight analysis of EU KLEMS data

- **For Criterion 3b,** we calculated the growth rate of capital stock between 2015 and 2020.[83] We then compared this to the capital stock growth rate for "Water supply; sewerage, waste management and remediation activities". We include this criterion on the basis that, where the growth rates are similar, this suggests that the comparator sector is similar to the water industry in terms of its capex accumulation, and hence fixed cost accumulation over time. Following this, we then assigned the three-colour scale in the following way: (i) "Green" where the absolute average divergence is less than 4.0%; (ii) "Amber" where the absolute average divergence is between 4.0% and 8.0%; and (iii) "Red" where the absolute average divergence is greater than 8.0%. Figure 16 shows the absolute divergence from the water sector.

[83] *We note that we used 2020 for Criterion 3b, but 2019 for Criteria 3a and 3c, as capital stock data was available in 2020, whilst gross output data was only available until 2019.*

Figure 16: Average absolute divergence in capital stock growth rate (2015-2020)[84]

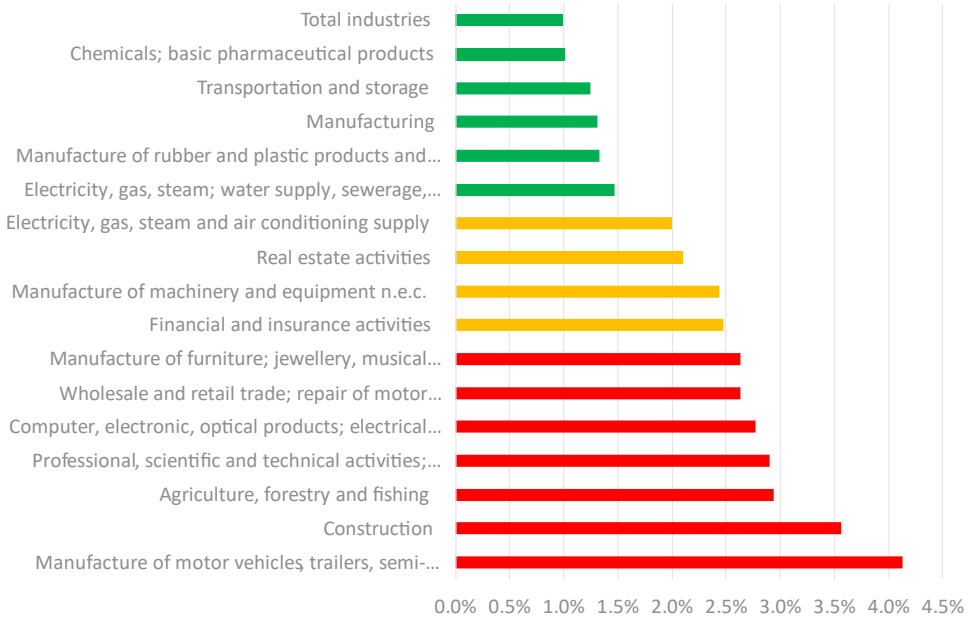


Source: Economic Insight analysis of EU KLEMS data
Notes: We do not include "Computer, electronic, optical products; electrical equipment", "Mining and quarrying" or "Construction" in this chart in order to improve comparability across sectors, as the absolute average divergences for these three sectors are 14.9%, 16.3% and 16.4%, respectively.

- **For Criterion 3c,** we calculated the growth rate of gross output in each year (the output growth rate) between 2015 and 2019, then took the absolute difference between this rate and the rate for "Water supply; sewerage, waste management and remediation activities". We include this criterion on the basis that, where the average divergence between growth rates is small, this suggests that scale effects are similar over time. We then assigned the three-colour scale as follows: (i) "Green" where the absolute average divergence is less than 1.5%; (ii) "Amber" where the absolute average divergence is between 1.5% and 2.5%; and (iii) "Red" where the absolute average divergence is greater than 2.5%. Figure 17 shows the absolute divergence from the water sector.

[84] *For "Total industries", we have taken the 2020 capital stock value from the corresponding entry in "Total - all NACE activities" as there is no data available in 2020 for "Total industries", but the entries in every year between 1995 and 2019 are identical for "Total industries" and "Total - all NACE activities".*

Figure 17: Absolute average divergence in gross output growth rate (2015-2019)



Source: Economic Insight analysis of EU KLEMS data
Notes: We do not include "Mining and quarrying" or "Manufacture of coke and refined petroleum products" in this chart in order to improve comparability across sectors, as the absolute average divergences for these two sectors are 13.0% and 15.7%, respectively.

5C. Our choice of comparators

Both the EU KLEMS and ONS datasets contain TFP information for a number of sectors (a full list of these is available in Annex 2). We note that, primarily due to limitations in available data (and because the extent to which any one data / analysis can 'precisely' inform the economic theory / evaluation criteria in question is limited), no choice of comparators will ever be perfect. Therefore, although we have applied the above set of three criteria, we recognise the inherent subjectivity in choosing comparators.

We define our *'preferred set'* of comparators as those that fulfil the following conditions.[85]

- Defined as "Green" or "Amber" in Criterion 1, such that the activities being undertaken by firms working in the comparator industry are similar (at least in part) to the water industry.
- Defined as being "Green" or "Amber" in Criterion 2, such that the industry is at least somewhat competitive.

[85] *We note that, although "Mining and quarrying" fulfils the below conditions, we have chosen not to include it in our 'preferred' set of comparators. We provide details below as to why this is the case.*

- Defined as "Green" in at least one of Criteria 3a, 3b and 3c, such that the magnitude and/or timing of scale effects are at least somewhat similar to the water industry.

In addition to this, we also included "Total industries" in our *'preferred set'* of comparators (and the sensitivities detailed below, unless specified otherwise). This reflects the inherent subjectivity in comparator choices, which means we think it beneficial to include a metric that captures productivity changes across the entire UK 'on average' (i.e. not assuming that the water industry would be either a 'low', or 'high', productivity industry).

We have also chosen to adopt five further sets of comparators, corresponding to several separate sensitivity analyses:

- **Sensitivity 1**, which includes all the same comparators as selected under our criteria, plus "Mining and quarrying". We have not included "Mining and quarrying" in our main analysis, despite it fulfilling the necessary conditions for inclusion. This is because the TFP estimates for this sector are significantly lower than for the other comparator sectors, implying it may be an outlier. However, we consider it beneficial to report it under a sensitivity analysis, in order to test the robustness of our *'preferred set'* of comparators to its inclusion.

- **Sensitivity 2**, where the assessment under Criterion 3 is strengthened. Specifically, this only includes comparators for which at least <u>two</u> of Criteria 3a, 3b and 3c are ranked as "Green" (and thus places more weight on the similarity of sectors as regards economies of scale).

- **Sensitivity 3**, in which: (i) the assessment under Criterion 3 is strengthened (in the same was as with **Sensitivity 2**); and (ii) highly aggregated sectors are excluded.[86] We implement condition (ii) in order to test whether the implicit inclusion of some activities that are less similar to water is affecting our results.

- **Sensitivity 4**, in which Criterion 2 is strengthened. We strengthen Criterion 2 in order to test the effect of including comparators that <u>may</u> be considered *'highly concentrated'* by the CMA (as detailed in our description of Criterion 2 in Section 5B) in our *'preferred set'* of comparators. Specifically, only comparators for which the adjusted HHI in Figure 14 is less than 2,000 are included.

[86] *This refers to "Total industries" and "Manufacturing".*

- **Sensitivity 5**, which includes all the same comparators as selected under our *'preferred set'*, plus "Construction". Although "Construction" does not fulfil our conditions (in relation to our three Criteria) to be included in either our *'preferred set',* or our above-mentioned sensitivities, we consider that there are some activities undertaken by water companies that may be consistent with those of construction companies. For instance, the creation and development of large-scale complex infrastructure. Therefore, although (under our criteria) construction is not sufficiently similar to the total water value chain 'as a whole' to be included, we consider it informative to have a sensitivity analysis that incorporates it. This may be more relevant if companies expect their mix of activities for PR24 to be 'more similar' to construction than in the past, for example.

Following from the above, there are some reasons to suppose that it may be beneficial to estimate frontier shift separately for the different elements of water companies' activities. For example: (i) by price control area; and / or (ii) split by opex and capex. This is because, for example, a good comparator for one price control area (as regards to the similarity of activities; or extent of scale effects, say) may be a less good comparator for another price control area. Indeed, we note that Ofwat's approach at PR19 was to set out separate estimates for totex and botex. Furthermore, in its PR24 Final Methodology, Ofwat stated that it may *"explore setting a specific frontier shift for bioresources that is separate from other wholesale activities"*,[87] but did not commit to this. Ofwat's Final Methodology for PR24 contained no further details as to its approach in this regard.

Table 6 presents the results of our assessment of comparators against the criteria detailed above. Table 6 also identifies: (i) which industries we have included in our *'preferred set'* of comparators (and those industries we have included in our five sensitivity analyses); and (ii) the industries selected by Ofwat as comparators under its PR19 approach.

As we have discussed above, we have sought to apply our three Criteria transparently; and have derived several sets of comparators that we use to derive our frontier shift estimates (both for our *'preferred set',* and the five sensitivity analyses detailed above). However, as previously noted, we would stress that the selection of comparators is inherently subjective. As such, we recognise that it is reasonable that some companies may consider alternative comparators to those we recommend (based on their specific circumstances). This forms part of our rationale for **Sensitivity 5,** whereby construction is included to allow for the possibility that some companies may intend to undertake a greater mix of large infrastructure project construction at PR24.

Where we set out our final frontier shift results in this report, we do so in relation to three defined 'ranges'.

[87] *'Creating tomorrow, together: Our final methodology for PR24: Appendix 4 Bioresources control.' Ofwat (December 2022); page 20.*

- **Plausible range**. This includes our *'preferred set'* of comparators.
- **PR24 focused range**. This also only includes our *'preferred set'* of comparators.
- **Sensitivity analysis range**. This includes our *'preferred set'* of comparators, in addition to those as tested under our sensitivity analyses (**Sensitivity 1**; **Sensitivity 2**; **Sensitivity 3**; **Sensitivity 4**; and **Sensitivity 5**).

In the following table we identify which comparators are included for each of the above three ranges.

Table 6: Assessment of industries against Criteria (**total water value chain**)

Industry	Criteria					Preferred set	Sensitivity					Used by Ofwat
	1	2	3a	3b	3c		1	2	3	4	5	
Total industries						✓	✓	✓	✗	✓	✓	✗
Agriculture, forestry and fishing						✓	✓	✓	✓	✓	✓	✗
Mining and quarrying						✗	✓	✗	✗	✗	✗	✗
Manufacturing						✓	✓	✓	✗	✗	✓	✓
Manufacture of coke and refined petroleum products						✗	✗	✗	✗	✗	✗	✗
Chemicals; basic pharmaceutical products						✓	✓	✓	✓	✗	✓	✓
Manufacture of rubber and plastic products and other non-metallic mineral products						✓	✓	✗	✗	✗	✓	✗
Computer, electronic, optical products; electrical equipment						✗	✗	✗	✗	✗	✗	✗
Manufacture of machinery and equipment n.e.c.						✗	✗	✗	✗	✗	✗	✓
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment						✗	✗	✗	✗	✗	✗	✗
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment						✓	✓	✗	✗	✗	✓	✓
Electricity, gas, steam and air conditioning supply						✗	✗	✗	✗	✗	✗	✗
Electricity, gas, steam; water supply, sewerage, waste management						✗	✗	✗	✗	✗	✗	✗

Industry	Criteria					Preferred set	Sensitivity					Used by Ofwat
	1	2	3a	3b	3c		1	2	3	4	5	
Water supply; sewerage, waste management and remediation activities						✗	✗	✗	✗	✗	✗	✗
Construction						✗	✗	✗	✗	✗	✓	✓
Wholesale and retail trade; repair of motor vehicles and motorcycles						✓	✓	✗	✗	✓	✓	✗
Transportation and storage						✓	✓	✓	✓	✓	✓	✓
Financial and insurance activities						✗	✗	✗	✗	✗	✗	✗
Real estate activities						✗	✗	✗	✗	✗	✗	✗
Professional, scientific and technical activities; administrative and support service activities						✗	✗	✗	✗	✗	✗	✓

Source: Economic Insight

5D. Comparison to Ofwat

As shown above in Table 6, our *'preferred set'* of comparators shares four comparators with Ofwat's PR19 approach. Our *'preferred set'* of comparators contains four further comparators not chosen by Ofwat, whilst its approach contains three comparators not in our *'preferred set'*.

We consider there to be two key reasons for these differences:

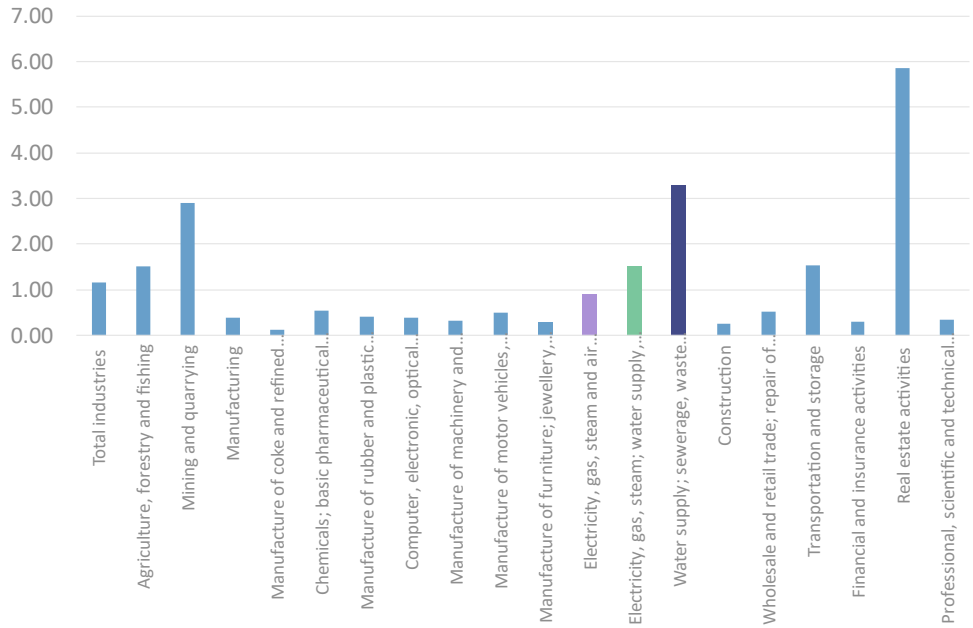
- **Relative importance of the three criteria**. Ofwat *"considered data on the capital intensity of each sector and how comparable that is to the water sector, although this was not treated as an over-riding consideration where there were other reasons for including a comparator."*[88] In relation to the criteria detailed in Section 5B, Ofwat therefore chose to place more weight on Criterion 1 (the activities of the comparators being similar to those of the water sector), than on Criterion 3 (the proportion of fixed costs between comparators and the water sector being relatively similar). On the other hand, we consider both these criteria to be important, with Criterion 3 highly important, to avoid wrongly attributing efficiency gains from economies of scale to frontier shift. We consider that there is an inherent subjectivity involved in Criterion 1, due to its inherently qualitative nature; and the fact that there are many industries that share some, but not all, of the activities with water (which can be seen in the Europe Economics report).[89] As a result of its approach, Ofwat has not systematically taken into account how differences in cost structure (and hence scale economies) can translate to differences in productivity growth across industries (even though theory and evidence shows this to be important).

[88] *'Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations.' Europe Economics (December 2019); page. 69.*

[89] *We note that Ofwat conducted a separate scale effects analysis but only on the comparators chosen for its analysis, and concluded that no adjustment was required. Please see:'Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations.' Europe Economics (December 2019); Appendix 2.*

- **Availability of data**. Ofwat's analysis for PR19 in relation to capital intensity involved a comparison of the energy and water sectors combined, as data on just the water industry was unavailable in the 2017 release of the EU KLEMS data. As we have noted, Ofwat's measure of capital intensity (capital stock-gross output ratio) is consistent with ours. However, Ofwat undertook this analysis only for 2014 (as this was the most recently available data at the time of the analysis). Figure 18 shows the capital stock-gross output ratio in this year, including: (i) the energy sector only (the purple bar); (ii) the water and energy sectors combined (the green bar); and (iii) the water sector only (the dark blue bar). The figure shows that the capital intensities are very different between the green and dark blue bars, which could lead to very different conclusions about appropriate comparators. Put simply, Ofwat was comparing industries against a benchmark that did not, in fact, reflect the capital intensity of the water industry. In any event, we again note that, in practice, Ofwat did not fully utilise this analysis, given its reliance on the more subjective criteria of 'similar activities' in its selection of comparators.

Figure 18: Capital stock-gross output ratios in 2014



Source: Economic Insight analysis of EU KLEMS data

6 Adjustments

Following from our comparator choice, in this chapter we consider whether, in light of the analytical issues discussed in Chapter 3, adjustments might be appropriate when inferring a frontier shift challenge for PR24 from TFP data.

6A. Multiple efficiency savings

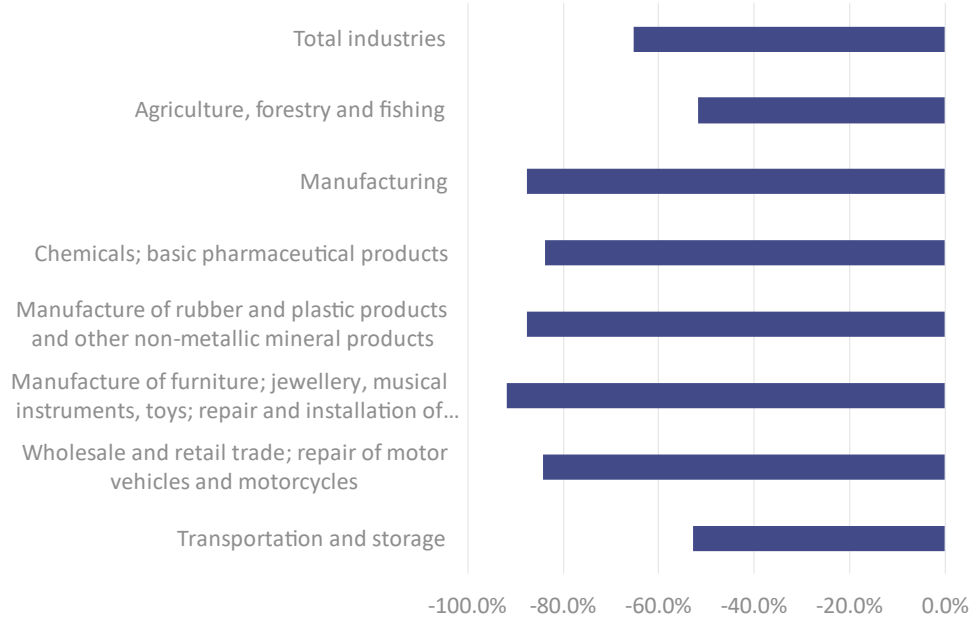
As discussed in Section 3C, there are multiple efficiency savings captured within TFP, beyond just frontier shift. By basing frontier shift estimates solely on unadjusted TFP, there is therefore the risk that the extent of frontier shift would be incorrectly estimated (where whether the net impact results in an overall under or overstatement of frontier shift depends on the effect of each of the individual efficiencies).

We present below how we have determined the likely direction of each the efficiencies on TFP estimates:

- **Catch-up efficiency**. This is based on Criterion 2, i.e. the competitiveness of the industry.
- **Scale effects**. In Figure 19, Figure 20 and Figure 21, we have determined the actual difference between our scale-related metrics for each comparator industry in our *'preferred set'*, and water.[90] Where the net divergence across the three appears to be conclusively negative (positive), we have concluded that there is an understatement (overstatement) of frontier shift as implied from TFP, due to efficiencies arising from scale effects also being captured. Where the overall divergence is ambiguous, we consider the direction of the effect to be unknown.

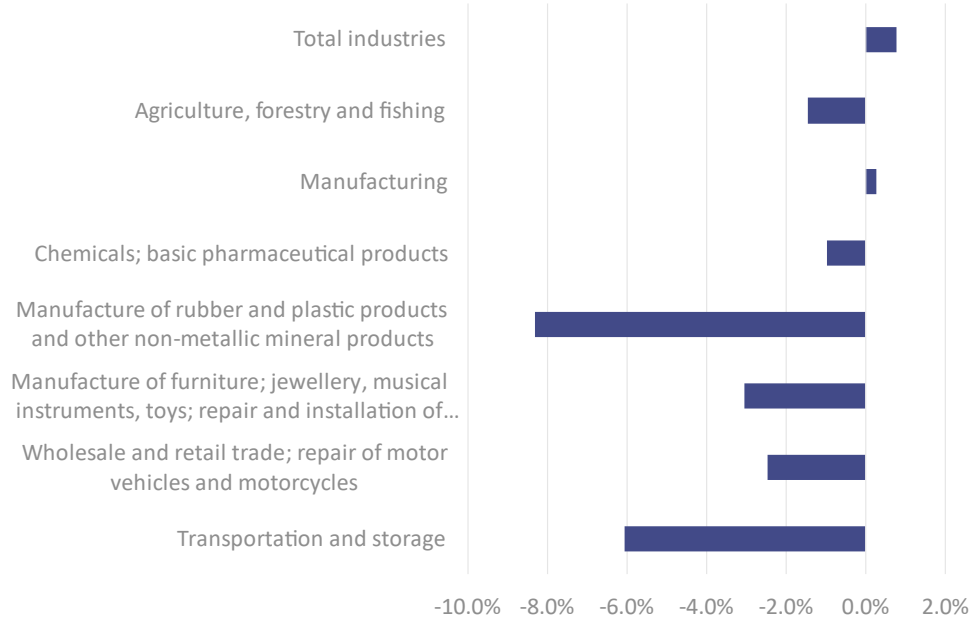
[90] *We note that when we undertook our assessment of Criteria 3 above, we used the absolute divergence between these metrics and water. However, it is necessary for us to include the sign of these differences in order to arrive at a conclusion of the likely direction of the bias resulting from scale effects.*

Figure 19: Actual divergence between average capital stock-gross output ratio of comparator industries and the water industry (2015-2019)



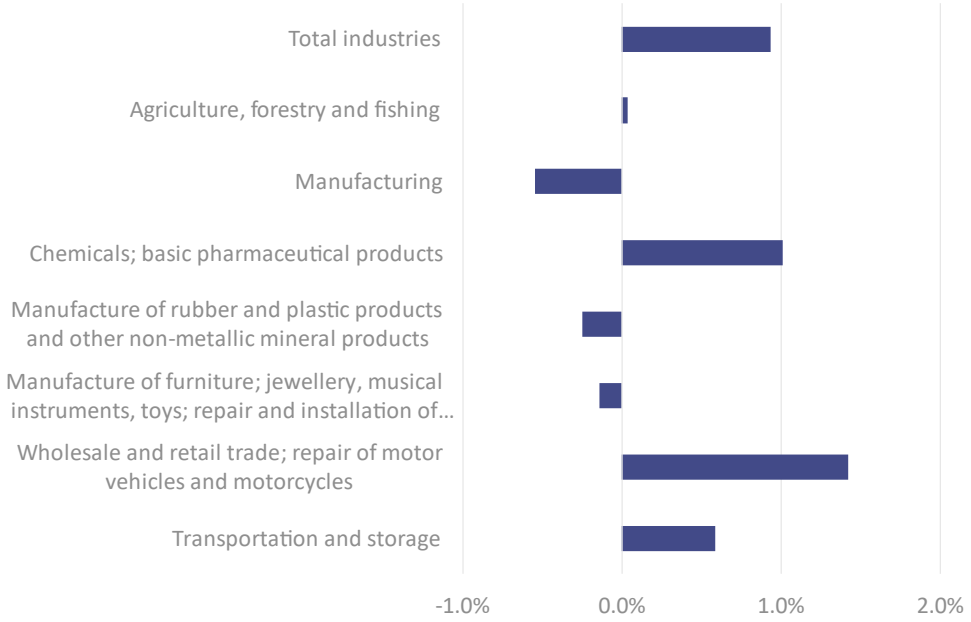
Source: Economic Insight of EU KLEMS data

Figure 20: Actual divergence between capital stock growth rates of comparator industries and the water industry (2015-2020)



Source: Economic Insight of EU KLEMS data

Figure 21: Actual divergence between gross output growth rates of comparator industries and the water industry (2015-2019)



Source: Economic Insight of EU KLEMS data

Table 7 presents our high-level expectation of the possible direction of each of these efficiencies on our TFP estimates for each of the comparator industries we identify. Entries reported as "Positive" in Table 7 mean that there is an upward bias to frontier shift (were one to infer this from TFP), which would thus warrant a downward adjustment to the TFP estimate (and vice-versa for "Negative").

Table 7: Likely direction of bias for each comparator in our analysis

Industry	Catch-up efficiency	Scale effects
Total industries	Positive[91]	Unclear
Agriculture, forestry and fishing	Slightly positive	Negative
Manufacturing	Positive	Negative
Chemicals; basic pharmaceutical products	Positive	Unclear
Manufacture of rubber and plastic products and other non-metallic mineral products	Positive	Negative
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	Positive	Negative
Wholesale and retail trade; repair of motor vehicles and motorcycles	Positive	Unclear
Transportation and storage	Positive	Unclear

Source: Economic Insight analysis

Overall, Table 7 is therefore consistent with:

- Frontier shift being *overstated* due to the exclusion of catch-up efficiency for all comparator industries (thus implying a downward adjustment to frontier shift).
- Frontier shift being *understated* due to the potential for efficiencies arising from economies of scale being smaller for some of the comparator industries, relative to water (thus implying a *small* upwards adjustment to frontier shift).[92]

[91] *Although a Criterion 2 ranking is not provided for "Total industries" in Table 6, we consider that there are likely to be some catch-up efficiencies within TFP estimates for this comparator, given that this is an aggregation across all sectors, some of which are uncompetitive.*

[92] *Because, for 'all' of our comparators, the data implies a downwards adjustment is required to account for catch-up; but in relation to scale economies, only some of the comparators are consistent with an upwards adjustment being appropriate.*

6B. Embodied change

As discussed in Section 3C, it is likely that TFP includes at least some, but not all of, the productivity gains made from embodied technological change. However, the discussion in Section 3C also highlighted that there is no easy / clear cut answer to the question of *'how much'* is included in (excluded from) the TFP data. Furthermore, we noted that (notwithstanding this first challenge) there is a second important step of determining the *relevance* of any excluded embodied technological change from a comparator industry's TFP to determining frontier shift for the water industry.

Following from the above, therefore, our position is that it is appropriate in principle to *consider* whether and how frontier shift should be adjusted to account for any excluded embodied technological change. However, in practice, this should be informed by an assessment of:

- the extent to which the TFP *for the comparators being used* includes / excludes embodied technological change; and
- the scope for the water industry to make productivity gains from embodied technological change, relative to the comparators being used (i.e. the relative scope for technological change across industries).

We discuss each of these in turn below, in the context of our comparator choice detailed in Section 5C.

The extent of embodied change that is included in / excluded from TFP

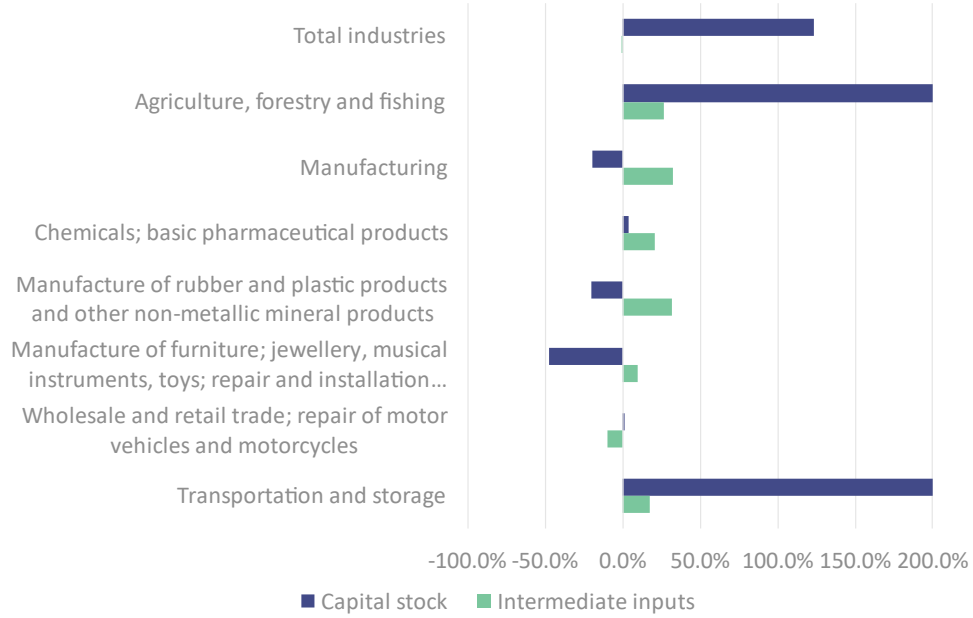
The extent of any embodied change that is captured in TFP likely varies by sector. Industries that: (i) are more capital intensive; and (ii) use *relatively* more intermediate inputs are likely to have a higher amount of gains from embodied technological change included within their TFP data (as was discussed in Section 3C). However, we reiterate that it is challenging to determine the exact amount of embodied change that is included in / excluded from TFP estimates with precision.

In order to inform this, we have calculated the following metrics for every industry in the NACE II database: (i) capital stock-gross output ratio;[93] and (ii) intermediate inputs-gross output ratio.[94] We then calculated the 'all industry' median for these metrics across 2015-19 (noting that the mean is more affected by extreme outliers). To then get a sense of whether our comparators might include 'more' or 'less' gains from embodied technological change in their TFP data than 'the average' for the UK, we calculated the difference between them on the above two metrics, relative to the all industry median. Figure 22 shows these divergences, for both capital intensity and the intermediate inputs-gross output ratio.

[93] *We note that this is the same way that Ofwat measured capital intensity in its PR19 assessment. Please see: 'Real Price Effects and Frontier Shift – Final Assessment and Response to Company Representations.' Europe Economics (December 2019); footnote 67, page 69.*

[94] *Data on the intermediate inputs was from the tab "II_CP", available from the file "National Accounts" for the UK here: https://euklems-intanprod-llee.luiss.it/download/.*

Figure 22: Difference between average capital stock-gross output ratio, and intermediate inputs-gross output ratio, and the median across all industries (2015-2019)



Source: Economic Insight analysis of EU KLEMS data

In terms of capital intensity, our analysis suggests:

- For three of the comparators in our *'preferred set'*, the average capital stock-gross output ratio is significantly greater than the median across all industries. This suggests, for these comparators, the amount of *included* (relative to *excluded*) embodied change, may be *greater* than for the average industry.
- For the other five comparators, the average capital stock-gross output ratio is either slightly lower than the median, or relatively similar. This suggests, for these comparators, the amount of *included* (relative to *excluded*) embodied change, may be *similar* to the average industry.

In terms of intermediate inputs, the analysis shows that, on average, the comparators in our *'preferred set' generally* contain more intermediate inputs than the median industry, but the difference is much less pronounced than for capital intensity. We note that the range of intermediate input-gross output ratios is significantly narrower than for capital stock-gross output ratios. Overall, this suggests that, for these comparators, the amount of *included* (relative to *excluded*) embodied change, may be *slightly greater* than for the average industry.

Taken together, the evidence presented in this section suggests that, across our comparators overall, the amount of *included* (vs *excluded*) embodied change *may* be greater than the UK industry average.

The applicability of embodied change from comparator sectors to the water industry

Having established a high-level view on the relative amount of *included* embodied change across our comparators, we now turn to the question of the applicability of embodied change in our comparator sectors to the water industry. As was discussed in Section 3C, this turns on one's view on the scope for embodied change in the water industry (and whether that is higher, or lower, than the comparator sectors in question).

As we previously discussed, the above largely turns on an assessment of the extent of likely technological change in the water industry, relative to those comparators, on a forward-looking basis. We also noted that the water industry is unlikely to be one where one would expect rapid technological progress (i.e. one would not expect high embodied technological related gains, relative to other industries). This is because it is characterised by high value capital assets that last for a long time, which are then replaced at the end of their lifecycle by (broadly) similar infrastructure assets.

For the purpose of this report, we have undertaken a high-level qualitative assessment of the expected rate of technological progress across our comparators. This is summarised in Table 8, using a three-colour scale (i.e. "Red", "Amber" and "Green"). We note that we would consider the water sector to be "Red", meaning that comparators rated "Amber" or "Green" would be expected to be able to make higher productivity gains from embodied technological change, relative to the water industry.

Table 8: High-level assessment of the rate of technological progress in comparator sectors

Comparator	Rate of technological progress
Total industries	
Agriculture, forestry and fishing	
Manufacturing	
Chemicals; basic pharmaceutical products	
Manufacture of rubber and plastic products and other non-metallic mineral products	
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	
Wholesale and retail trade; repair of motor vehicles and motorcycles	
Transportation and storage	

Source: Economic Insight analysis

Based on our initial assessment, we consider that three of the comparators in our *'preferred set'* likely exhibit low rates of technological progress over time. Therefore, we consider that embodied change in these three industries is likely relatively *similar* to water. However, importantly, by "similar", we are actually highlighting their common *limited capacity* to make gains from embodied technological change in the first place. Therefore, with reference to these, it would (in principle) be appropriate to make an upwards adjustment to frontier shift for the water industry to reflect any embodied technological change not captured in their TFP data, but in practice the absolute size of that embodied change must logically be limited (therefore, the upwards adjustment would also be relatively small).

The remaining five comparators (the majority) likely have *greater scope* for making productivity gains from embodied technological change, relative to the water industry. Therefore, (and the corollary of the above) is that whilst the absolute size of their gains from embodied change going forward may be larger, a much smaller proportion of those gains would be relevant to a forward-looking assessment of frontier shift in the water industry. Hence, again, in principle an upwards adjustment to frontier shift may be appropriate. However, it is likely to be small, *and could conceivably be negative* (if, for example, the scope for technological change related gains in water was sufficiently lower relative to these industries).

6C. Overall adjustment

To conclude, the evidence presented in Sections 6A and 6B suggests the following when inferring frontier shift for the water industry at PR24 from TFP data:

- A downward adjustment due to catch-up efficiencies that are captured in the TFP estimates for our choice of comparator industries.
- An upwards adjustment due to an understatement of scale effects in the TFP estimates for our choice of comparator industries (although the magnitude of this understatement would likely be *smaller* than the equivalent overstatement for catch-up efficiency).
- A likely upwards adjustment due to the excluded embodied change from comparator industries' TFP estimates that is applicable to the water industry. We reiterate that the likely magnitude of this adjustment would be small, and note that we cannot preclude the possibility of the appropriate adjustment in fact being a downwards one (i.e. if the scope for technologically driven embodied change in water was sufficiently smaller than for the comparators).

Following from the above, it is not possible to specify a precise net adjustment to frontier shift, based on the currently available evidence (or even determine whether that net adjustment would be positive or negative). Rather, at this time, we suggest the above is largely considered in terms of 'where' in our recommended ranges companies elect to set their proposed frontier shift at PR24. Given that we cannot say whether, in net terms, the above considerations over, or understate frontier shift, our recommendation is therefore that companies should: (i) generally adopt numbers at the mid-points of our ranges; or (ii) could deviate from that (i.e. selecting higher or

lower numbers within our ranges) if that decision was informed by additional evidence relating to:

- the assessment of the rate of technological change in the water industry, relative to the comparator sectors; and / or
- the scope for other efficiencies (e.g. economies of scale) in the water industry, relative to the comparator sectors.[95]

[95] *Relatedly, and as noted previously in this executive summary, companies could further consider whether the comparator set itself might change, if (for example) the expected mix of activities they will undertake at PR24 is sufficiently different from the past.*

7 Results – total water value chain

In this chapter we summarise the results of our analysis, where we report three frontier shift ranges for the total water value chain: (i) our *'plausible range'* (**0.3%-0.8%**); (ii) our *'PR24 focused range'* (**0.3%-0.7%**); and (iii) our *'sensitivity analysis range'* (**0.1%-1.1%**). For the upper and lower ends of each of these ranges, we provide details of the specific time period and comparator set it relates to.

Following our choice of time periods and comparators, detailed previously in Chapter 4 and Chapter 5 respectively, we arrive at our proposed frontier shift estimates for PR24. We have grouped these into three distinct ranges, which are as follows:

- **Plausible range** (**0.3%-0.8%**). This is the range that we consider frontier shift could *plausibly* sit within, over PR24 (i.e. numbers outside of this range are *implausible*, but not *impossible*, in our view). This range is based on our *'preferred set'* of comparators (shown in Table 6). It is further based on the following time periods:
  - **2010-2019 (NACE II)**. This period includes: (i) the most recently available data following the structural break coinciding with the 2008 financial crisis; and (ii) all of the data available from the most recent business cycle (noting that 2019 is the last year that data is available). This period leads to a frontier shift estimate of **0.3%.** This gives the lower end of our *'plausible range'*; the rationale being that the prevailing low productivity performance (as seen for the UK as a whole) persists over PR24.
  - **1995-2019 (NACE II)**. This period includes: (i) all of the available data following the financial crisis (as with 2010-2019); and (ii) all of the data available from the previous two business cycles. This period leads to a frontier shift estimate of **0.7%**. The rationale for this is that by balancing pre, and post, financial crisis time periods, we allow for a reversion (increase) in productivity, back to levels that were observed pre-crisis.
  - **1970-2007 (NACE I)**. This period allows us to show what frontier shift *could* be, if the structural break in productivity from the financial crisis fully unwinds over the course of PR24 towards its long-term average. This period leads to a frontier shift estimate of **0.8%.** The rationale being that this 'unwinding' represents (in our view) the maximum plausible productivity performance over PR24.

- **PR24 focused range (0.3%-0.7%)**. This represents the range we think frontier shift is *most likely* to lie within over PR24. This is also based on our preferred comparator sectors. However, relative to our *'plausible range'*, here we place greater weight on time periods that we consider to be most reflective of PR24 (given the trends in productivity over time and the economic outlook detailed in Section 4B). The time periods on which our focused range is based are as follows.
  - **2010-2019 (NACE II)**. As per the rationale for inclusion in our *'plausible range'*, this period contains all the data that is available from the most recent business cycle (which we consider most likely corresponds to the PR24 period), and leads to a frontier shift estimate of **0.3%** (i.e. the lower end of our *'PR24 focused range'*). This is on the basis that we think it is *unlikely* that productivity will deteriorate further; and so a persistence of the recent past also provides a likely lower bound.
  - **Weighted average of 1995-2019 (NACE II) and 1970-2007 (NACE I)**. In addition to the most recent business cycle, we have included an estimate that aims to capture data from the entire period for which we have data. We are unable to combine the NACE I and NACE II databases, because the data is recorded differently in overlapping years. We have therefore combined estimates from the two databases by calculating a weighted average.[96] This estimate effectively provides a long-term view, which balances the low productivity seen post financial crisis against higher productivity performance in the more distant past. As such, it implicitly allows for 'some' (but not full) unwinding of the productivity structural break over PR24. This leads to a frontier shift estimate of **0.7%,** which provides the upper end of our *'PR24 focused range'*. As this still amounts to (slightly more than) a 'doubling' of productivity, relative to prevailing levels, we consider it unlikely that performance in the water industry will be above this level over PR24.
- **Sensitivity analysis range (0.1%-1.1%)**. We have tested a number of sensitivities around our *'plausible'* and *'PR24 focused'* ranges, as regards to both alternative time periods and comparators (as detailed in Sections 4C and 5C respectively). Whilst this widens our estimates beyond the *'plausible range'*, the impact is relatively small, indicating our main estimates are reasonably robust. Further, the sensitivities we have run should not be interpreted as representing us endorsing selecting frontier shift estimates at the extreme ends of the scale. That is to say, our view is that frontier shift *below* 0.3% or *above* 0.8% is 'implausible'; and that the likely (focused) range over PR24 is narrower still.

[96] *We have calculated this average by weighting (for each comparator and also for the average across all comparators): (i) the average estimate derived from the 1995-2019 period (0.7%) to correspond to each year between 1995 and 2019, inclusive; and (ii) the average estimate derived from the 1970-2007 period (0.8%) to correspond to each year between 1970 and 1994, inclusive.*

Table 9 summarises our results for each of the three ranges and recaps the comparators and time periods used. We present our full set of results in Annex 3.

Table 9: Summary table of minimum and maximum results across our three ranges[97]

Comparator	Plausible range		PR24 focused range		Sensitivity analysis range	
	Low	High	Low	High	Low[98]	High[99]
Total industries	0.2%	0.2%	0.2%	0.2%	0.2%	
Agriculture, forestry and fishing[100]	1.1%	1.0%	1.1%	1.1%	1.1%	1.0%
Mining and quarrying					-1.7%	
Manufacturing	0.4%	0.7%	0.4%	0.9%	0.4%	
Chemicals; basic pharmaceutical products	1.2%	1.3%	1.2%	1.6%	1.2%	1.3%
Manufacture of rubber and plastic products and other non-metallic mineral products	1.0%	0.9%	1.0%	0.9%	1.0%	
Manufacture of furniture; jewellery, musical instruments, toys; repair & install of machinery & equip.	-0.4%		-0.4%	1.0%	-0.4%	
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	0.1%	-0.1%	-0.1%	-0.1%	
Transportation and storage	-0.6%	1.1%	-0.6%	0.5%	-0.6%	1.1%
Final results (average)	**0.3%**	**0.8%**	**0.3%**	**0.7%**	**0.1%**	**1.1%**

Source: Economic Insight analysis of EU KLEMS data

[97] *We note that, for some comparators in NACE II, there is no NACE I equivalent (e.g. "Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment"), hence there is no TFP estimate for this comparator at the 'High' end of our 'plausible range', but there is at the 'Low' end. For these comparators, the TFP estimate at the 'Low' end of our 'PR24 focused range' (1970-2019) is equal to the 1995-2019 average. As such, the average across comparators in 1970-2019 may not equate to the average of the individual comparator TFP estimates, as it is calculated using a weighted average of the total averages across comparators in 1995-2019 and 1970-2007.*

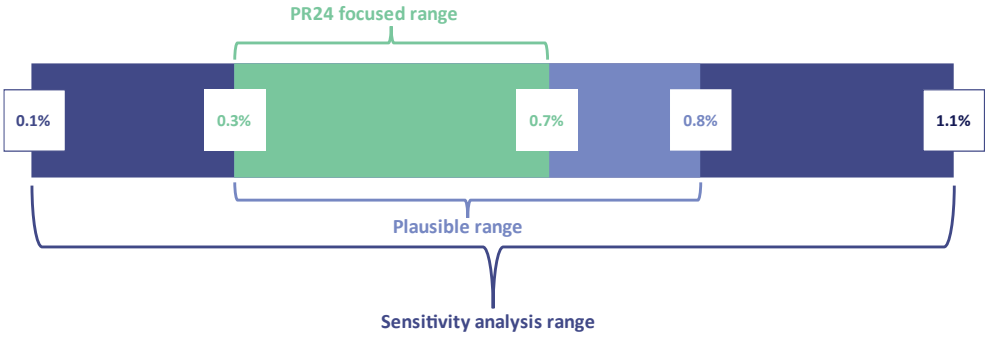
[98] *This corresponds to: (i) the 'preferred set' of comparators plus "Mining and quarrying" (i.e. **Sensitivity 1**); and (ii) the 2010-2019 period.*

[99] *This corresponds to: (i) comparators that are (a) not highly aggregated and (b) rated as "Green" in at least two of Criteria 3a, 3b or 3c (**Sensitivity 3**); and (ii) the 1970-2007 period.*

[100] *We note that TFP data is unavailable in the 2023 release of the NACE II database for "Agriculture, forestry and fishing" in 2019. Therefore, for any specified range that includes 2019, for "Agriculture, forestry and fishing" the average TFP growth estimate is based on growth rates up to 2018.*

Figure 23 provides a visual summary of our ranges.

Figure 23: Illustration of our three ranges (total water value chain)



Source: Economic Insight

We note two further details regarding the above results.

- These results are based on a gross output, rather than value added, measure of TFP. In our view, gross output more accurately represents the actual scope for frontier shift at PR24 (for further details, see Section 3B). TFP estimates based on a value added approach can be found in Annex 3.
- The results are based on an arithmetic mean approach, rather than a geometric mean. We consider that a geometric approach may be more appropriate over longer time periods, for the reasons detailed in Annex 5 (where we also report our estimates using a geometric mean; which, in practice, fractionally *reduces* our estimates, relative to those reported above).

We also note that we have extended Ofwat's choice of comparators at PR19 to the three time periods included in our *'plausible range'*. This gives a range of **0.0%-0.8%**, with 2010-2019 forming the lower end of this range, and 1970-2007 the higher end. We present these results in full in Annex 3.

8 Water retail frontier shift estimates

In this chapter we set out our estimates of frontier shift relating to the retail part of the value chain. Our method is consistent with that set out for the total water value chain. We similarly frame our retail results in terms of three ranges: (i) our *'plausible range'* (**0.3%-0.6%**); (ii) our *'PR24 focused range'* (**0.4%-0.6%**); and (iii) our *'sensitivity analysis range'* (-**0.2%-1.2%**). As can be seen, our estimates for retail do not materially differ from those for the total value chain (with the upper end of our *'plausible range'* and *'PR24 focused range'* being fractionally lower for retail).

8A. Methodology

Our overall approach to arriving at retail-specific frontier shift estimates is consistent with that for the total water value chain. Specifically, we have adopted the same framework in considering the three criteria detailed previously in Section 5B:

- **Criterion 1**: similarity of activities being undertaken.
- **Criterion 2**: competitiveness of industry.
- **Criterion 3:** extent of scale effects.

In a broadly similar way to the total water value chain, we first filtered all the industries (in both the EU KLEMS and ONS databases) down to a set that contained just those that: (i) we considered could share similar characteristics to the water industry (i.e. not ranked as "Red" according to Criterion 1); and (ii) are neither in regulated nor public sector industries (i.e. not ranked as "Red" according to Criterion 2).

Following this initial filtering process, we applied Criterion 3 to the remaining industries. Given that a split between retail and wholesale activities (for the water industry) is unavailable in the EU KLEMS database, we used proxies for gross output and capital stock, noting that our choice of proxies was constrained by data availability. To proxy for each metric we used (respectively): (i) gross profit; and (ii) tangible fixed assets. We used two data sources to derive the data on each of these two metrics.

- For water retail, we used APR data for each year between 2015-16 and 2020-21. Specifically:[101]
  - We used Table 2F for gross profit, taking the sum (across all companies) of total revenue minus wholesale charges (i.e. "Retail revenue"). We note that this data is only available for residential retail, and not non-household retail.
  - We used Table 2D for tangible fixed assets, summing the value of the assets at the end of the financial year end across all companies. For consistency with gross profit, we did not include the value of non-household tangible fixed assets.
- For comparator industries, we used the FAME database between 2015-16 and 2020-21,[102] which contains data from companies' accounts. For each of tangible fixed assets and gross output, we used the annual average (for each industry) of that metric across the companies for which data was recorded in that year.[103]

Following the above steps, we then applied Criteria 3a-3c in a similar way as per our approach for the total water value chain (as is detailed in Section 5B). Our findings can be seen below:

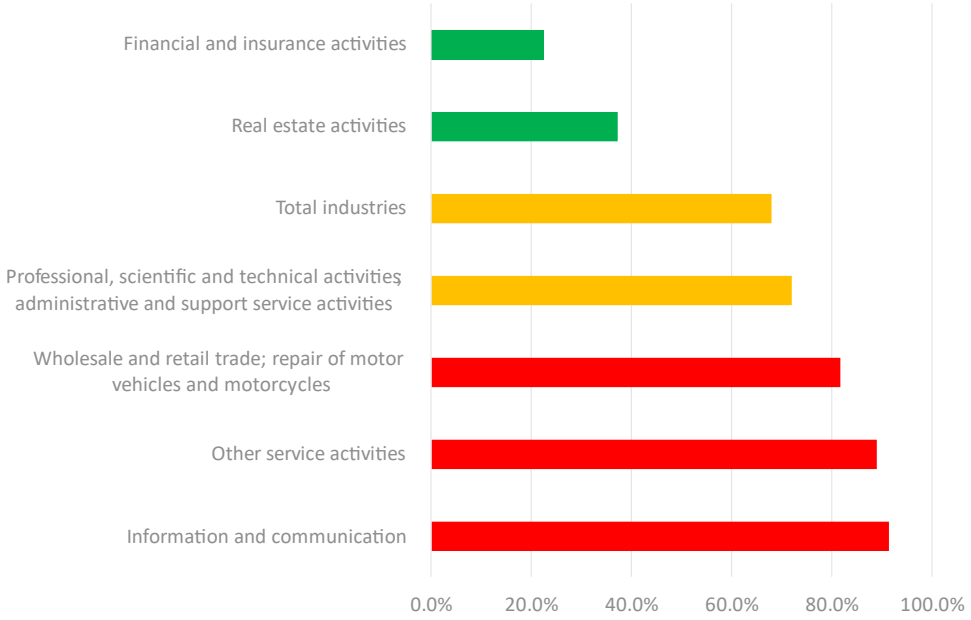
- **For Criterion 3a**, we assigned our three-colour scale in the following way: (i) "Green" where the absolute divergence between the averages is less than 40.0%; (ii) "Amber" where the absolute divergence is between 40.0% and 80.0%; and (iii) "Red" where the absolute divergence is greater than 80.0%. Figure 24 shows the absolute divergence from water retail.

[101] *We adjusted data taken from both these sources to be in 2020-21 prices using quarterly CPIH index data. Specifically, we averaged the index for a given financial year over the four quarters in that year. Please see: https://www.ons.gov.uk/generator?format=xls&uri=/economy/inflationandpriceindices/timeseries/l522/mm23.*

[102] *Please see: https://fame4.bvdinfo.com/ (last accessed 27 March 2023).*

[103] *As the FAME database contains data from individual company accounts, there can be significant differences in the number of companies that have submitted data on each metric. As such, comparing sums across gross profit and tangible fixed assets could lead to inconsistencies; thus we chose to use the average across companies*

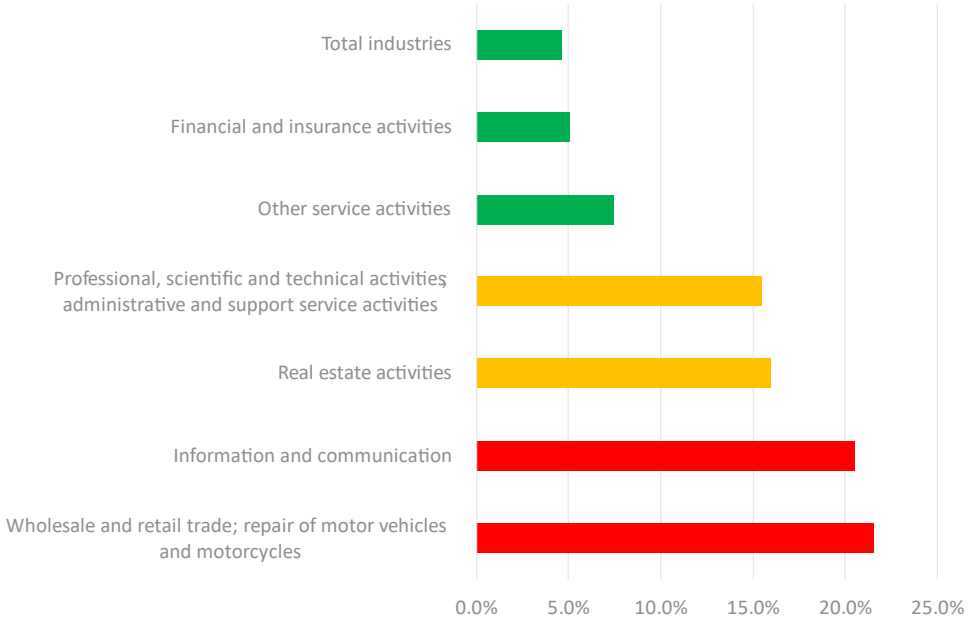
Figure 24: Absolute divergence in average tangible fixed asset-gross profit ratio (2015-16 to 2020-21)



Source: Economic Insight analysis of APR and FAME data

- **For Criterion 3b**, we assigned the three-colour scale in the following way: (i) "Green" where the absolute divergence between the averages is less than 10.0%; (ii) "Amber" where the absolute divergence is between 10.0% and 20.0%; and (iii) "Red" where the absolute divergence is greater than 20.0%. Figure 25 shows the absolute divergence from water retail.

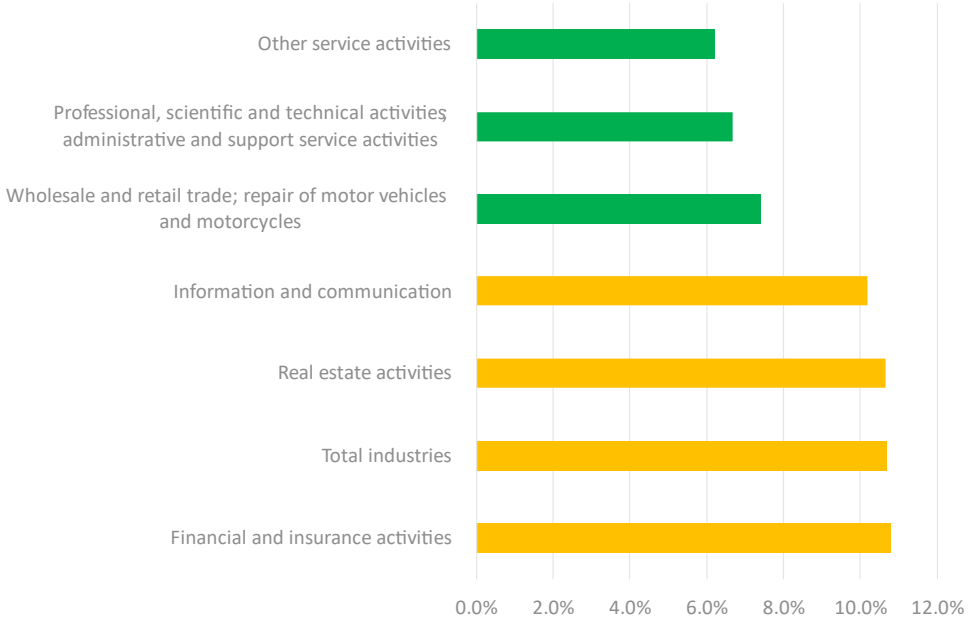
Figure 25: Absolute divergence in tangible fixed asset growth rate (2015-16 to 2020-21)



Source: Economic Insight analysis of APR and FAME data

- **For Criterion 3c**, we assigned the three-colour scale in the following way: (i) "Green" where the absolute divergence between the comparator and the water industry is between 6.0% and 8.0%; and (ii) "Amber" where the absolute divergence is greater than 8.0%. Figure 26 shows the absolute divergence from water retail.

Figure 26: Absolute divergence in gross profit growth rate (2015-16 to 2020-21)



Source: Economic Insight analysis of APR and FAME data

In the same way as per the total water value chain, we have defined a *'preferred set'* of comparators for our retail-specific analysis. In doing so, we have applied somewhat less stringent thresholds in order for a comparator industry to be included. Specifically, we have included any industry that is defined as "Green" in at least one of Criteria 1, 2, 3a, 3b and 3c.[104] In doing so, we are therefore attaching more weight to Criterion 1 (similarity of activities) and somewhat less weight to Criterion 3 (economies of scale) under our retail analysis, relative to our analysis for the total water value chain.

- We consider that more weight can be placed on Criterion 1 for water retail (relative to the total water value chain). This is because we are considering the activities of water retail specifically (as opposed to the totality of activities of a water company) meaning that choosing comparators with similar activities is easier.

[104] *We note that, although "Total industries" fulfils this condition, we have chosen not to include it in our 'preferred set' of comparators. As we discuss below, we consider that more weight can be placed on Criterion 1 for water retail, relative to the total water value chain. As such, we consider that our 'preferred set' comprises industries that are more similar to water retail, than the equivalent set for the total water value chain. Therefore, we do not consider it necessary to include a metric that captures productivity changes across the entire UK 'on average' in our 'preferred set'.*

- We consider that less weight can be placed on Criterion 3 for water retail (relative to the total water value chain), due to the need to: (i) proxy for capital stock and gross output; and (ii) combine data from two separate data sources (APR and FAME), which might reduce comparability.

In addition to our recommended comparators, we have examined how varying the comparator set impacts our results by running four sensitivity analyses, as follows:

  - **Sensitivity 1**. In addition to our *'preferred set'* of comparators, this also includes "Total industries". This tests whether the inclusion of a metric that captures productivity changes across the entire UK 'on average' affects our results.

  - **Sensitivity 2**. Whereby the assessment under Criterion 1 is strengthened. Specifically, this only includes comparators for which Criterion 1 is defined as "Green" (and thus places more weight on the similarity of sectors).

  - **Sensitivity 3**. Here, the assessment under Criterion 2 is strengthened. Specifically, only comparators for which the adjusted HHI in Figure 14 is less than 2,000 are included.

  - **Sensitivity 4**. Finally, under this sensitivity, the assessment under Criterion 3 is strengthened. Specifically, this only includes comparators for which at least one of Criteria 3a-3c is defined as "Green" (and thus places more weight on the similarity of sectors as regards economies of scale).[105]

Table 10 presents the results of our assessment of comparators against the criteria detailed above. As with the total water value chain, we report our results in relation to three defined 'ranges'; and so below we detail which comparators we include under each. We also note that the time periods corresponding to each of the below ranges are consistent with those used for the total water value chain (as detailed in Section 4C).

- **Plausible range**. This includes our *'preferred set'* of comparators for water retail.

- **PR24 focused range**. This also only includes our *'preferred set'* of comparators for water retail.

- **Sensitivity analysis range**. This includes our *'preferred set'* of comparators for water retail, in addition to those as tested under our sensitivity analyses (**Sensitivity 1**; **Sensitivity 2**; **Sensitivity 3**; and **Sensitivity 4**).

[105] *This also includes "Total industries".*

Table 10: Assessment of industries against Criteria (**water retail**)

Industry	Criteria					Preferred set	Sensitivity			
	1	2	3a	3b	3c		1	2	3	4
Total industries						✗	✓	✗	✗	✓
Wholesale and retail trade; repair of motor vehicles and motorcycles						✓	✓	✓	✓	✓
Information and communication						✓	✓	✓	✗	✗
Financial and insurance activities						✓	✓	✓	✗	✓
Real estate activities						✓	✓	✗	✓	✓
Professional, scientific and technical activities; administrative and support service activities						✓	✓	✓	✓	✓
Other service activities						✓	✓	✗	✗	✓

Source: Economic Insight analysis

8B. Results

Following our methodology for arriving at frontier shift estimates for water retail across the three above-mentioned ranges, we arrive at the following frontier shift estimates for PR24. These ranges are as follows:

- **Plausible range (0.3%-0.6%)**. The lower end of this range corresponds to 1970-2007 (NACE I), and the upper end to 1995-2019 (NACE II).
- **PR24 focused range (0.4%-0.6%)**. The lower end corresponds to Weighted average of 1995-2019 (NACE II) and 1970-2007 (NACE I), and the upper end to 2010-2019 (NACE II).
- **Sensitivity analysis range (-0.2%-1.2%)**. Details of the comparators and time periods for both the upper and lower ends of this range are given in Table 11.

Table 11 summarises our results for each of the three ranges and recaps the comparators used. We present our full set of results in Annex 4.

Table 11: Summary table of minimum and maximum results across our three ranges[106]

Comparator	Plausible range		PR24 focused range		Sensitivity analysis range	
	Low	High	Low	High	Low[107]	High[108]
Total industries					0.2%	
Wholesale and retail trade; repair of motor vehicles and motorcycles	0.1%	-0.1%	-0.1%	-0.1%	-0.2%	0.7%
Information and communication	1.8%	3.7%	2.9%	3.7%		3.2%
Financial and insurance activities	-0.2%	-0.6%	-0.3%	-0.6%	-0.3%	0.9%
Real estate activities	-0.5%	1.3%	0.0%	1.3%	0.5%	-0.1%
Professional, scientific and technical activities; administrative and support service activities		-0.1%	-0.3%	-0.1%	-0.3%	
Other service activities		-0.3%	-1.2%	-0.3%	-1.2%	
Final results (average)	**0.3%**	**0.6%**	**0.4%**	**0.6%**	**-0.2%**	**1.2%**

Source: Economic Insight analysis of EU KLEMS data

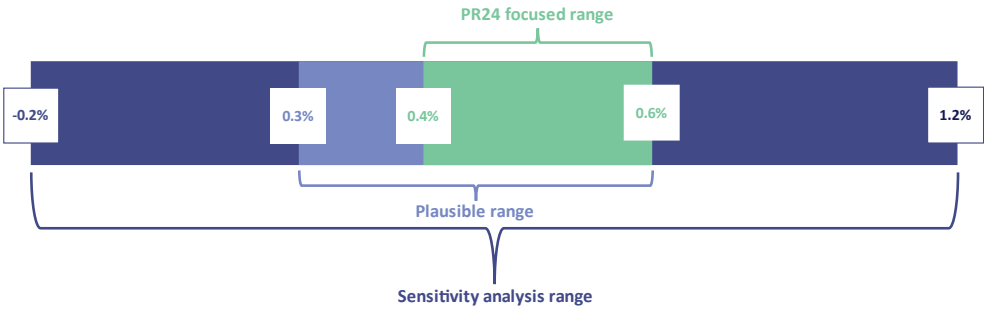
[106] *We note that, for some comparators in NACE II, there is no NACE I equivalent (e.g. "Other service activities"), hence there is no TFP estimate for this comparator at the 'Low' end of our 'plausible range', but there is at the 'High' end. For these comparators, the TFP estimate at the 'Low' end of our 'PR24 focused range' (1970-2019) is equal to the 1995-2019 average. As such, the average across comparators in 1970-2019 may not equate to the average of the individual comparator TFP estimates, as it is calculated using a weighted average of the total averages across comparators in 1995-2019 and 1970-2007.*

[107] *This corresponds to: (i) comparators that are defined as "Green" in at least one of Criteria 3a, 3b or 3c (**Sensitivity 4**); and (ii) the 1995-2019 period.*

[108] *This corresponds to: (i) comparators that are included in our 'preferred set'; and (ii) the 1992-2007 period.*

Figure 27 provides a visual summary of our ranges.

Figure 27: Illustration of our three ranges (water retail)



Source: Economic Insight

As with the total water value chain, our retail-specific estimates are based on: (i) a gross output approach; and (ii) an arithmetic mean.

In this report, we do not provide separate wholesale-specific frontier shift estimates, although we note that these would be very similar to those provided for the total water value chain, due to the fact that the vast majority of totex is wholesale-based. However, if companies wish to derive a wholesale-specific estimate, then the following formula can be used:

$$Frontier\ shift_W = \frac{Frontier\ shift_T \times Totex_T - Frontier\ shift_R \times Totex_R}{Totex_W}$$

In the above equation: "T" refers to total water; "W" to wholesale; and "R" to retail; and $Totex_T = Totex_W + Totex_R$.

9 Recommendations

Having presented our range of frontier shift estimates for both the total water value chain and water retail specifically, we now present a series of recommendations in light of these estimates. Firstly, we set out recommendations for companies, going into the development of their PR24 business plans. Secondly, we present a set of recommendations for both companies and Ofwat regarding the approach to frontier shift at PR24.

9A. Recommendations to companies

In terms of how we recommend companies utilise our estimates in developing their PR24 business plans, this is as follows:

- The estimation of frontier shift is inherently uncertain. As such, companies have some discretion as to what evidence / approaches they place most weight on when determining what frontier shift to assume in their business plans for PR24. Our own analysis suggests frontier shift for the total water value chain could plausibly lie between 0.3% and 0.8% pa (0.3% and 0.6% for water retail); and so companies could select any figure within this range and it would be supportable, on the evidence. In determining 'where' in that range to select, companies should consider (and explain in their plans) the specific evidence / rationale in our report (or from elsewhere) they rely on.

- That said, with a focus specifically on the PR24 time period, it seems *likely* (both on the evidence and intuition, given the persistence of low productivity) that frontier shift will sit within a narrower range (which we find to be 0.3% to 0.7% for the total water value chain; and 0.4% to 0.6% for water retail). Companies should therefore consider with care the case for selecting figures outside of these narrower ranges (noting that, prior to PR14, frontier shift in the water industry was typically set around these levels by Ofwat).

- The fact that embodied technological change is only partially captured in our estimates may provide some basis for choosing numbers towards the higher end of our ranges. On the other hand, the fact that our raw estimates implicitly include efficiencies other than frontier shift means they are overstated, providing some

basis for choosing numbers towards the lower end of our ranges.[109] Our recommendation is therefore that companies should: (i) generally adopt numbers at the mid-points of our ranges; or (ii) could deviate from that (i.e. selecting higher or lower numbers within our ranges) if that decision was informed by additional evidence relating to:

  - an assessment of the rate of technological change in the water industry, relative to the comparator sectors; and / or
  - additional evidence as to the scope for other efficiencies (e.g. economies of scale) in the water industry, relative to the comparator sectors.[110]

- We consider that (in principle) frontier shift gains should be applied to the totality of company costs (i.e. both base and enhancement), other than costs which are deemed outside of management control. In relation to enhancement costs, in order to avoid either omitting (or double-counting) a frontier shift challenge, companies should provide clear evidence as to how the frontier shift has been applied. If companies consider a frontier shift challenge has been implicitly included, they should explain why and provide evidence to support that. Where the challenge has been explicitly applied, they should state so and demonstrate this.

- Companies may want to consider whether, and to what extent, the possible use of Ofwat's innovation fund may affect the scope for frontier shift on a forward-looking basis. However, we note that the size of the fund (£200m)[111] relative to total industry totex set by Ofwat in its PR19 FD (£49.6bn)[112] is sufficiently small that it seems doubtful that this can materially affect productivity and thus, we do not recommend making an adjustment for this.

9B. Wider recommendations for PR24

Below we set out recommendations for Ofwat and companies for PR24, in order to ensure that the most appropriate estimate of frontier shift is selected:

- Ensure that any choice of time period is based on a transparent assessment against the considerations captured within our criteria (specifically: internal consistency; use of complete business cycles; utilisation of data; and reflecting the structural break in productivity in the UK, post 2008). The UK's economic outlook should be reviewed as plans are finalised / regulatory determinations are made, to help ensure this is the case.

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[109] *Noting that the overstatement of frontier shift due to catch-up is likely greater in magnitude than a potential understatement due to scale effects.*

[110] *Relatedly, and as noted previously in this executive summary, companies could further consider whether the comparator set itself might change, if (for example) the expected mix of activities they will undertake at PR24 is sufficiently different from the past.*

[111] *'Creating tomorrow, together: Our final methodology for PR24 Appendix 9 Setting expenditure allowances.' Ofwat (December 2022); page 38.*

[112] *'PR19 slow track draft determinations: Securing cost efficiency technical appendix.' Ofwat (December 2019); page 8.*

- In selecting comparators, undertake analysis to apply the evaluation criteria outlined in this report; critically assessing each comparator industry to objectively determine its applicability. This will also help inform how (or whether) to reflect any efficiencies other than frontier shift captured in the raw TFP data.

- Any updated productivity data (in particular, the EU KLEMS or ONS datasets) that is published between now and the determinations should, ideally, be utilised and frontier shift estimates updated prior to the determinations.

- Any further information / evidence relating the relative competitiveness of comparator sectors (published prior to the determinations) should be reviewed and taken into consideration.

- Frontier shift estimates should be based on gross output TFP productivity, with little or no weight given to value added estimates.

- If frontier shift is estimated over a very long time period, the use of a geometric mean should be considered.

- In relation to embodied technological change, this matter could be further informed by the following:

  (ii) Analyse historical TFP growth in the industry; and track the extent to which periods of higher technological change correlate with increased TFP growth. Then one could 'map forward' any anticipated technological change over PR24, to determine whether it is likely to be a relatively 'high', or 'low', period of technological change.

  (iii) Undertake a literature review regarding empirical estimates of embodied technological change. From our existing research, we have identified academic articles that estimate between 20%[113] and 60%[114] of TFP growth may represent embodied change. However, these estimates should be taken with certain caveats. Firstly, both studies rely upon data that is 40 years old (i.e. when productivity growth was much higher than it is now). Secondly, they take data from the US, whose economy has been consistently subject to higher levels of investment and greater productivity growth than the UK. Therefore, although these academic sources are informative in providing a starting point for quantifying the degree to which TFP may underestimate achievable frontier shift, their calculations should not be taken as a 'rule' for any adjustments required (further noting our finding that, in any event, TFP already includes *some* embodied technological change).

  (iv) For each chosen comparator, undertake a two-stage process to determine the importance of potentially excluded embodied technological change. Firstly, develop evidence as to the amount of embodied change that is likely reflected in the TFP data of the comparators. Secondly, examine the rate of technological change in the comparators, and compare this to the rate of

[113] *'Growth Accounting When Technical Change is Embodied in Capital.' Hulten, C. (January 1992).*
[114] *'Embodied and disembodied technical change and the constant elasticity of substitution production function.' Uri, N. (December 1983).*

technological change in the water industry. Where the rates are similar, the more appropriate it is to adjust for excluded embodied technological change. Conversely, where the rate of technological change is materially different in the water industry, relative to the comparators, adjustments for embodied change are more likely to result in an over or understatement of frontier shift. For example, where technological change in the water industry is slower than that for the comparators, an adjustment would likely result in an overstatement of frontier shift (and vice-versa).

- As a matter of urgency, the industry needs some way to scale the size of the efficiency challenge being set under the performance commitments at PR24. Without this, the totality of the efficiency challenge (both catch-up and frontier shift) cannot be determined; and a 'double-count' will likely occur. This is a material limitation under the current regulatory framework.

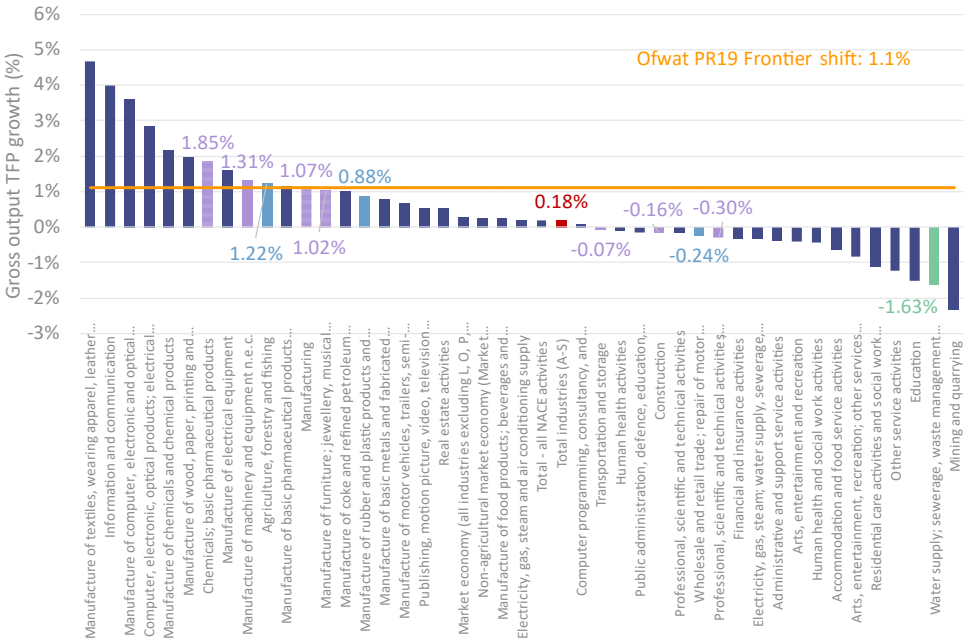
- Ofwat should adopt an internally consistent approach between that which is currently taken for real price effects, and what should be taken for frontier shift. Specifically, any frontier shift challenge should only account for ongoing efficiency gains specific to the water industry, that are not already implicitly captured within CPIH.

10 Annex 1: Ofwat's PR19 target compared to UK industry-wide productivity performance

Below, we present Ofwat's assumed frontier shift (1.1% pa) at PR19 against the distribution of TFP growth across industries using EU KLEMS data. We show this firstly against the three periods included in our *'plausible range'*: (i) 1995-2019 (the majority of the last two business cycles, and the entirety of the period for which NACE II data is available); (ii) 2010-2019 (the majority of the most recent business cycle); and (iii) 1970-2007 (the majority of the four business cycles prior to the financial crisis, and the entirety of the period for which NACE I data is available). Secondly, we show this against the additional period included in our *'sensitivity range'*: 1992-2007 (the majority of the business cycle before the financial crisis). In each of these figures in this annex (in addition to Figure 2 and Figure 5 in the main body of the report), the colour and style of the bars correspond to the following:

- Solid green bar: water sector only in NACE II ("Water supply; sewerage, waste management and remediation activities"); electricity and water sectors combined in NACE I ("Electricity, gas, steam; water supply, sewerage, waste management").
- Red bar: "Total industries", which is also a comparator included in our *'preferred set'* but not used by Ofwat.
- Dashed purple bar: comparators used by Ofwat and also included in our *'preferred set'*.
- Solid purple bar: comparators chosen by Ofwat but not included in our *'preferred set'*.
- Solid light blue bar: comparators included in our *'preferred set'* but not chosen by Ofwat (excluding "Total industries").
- Dark blue bar: all other comparators.

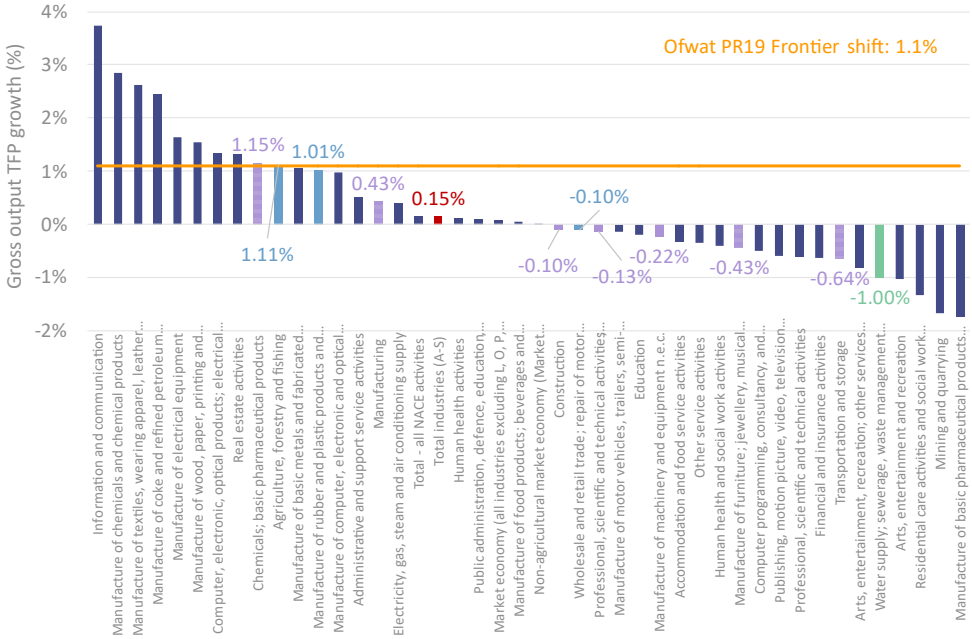
Figure 28: Sector level gross output TFP growth – EU KLEMS (1995 to 2019)



Source: Economic Insight analysis of EU KLEMS data

Notes: We have not included "Telecommunications" in this chart in order to improve readability, as its average TFP growth is 12.9%.

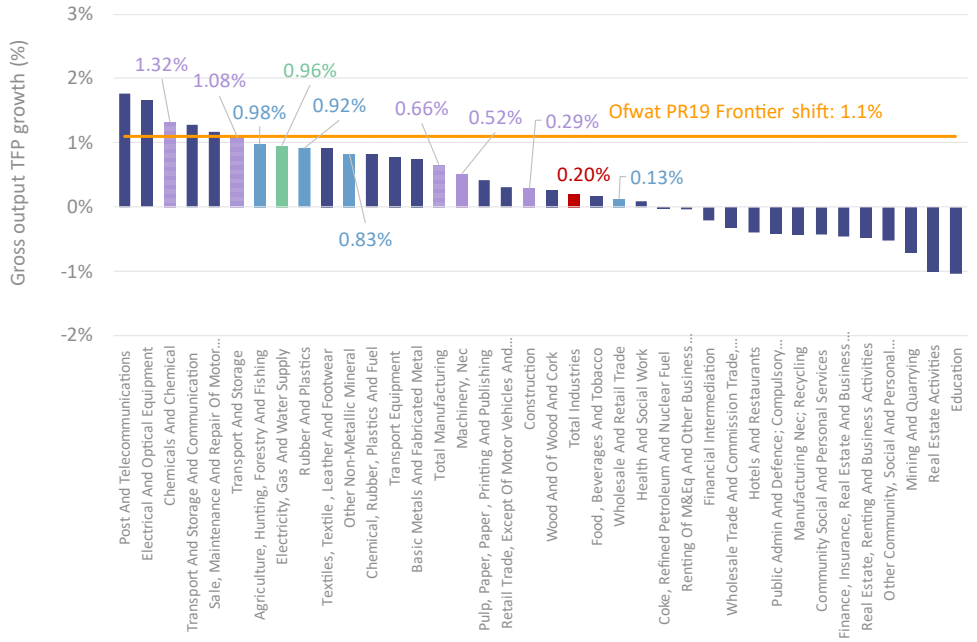
Figure 29: Sector level gross output TFP growth – EU KLEMS (2010 to 2019)



Source: Economic Insight analysis of EU KLEMS data

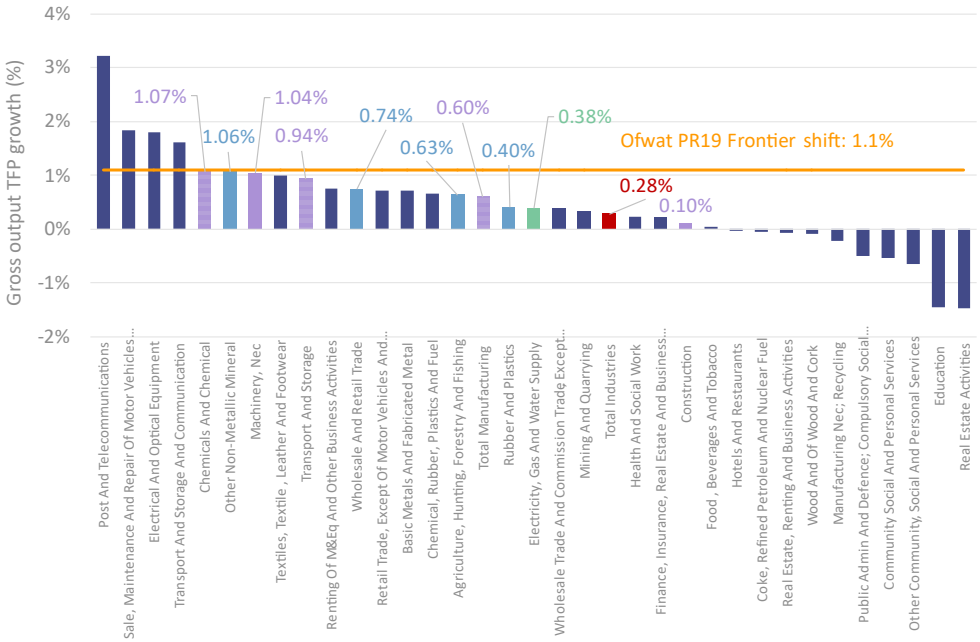
Notes: We have not included "Telecommunications" in this chart in order to improve readability, as its average TFP growth is 15.4%.

Figure 30: Sector level gross output TFP growth – EU KLEMS (1970 to 2007)



Source: Economic Insight analysis of EU KLEMS data

Figure 31: Sector level gross output TFP growth – EU KLEMS (1992 to 2007)



Source: Economic Insight analysis of EU KLEMS data

These figures show that, under any of these four time periods, Ofwat's PR19 frontier shift challenge (1.1%) is driving a frontier shift position that is an *'outlier'* (although clearly this is a matter of degree). Specifically, the average TFP productivity growth for "Total industries" is consistently below 1.1%. Furthermore, this is borne out by the number of sectors that would meet Ofwat's frontier shift challenge over the various time periods (noting that these often, as one would expect, relate to high-tech industries, such as telecoms; chemicals; and computing):

- Between 1995 and 2019, 12 sectors would achieve Ofwat's challenge out of the 46 considered in the dataset (as shown in Figure 28).
- Between 2010 and 2019, 11 sectors would achieve Ofwat's challenge out of the 46 considered in the dataset (as shown in Figure 29).
- Between 1970 and 2007, 5 sectors would achieve Ofwat's challenge out of the 38 considered in the dataset (as shown in Figure 30).
- Between 1992 and 2007, 4 sectors would achieve Ofwat's challenge out of the 38 considered in the dataset (as shown Figure 31).

Below, we compare whether productivity measures differ markedly when using ONS MFP as a proxy instead of EU KLEMS TFP. The time periods correspond to those detailed in Section 4C that are included in our sensitivity range: (i) 2010-2019 (the last full business cycle, excluding 2020 which was affected by COVID-19); (ii); 2010-2021 (the last full business cycle, applying an alternative definition for its end); and (iii) 1970-2021 (entire full period for which data is available, and applying an alternative definition for the end of the most recent business cycle).

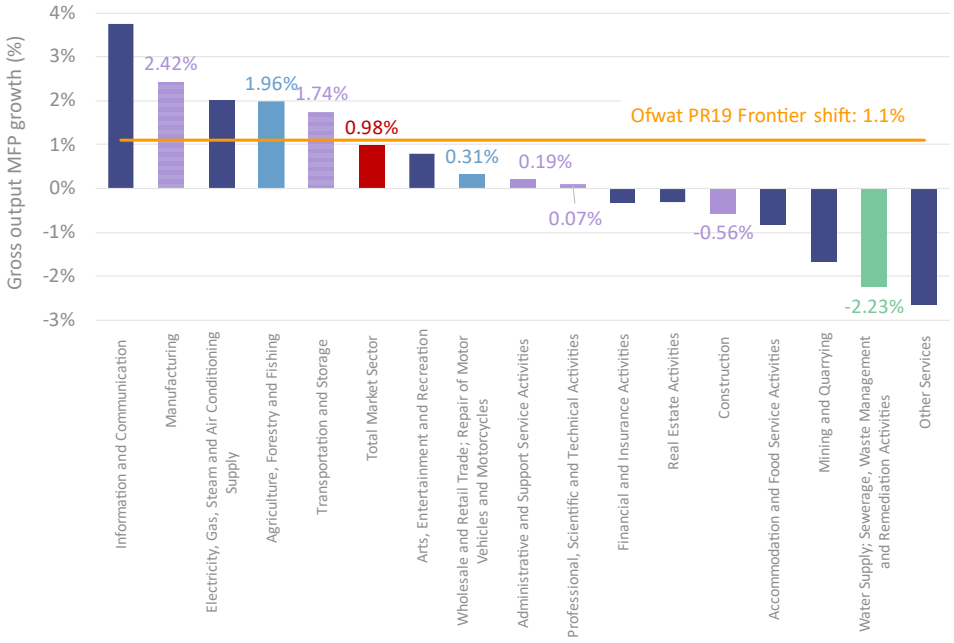
We note the following differences between the EU KLEMS and ONS measures.

- Firstly, the ONS dataset assesses how MFP varies over the time period, whilst EU KLEMS analyses how TFP varies over the time period. Whilst these measures are substantively the same, there are some slight differences. We explain these in Annex 2.
- Secondly, whilst 2019 is the last year captured in the EU KLEMS TFP data available, ONS MFP captures data up to and including 2021. To make maximum use of the available data, we therefore extend the end date of the period under consideration for two of the time periods in the figures below. Not only does this allow us to more fully assess the most recent complete business cycle, but it also means estimates include (part of) the effect of the COVID-19 period. As the effects of COVID-19 are likely to linger over PR24, it is important to have an in-depth understanding of them.
- Thirdly, when considering the results of these graphs, it is important to bear in mind that they present a value added estimate. This means that, ceteris paribus, we would expect their results to be higher than the EU KLEMS figures, which represent a gross output estimate. The economic theory underlying this rationale is explained in Section 3B.

- Lastly, the ONS and EU KLEMS data estimate productivity over slightly different sectors. As a generalisation, ONS only considers sectors at a high-level of aggregation, whilst EU KLEMS also breaks sectors down to a more granular level. This is made obvious when analysing the number of sectors each dataset considers – EU KLEMS considers up to 46 sectors in its NACE II dataset, whilst ONS only considers 17 sectors.

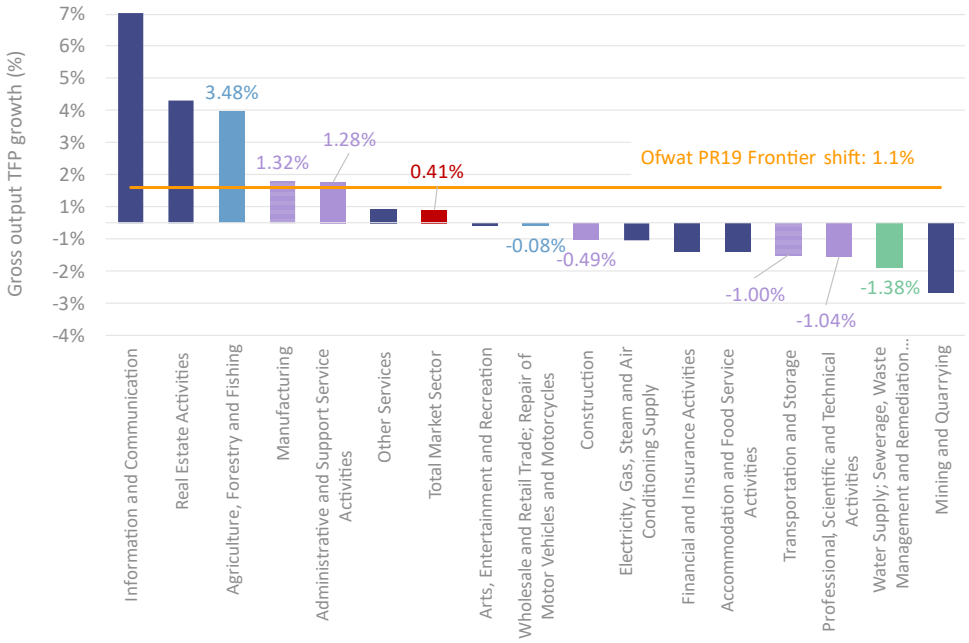
In the below figures, the colour coding used is the same as for the EU KLEMS figures, but we note that Ofwat did not use the ONS dataset in its analysis so the purple (both dashed and solid) bars correspond to the bars that would have been chosen by Ofwat had it used the ONS database, based on its choice of EU KLEMS comparators.

Figure 32: Sector level productivity growth – ONS (1970 to 2021)



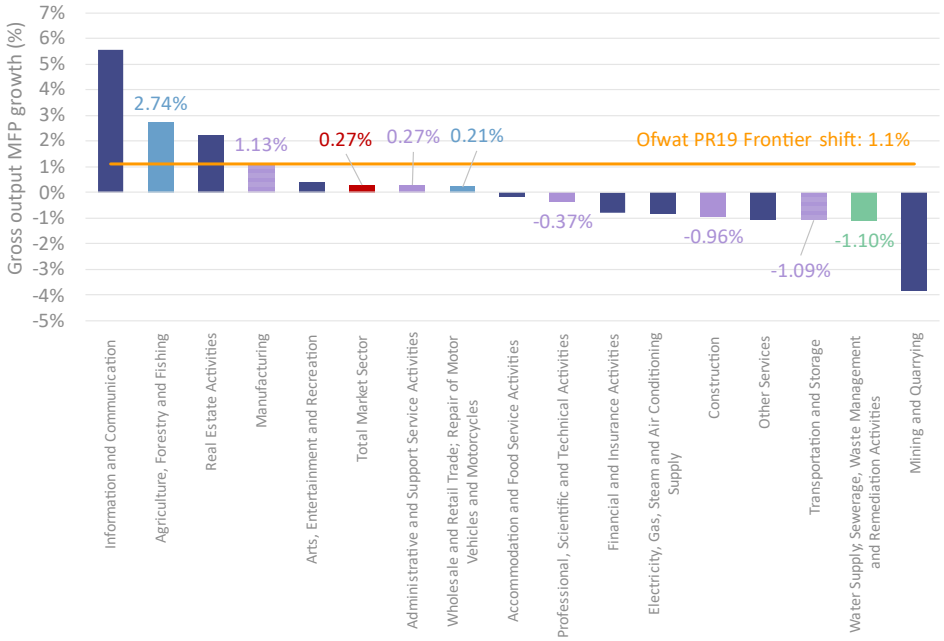
Source: Economic Insight analysis of ONS MFP data

Figure 33: Sector level productivity growth – ONS (2010 to 2019)



Source: Economic Insight analysis of ONS MFP data

Figure 34: Sector level productivity growth – ONS (2010 to 2021)



Source: Economic Insight analysis of ONS data

Despite the differences between the ONS and EU KLEMS datasets, we find that the headline takeaway from both graphs is the same. ONS MFP data also makes it clear that only a minority of sectors meet Ofwat's frontier shift challenge over the various time periods.

- Between 1970 and 2021, 5 sectors would achieve Ofwat's challenge out of the 17 considered in the dataset (as shown in Figure 32).

- Between 2010 and 2019, 5 sectors would achieve Ofwat's challenge out of the 17 considered in the dataset (as shown in Figure 33).
- Between 2010 and 2021, 4 sectors would achieve Ofwat's challenge out of the 17 considered in the dataset (as shown in Figure 34).

Therefore, for ONS MFP the implication of these results is the same as for EU KLEMS TFP – Ofwat expects that the water sector should be able to achieve productivity growth at a level well above the rate achieved for most sectors in the UK economy.

11 Annex 2: Description of ONS and KLEMS datasets

In this annex we set out a description of the datasets used in our analysis. We do this firstly for the EU KLEMS database (that we use for TFP estimates); and secondly for the ONS database (that we use for MFP estimates).

11A. EU KLEMS

The EU KLEMS dataset provides productivity information that is comparable across a range of countries, including those from the EU, UK, US, and Japan. EU KLEMS draws its source information from national statistics agencies. These bodies, such as the ONS, provide the input values used as part of the index. EU KLEMS uses this source data for its measures of output, intermediate inputs (such as energy and materials), capital and labour to develop productivity estimates. The latest iteration, released in 2021, contains data for these countries from 1995. EU KLEMS calculates TFP growth by decomposing the contribution to growth in volume terms of capital, labour and TFP. TFP is then calculated from this as a residual.[115] The sources used for each category of the TFP calculation are shown below.

- **Output.** Gross value added and gross output are both used, with figures taken from Eurostat and other national agencies. In the 2023 EU KLEMS dataset, 2015 is used as the base year.

- **Labour.** The European Labour Force Survey is used to determine the employment level and structure for most European countries. However, UK employment figures are taken from the Labour Force Survey. Wage information is taken from the Structure of Earnings Survey for EU countries. To capture variations in volume and quality of labour over time, EU KLEMS assumes that the labour force is divided into different categories based on age, gender and education level. They assume that labour services are proportional to hours worked, and that wages are based on marginal productivities. To calculate total labour services, these individual categories are aggregated and weighted based on the share of total labour compensation that each category makes up.

[115] *'EUKLEMS & INTANProd: industry productivity accounts with intangibles.' Bontadini. F (February 2023); page 7.*

- **Capital.** A combination of Eurostat information and data from national agencies is used to estimate capital formation. In the first stage of the calculation, the volume and price of the services provided by each type of asset are estimated. This assessment is undertaken using a standard neoclassical approach. In the second stage, the flows of capital services provided by each asset type are estimated. This cannot be observed, so must be measured by proxy. Consistent with accepted practice, EU KLEMS assumes that capital service flows are proportional to the volume of capital stock. We note that EU KLEMS slightly adapted its methodology for assessing capital stocks from 2017 onwards. It used to estimate capital stocks using a perpetual inventory method, but has modified its approach - estimates of capital stocks by industry are now taken directly from Eurostat.

Output and input volumes are aggregated across industries using the Tornqvist quantity index. This method enables the measurement of the difference in productivity between two or more consecutive periods, or firms. To undertake the calculation, certain assumptions are required including: constant returns to scale; that inputs are paid the value of their marginal product; and that output prices reflect consumer willingness to pay.[116]

An advantage of using EU KLEMS is that the dataset is consistent with the national accounts data of the countries it reports on. This is an improvement upon the alternative of using firm-level data, which is not usually consistent with national accounts, and contains estimates that are crude. Furthermore, the EU KLEMS dataset builds upon the national accounts data of individual countries by using a common methodology to estimate the labour quality and capital.[117] This enables productivity comparisons to be drawn.

However, we note that the reliability of the data reduces when greater industry granularity is used, particularly for services industries. This is because, to increase the granularity of the data, adjustments must be made to national accounts data. These adjustments will require estimations to be made of capital and labour, that could be unreliable.

As was detailed in Section 4C, two separate datasets are available from EU KLEMS: (i) NACE I (1970-2007); and (ii) NACE II (1995-2019). We note that many of the sectors correspond 1:1 between the two datasets, but for other sectors this is not the case. Table 12 shows the industries included in the EU KLEMS database, with the NACE I sector that we have taken to correspond to that NACE II sector also listed. Where there is no equivalent to a particular sector (either in NACE I or NACE II), the corresponding row is left blank.

[116] *'Productivity improvement in the water and sewerage industry in England since privatisation,' Frontier Economics; (September 2017)*
[117] *'The mystery of TFP,' Oulton, S. (October 2017).*

Table 12: Industries in EU KLEMS NACE II dataset

Industry NACE II	Industry NACE I
Accommodation and food service activities	
Activities of extraterritorial organisations and bodies	Extra-Territorial Organizations And Bodies
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	
Administrative and support service activities	
Agriculture, forestry and fishing	Agriculture, Hunting, Forestry And Fishing
Air transport	
Arts, entertainment and recreation	
Arts, entertainment, recreation; other services and service activities, etc.	
Chemicals; basic pharmaceutical products	Chemicals And Chemical
Computer programming, consultancy, and information service activities	
Computer, electronic, optical products; electrical equipment	
Construction	Construction
Education	Education
Electricity, gas, steam and air conditioning supply	
Electricity, gas, steam; water supply, sewerage, waste management	Electricity, Gas And Water Supply
Financial and insurance activities	Financial Intermediation
Human health activities	
Human health and social work activities	Health And Social Work
Imputed rents of owner-occupied dwellings	

Industry NACE II	Industry NACE I
Information and communication	Post And Telecommunications[118]
Land transport and transport via pipelines	
Manufacture of basic metals and fabricated metal products, except machinery and equipment	Basic Metals And Fabricated Metal
Manufacture of basic pharmaceutical products and pharmaceutical preparations	
Manufacture of chemicals and chemical products	
Manufacture of coke and refined petroleum products	Coke, Refined Petroleum And Nuclear Fuel
Manufacture of computer, electronic and optical products	Electrical And Optical Equipment
Manufacture of electrical equipment	
Manufacture of food products; beverages and tobacco products	Food , Beverages And Tobacco
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	
Manufacture of machinery and equipment n.e.c.	Machinery, Nec
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	Transport Equipment
Manufacture of rubber and plastic products and other non-metallic mineral products	Rubber And Plastics[119]
	Other Non-Metallic Mineral
Manufacture of textiles, wearing apparel, leather and related products	Textiles, Textile , Leather And Footwear

[118] *We note that in the NACE I database there is not a direct equivalent to "Information and communication", neither is there an equivalent in the NACE II database for "Post and Telecommunications". However, having considered the two comparators separately, we consider that they are sufficiently comparable to be considered as equivalent comparators for the purposes of our analysis.*

[119] *We note that we have taken "Rubber and Plastics" as the NACE I equivalent for the NACE II entry "Manufacture of rubber and plastic products and other non-metallic mineral products", as the exact weighting between "Rubber and Plastics" and "Other Non-Metallic Mineral" is unclear.*

Industry NACE II	Industry NACE I
Manufacture of wood, paper, printing and reproduction	Wood And Of Wood And Cork
Manufacturing	Total Manufacturing
Market economy (all industries excluding L, O, P, Q, T and U)	
Mining and quarrying	Mining And Quarrying
Non-agricultural market economy (Market economy less industry A)	
Other service activities	
Postal and courier activities	
Professional, scientific and technical activities	
Professional, scientific and technical activities; administrative and support service activities	
Public administration and defence; compulsory social security	Public Admin And Defence; Compulsory Social Security
Public administration, defence, education, human health and social work activities	
Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	
Real estate activities	Real Estate, Renting And Business Activities
Residential care activities and social work activities without accommodation	
Retail trade, except of motor vehicles and motorcycles	Retail Trade, Except Of Motor Vehicles And Motorcycles; Repair Of Household Goods
Telecommunications	
Total - all NACE activities	
Total industries (A-S)	Total Industries
Transportation and storage	Transport And Storage

Industry NACE II	Industry NACE I
Warehousing and support activities for transportation	
Water supply; sewerage, waste management and remediation activities	
Water transport	
Wholesale and retail trade; repair of motor vehicles and motorcycles	Wholesale And Retail Trade
Wholesale and retail trade and repair of motor vehicles and motorcycles	Sale, Maintenance And Repair Of Motor Vehicles And Motorcycles; Retail Sale Of Fuel
Wholesale trade, except of motor vehicles and motorcycles	Wholesale Trade And Commission Trade, Except Of Motor Vehicles And Motorcycles
	Chemical, Rubber, Plastics And Fuel
	Community Social And Personal Services
	Finance, Insurance, Real Estate And Business Services
	Hotels And Restaurants
	Manufacturing Nec; Recycling
	Other Community, Social And Personal Services
	Private Households With Employed Persons
	Pulp, Paper, Paper , Printing And Publishing
	Real Estate Activities
	Renting Of M&Eq And Other Business Activities
	Transport And Storage And Communication

Source: Economic Insight analysis

11B. ONS MFP

ONS MFP is a value added measure of outputs per unit of total relevant input. It is calculated using a growth accounting framework. Its estimates cover only the market sector in the UK, which means that they exclude government and non-profit organisations. Like the EU KLEMS dataset, output and input volumes are aggregated across industries using the Tornqvist quantity index. To construct the index, the following input measures were used.[120]

- **Capital.** The ONS assesses the volume of capital services employed across the economy over a given period of time, using its volume index of capital services (VICS). The measure considers the flows of services produced by different types of assets. VICS covers 57 component industries and is collected on a quarterly basis. The primary data source for VICS is business investment (sourced from their Quarterly Acquisitions and Disposals of Capital Assets Survey). This assesses the acquisition and disposal of capital assets across the UK. This represents a different modelling choice to EU KLEMS; put simply, ONS MFP assesses the 'flow' of capital, whilst EU KLEMS TFP examines the 'stock' of capital. Whilst both modelling choices follow strong economic intuition, international comparisons cannot be drawn using ONS MFP, as business investment is not an internationally defined concept.

- **Labour.** The ONS accounts for the change in volume of labour by assessing the change in hours worked. As input data for this, the ONS uses the Labour Force Survey (which is the same to that used in EU KLEMS), and the Annual Survey of hours and earnings (ASHE). Changes in labour quality are assessed through the quality-adjusted labour input (QALI) index, which is computed using the OECD's growth accounting methodology.[121] To calculate this, the hours worked by different categories of workers are weighted by their relative income share. Workers are categorised by age, gender, industry of employment and education. This represents a slightly different set of characteristics to those used in EU KLEMS. The Labour Force Survey and ASHE are also used as the input data for labour quality.

- **Quarterly data from the national accounts is used as output data.** This is ONS GVA data of the UK market sector. Consequently, the ONS MFP index only provides an MFP figure using a value added methodology.

As a consequence of the input and output variables chosen by the ONS, its measure is slightly different to EU KLEMS. The most significant difference is that the ONS only uses a value added methodology, whilst EU KLEMS provides estimates using both a value added and gross output methodology. Due to this, when we compare ONS MFP estimates with EU KLEMS gross output results, we would expect the ONS estimates to be higher due to this modelling choice, with an explanation of this provided in Section 3B.

[120] *'Multi-factor productivity (MFP) QMI.' ONS (March 2020).*
[121] *'Multi-factor productivity (MFP) QMI.' ONS (March 2020).*

Less significantly, EU KLEMS and the ONS compile their labour and capital inputs slightly differently. This input variation is likely to produce different estimates.

The industries included in the ONS database are included in Table 13.

Table 13: Industries in ONS dataset

Industry
Agriculture, Forestry and Fishing
Mining and Quarrying
Manufacturing
Electricity, Gas, Steam and Air Conditioning Supply
Water Supply; Sewerage, Waste Management and Remediation Activities
Construction
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles
Transportation and Storage
Accommodation and Food Service Activities
Information and Communication
Financial and Insurance Activities
Real Estate Activities
Professional, Scientific and Technical Activities
Administrative and Support Service Activities
Public Administration and Defence; Compulsory Social Security
Education
Human Health and Social Work Activities
Arts, Entertainment and Recreation
Other Services
Total Market Sector

Source: Economic Insight analysis

12 Annex 3: Full set of results – total water value chain

In this annex, we provide the full set of our results for the total water value chain, across each of: (i) our *'plausible range'*; (ii) our *'PR24 focused range'*; and (iii) our *'sensitivity analysis range'*. We also provide value added estimates across (i), (ii) and (iii); and also from the ONS MFP dataset. In addition, we extend Ofwat's set of comparators to the time periods included in our *'plausible range'*.

12A. Plausible range

Table 14: Gross output TFP estimates (plausible range)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.2%	0.2%	0.2%
Agriculture, forestry and fishing	1.1%	1.2%	1.0%
Manufacturing	0.4%	1.1%	0.7%
Chemicals; basic pharmaceutical products	1.2%	1.9%	1.3%
Manufacture of rubber and plastic products and other non-metallic mineral products	1.0%	0.9%	0.9%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.4%	1.0%	
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Transportation and storage	-0.6%	-0.1%	1.1%
Final results (average)	**0.3%**	**0.7%**	**0.8%**

Source: Economic Insight analysis of EU KLEMS data

12B. PR24 focused range

Table 15: Gross output TFP estimates (PR24 focused range)[122]

Comparator	2010-2019	1970-2019 (weighted average of 1970-2007; 1995-2019)
Total industries	0.2%	0.2%
Agriculture, forestry and fishing	1.1%	1.1%
Manufacturing	0.4%	0.9%
Chemicals; basic pharmaceutical products	1.2%	1.6%
Manufacture of rubber and plastic products and other non-metallic mineral products	1.0%	0.9%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.4%	1.0%
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.1%
Transportation and storage	-0.6%	0.5%
Final results (average)	**0.3%**	**0.7%**

Source: Economic Insight analysis of EU KLEMS data

[122] *We note that, for some comparators in NACE II, there is no NACE I equivalent (e.g. "Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment"), hence there is no TFP estimate for these comparators in the 1970-2007 period. Therefore, for these comparators, the TFP estimate for 1970-2019 is equal to the 1995-2019 average. As such, the average across comparators in 1970-2019 may not equate to the average of the individual comparator TFP estimates, as it is calculated using a weighted average of the total averages across comparators in 1995-2019 and 1970-2007.*

12C. Sensitivity analysis range

Time period

Below we present the results of using the **1992-2007 (NACE I)** period on our *'preferred set'* of comparators. We include it in our *'sensitivity analysis range'* as it includes (almost) the entirety of the business cycle prior to the financial crisis (which we consider to be 1992-2009), noting that data is unavailable beyond 2007 in the NACE I database. It is not included in our *'plausible range'* or our *'PR24 focused range'* as it does not utilise all the data available in the NACE I database.

Table 16: Gross output TFP estimates – 1992-2007 (NACE I)

Comparator	1992-2007
Total Industries	0.3%
Agriculture, Hunting, Forestry And Fishing	0.6%
Total Manufacturing	0.6%
Chemicals And Chemical	1.1%
Rubber And Plastics	0.4%
Wholesale And Retail Trade	0.7%
Transport And Storage	0.9%
Final results (average)	**0.7%**

Source: Economic Insight analysis of EU KLEMS data

Comparator choice

We also include different comparators in our assessment in order to test modifications to our *'preferred set'* of comparators.

As was detailed in Section 5C, we have included **Sensitivity 1**, which adds "Mining and quarrying" to our *'preferred set'* of comparators. This is because it fulfils the conditions to be included in our *'preferred set'*, but the TFP estimates are much lower for this sector, implying it is an outlier. However, we consider it beneficial to report it under a sensitivity analysis, in order to test the robustness of our *'preferred set'* of comparators to its inclusion.

Table 17: Gross output TFP estimates (Sensitivity 1)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.2%	0.2%	0.2%
Agriculture, forestry and fishing	1.1%	1.2%	1.0%
Mining and quarrying	-1.7%	-2.3%	-0.7%
Manufacturing	0.4%	1.1%	0.7%
Chemicals; basic pharmaceutical products	1.2%	1.9%	1.3%
Manufacture of rubber and plastic products and other non-metallic mineral products	1.0%	0.9%	0.9%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.4%	1.0%	
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Transportation and storage	-0.6%	-0.1%	1.1%
Final results (average)	**0.1%**	**0.4%**	**0.6%**

Source: Economic Insight analysis of EU KLEMS data

Furthermore, as was detailed in Section 5C, we have included **Sensitivity 2**, where the assessment under Criterion 3 strengthened. Specifically, this only includes comparators for which at least two of Criteria 3a, 3b and 3c are ranked as "Green" (and thus places more weight on the similarity of sectors as regards economies of scale).

Table 18: Gross output TFP estimates (Sensitivity 2)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.2%	0.2%	0.2%
Agriculture, forestry and fishing	1.1%	1.2%	1.0%
Manufacturing	0.4%	1.1%	0.7%
Chemicals; basic pharmaceutical products	1.2%	1.9%	1.3%
Transportation and storage	-0.6%	-0.1%	1.1%
Final results (average)	**0.4%**	**0.9%**	**0.8%**

Source: Economic Insight analysis of EU KLEMS data

Furthermore, as was detailed in Section 5C, we have included **Sensitivity 3**, where: (i) the assessment under Criterion 3 is strengthened (in the same as with **Sensitivity 2**); and (ii) aggregated sectors are excluded. We implement condition (ii) in order to test whether the implicit inclusion of some activities that are less similar to water is affecting our results.

Table 19: Gross output TFP estimates (Sensitivity 3)

Comparator	2010-2019	1995-2019	1970-2007
Agriculture, forestry and fishing	1.1%	1.2%	1.0%
Chemicals; basic pharmaceutical products	1.2%	1.9%	1.3%
Transportation and storage	-0.6%	-0.1%	1.1%
Final results (average)	**0.5%**	**1.0%**	**1.1%**

Source: Economic Insight analysis of EU KLEMS data

In addition, as is detailed in Section 5C, we have included a **Sensitivity 4**, where Criterion 2 is strengthened. We strengthen Criterion 2 in order to test the effect of including comparators that may be considered *'highly concentrated'* by the CMA (as detailed in our description of Criterion 2 in Section 5B) in our *'preferred set'* of comparators. Specifically, only comparators for which the adjusted HHI in Figure 14 is less than 2,000 are included.

Table 20: Gross output TFP estimates (Sensitivity 4)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.2%	0.2%	0.2%
Agriculture, forestry and fishing	1.1%	1.2%	1.0%
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Transportation and storage	-0.6%	-0.1%	1.1%
Final results (average)	**0.1%**	**0.3%**	**0.6%**

Source: Economic Insight analysis of EU KLEMS data

Finally, as is detailed in Section 5C, we have included a **Sensitivity 5**, in which we have added "Construction" to our *'preferred set'*. This is because, although "Construction" does not fulfil our conditions (in relation to our three Criteria) to be included in either our *'preferred set'*, or our above-mentioned sensitivities, we consider that there are some activities undertaken by water companies that may be consistent with those of construction companies. Therefore, although (under our criteria) construction is not sufficiently similar to the total water value chain to be included, we consider it informative to have a sensitivity analysis that incorporates it.

Table 21: Gross output TFP estimates (Sensitivity 5)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.2%	0.2%	0.2%
Agriculture, forestry and fishing	1.1%	1.2%	1.0%
Manufacturing	0.4%	1.1%	0.7%
Chemicals; basic pharmaceutical products	1.2%	1.9%	1.3%
Manufacture of rubber and plastic products and other non-metallic mineral products	1.0%	0.9%	0.9%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.4%	1.0%	
Construction	-0.1%	-0.2%	0.3%
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Transportation and storage	-0.6%	-0.1%	1.1%
Final results (average)	**0.3%**	**0.6%**	**0.7%**

Source: Economic Insight analysis of EU KLEMS data

12D. Value added estimates

We now provide estimates using value added TFP productivity growth, rather than gross output, for each of the sets of comparators and time periods detailed above; in addition to the ONS MFP dataset.

Plausible range

Table 22: Value added TFP estimates (plausible range)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.3%	0.3%	0.4%
Agriculture, forestry and fishing	2.2%	2.3%	2.4%
Manufacturing	1.2%	2.9%	1.9%
Chemicals; basic pharmaceutical products	2.7%	4.4%	3.9%
Manufacture of rubber and plastic products and other non-metallic mineral products	2.8%	2.2%	2.3%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.9%	2.1%	
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.2%	-0.4%	0.4%
Transportation and storage	-1.5%	-0.2%	2.2%
Final results (average)	**0.8%**	**1.7%**	**1.9%**

Source: Economic Insight analysis of EU KLEMS data

PR24 focused range

Table 23: Value added TFP estimates (PR24 focused range)[123]

Comparator	2010-2019	1970-2019 (weighted average of 1970-2007; 1995-2019)
Total industries	0.3%	0.4%
Agriculture, forestry and fishing	2.2%	2.4%
Manufacturing	1.2%	2.4%
Chemicals; basic pharmaceutical products	2.7%	4.2%
Manufacture of rubber and plastic products and other non-metallic mineral products	2.8%	2.2%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.9%	2.1%
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.2%	0.0%
Transportation and storage	-1.5%	1.0%
Final results (average)	**0.8%**	**1.8%**

Source: Economic Insight analysis of EU KLEMS data

[123] *We note that, for some comparators in NACE II, there is no NACE I equivalent (e.g. "Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment"), hence there is no TFP estimate for these comparators in the 1970-2007 period. Therefore, for these comparators, the TFP estimate for 1970-2019 is equal to the 1995-2019 average. As such, the average across comparators in 1970-2019 may not equate to the average of the individual comparator TFP estimates, as it is calculated using a weighted average of the total averages across comparators in 1995-2019 and 1970-2007.*

Sensitivity analysis range

1992-2007 (NACE I)

Table 24: Value added TFP estimates – 1992-2007 (NACE I)

Comparator	1992-2007
Total Industries	0.6%
Agriculture, Hunting, Forestry And Fishing	1.5%
Total Manufacturing	1.8%
Chemicals And Chemical	3.1%
Rubber And Plastics	1.1%
Wholesale And Retail Trade	1.4%
Transport And Storage	2.1%
Final results (average)	**1.7%**

Source: Economic Insight analysis of EU KLEMS data

Sensitivity 1

Table 25: Value added TFP estimates (Sensitivity 1)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.3%	0.3%	0.4%
Agriculture, forestry and fishing	2.2%	2.3%	2.4%
Mining and quarrying	-2.0%	-3.5%	-0.8%
Manufacturing	1.2%	2.9%	1.9%
Chemicals; basic pharmaceutical products	2.7%	4.4%	3.9%
Manufacture of rubber and plastic products and other non-metallic mineral products	2.8%	2.2%	2.3%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.9%	2.1%	
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.2%	-0.4%	0.4%
Transportation and storage	-1.5%	-0.2%	2.2%
Final results (average)	**0.5%**	**1.1%**	**1.6%**

Source: Economic Insight analysis of EU KLEMS data

Sensitivity 2

Table 26: Value added TFP estimates (Sensitivity 2)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.3%	0.3%	0.4%
Agriculture, forestry and fishing	2.2%	2.3%	2.4%
Manufacturing	1.2%	2.9%	1.9%
Chemicals; basic pharmaceutical products	2.7%	4.4%	3.9%
Transportation and storage	-1.5%	-0.2%	2.2%
Final results (average)	**1.0%**	**2.0%**	**2.2%**

Source: Economic Insight analysis of EU KLEMS data

Sensitivity 3

Table 27: Value added TFP estimates (Sensitivity 3)

Comparator	2010-2019	1995-2019	1970-2007
Agriculture, forestry and fishing	2.2%	2.3%	2.4%
Chemicals; basic pharmaceutical products	2.7%	4.4%	3.9%
Transportation and storage	-1.5%	-0.2%	2.2%
Final results (average)	**1.1%**	**2.2%**	**2.8%**

Source: Economic Insight analysis of EU KLEMS data

Sensitivity 4

Table 28: Value added TFP estimates (Sensitivity 4)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.3%	0.3%	0.4%
Agriculture, forestry and fishing	2.2%	2.3%	2.4%
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.2%	-0.4%	0.4%
Transportation and storage	-1.5%	-0.2%	2.2%
Final results (average)	**0.2%**	**0.5%**	**1.3%**

Source: Economic Insight analysis of EU KLEMS data

Sensitivity 5

Table 29: Value added TFP estimates (Sensitivity 5)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.3%	0.3%	0.4%
Agriculture, forestry and fishing	2.2%	2.3%	2.4%
Manufacturing	1.2%	2.9%	1.9%
Chemicals; basic pharmaceutical products	2.7%	4.4%	3.9%
Manufacture of rubber and plastic products and other non-metallic mineral products	2.8%	2.2%	2.3%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.9%	2.1%	
Construction	-0.3%	-0.4%	0.8%
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.2%	-0.4%	0.4%
Transportation and storage	-1.5%	-0.2%	2.2%
Final results (average)	**0.7%**	**1.5%**	**1.8%**

Source: Economic Insight analysis of EU KLEMS data

ONS MFP

Below, we present the results of our MFP growth estimates from the ONS database. We note that these are not included in our *'sensitivity analysis range'* as they are based on value added rather than gross output, and to allow for a comparison with the approach taken by Ofwat in its analysis. However, we consider it helpful to present the results from this database, as it includes data beyond 2019 (the final year that data is available in the EU KLEMS database), meaning that it includes a greater part of the most recent financial crisis (which we consider to be 2010-2020). We include three different time periods using our ONS MFP data:

- **2010-2019**, which includes almost the entirety of the most recent business, cycle, but without 2020 (which could downward bias the results due to the exogeneity of the COVID-19 pandemic).
- **2010-2021**, which includes an alternative definition of the end of the most recent business cycle (i.e. 2021 rather than 2020).
- **1970-2021**, which includes the entirety of the period for which ONS MFP data is available.

Table 30: Value added MFP estimates (ONS)

Comparator	2010-2019	2010-2021	1970-2021
Total Market Sector	0.4%	0.3%	1.0%
Agriculture, Forestry and Fishing	3.5%	2.7%	2.0%
Manufacturing	1.3%	1.1%	2.4%
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	-0.1%	0.2%	0.3%
Transportation and Storage	-1.0%	-1.1%	1.7%
Final results (average)	**0.8%**	**0.7%**	**1.5%**

Source: Economic Insight analysis of ONS MFP data

12E. Ofwat's choice of comparators

Furthermore, as was detailed above, we have also extended our choice of time periods in our *'plausible range'* to Ofwat's choice of comparators. These results can be seen in the tables below, both in terms of gross output and value added.

Table 31: Gross output TFP estimates (Ofwat's comparators)

Comparator	2010-2019	1995-2019	1970-2007
Manufacturing	0.4%	1.1%	0.7%
Chemicals; basic pharmaceutical products	1.2%	1.9%	1.3%
Manufacture of machinery and equipment n.e.c.	-0.2%	1.3%	0.5%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.4%	1.0%	
Construction	-0.1%	-0.2%	0.3%
Transportation and storage	-0.6%	-0.1%	1.1%
Professional, scientific and technical activities; administrative and support service activities	-0.1%	-0.3%	
Final results (average)	**0.0%**	**0.7%**	**0.8%**

Source: Economic Insight analysis of EU KLEMS data

Table 32: Value added TFP estimates (Ofwat's comparators)

Comparator	2010-2019	1995-2019	1970-2007
Manufacturing	1.2%	2.9%	1.9%
Chemicals; basic pharmaceutical products	2.7%	4.4%	3.9%
Manufacture of machinery and equipment n.e.c.	-0.6%	2.7%	1.3%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	-0.9%	2.1%	
Construction	-0.3%	-0.4%	0.8%
Transportation and storage	-1.5%	-0.2%	2.2%
Professional, scientific and technical activities; administrative and support service activities	-0.2%	-0.5%	
Final results (average)	**0.1%**	**1.6%**	**2.0%**

Source: Economic Insight analysis of EU KLEMS data

13 Annex 4: Full set of results – water retail

In this annex, we provide the full set of our results for water retail, across each of: (i) the *'plausible range'*; (ii) the *'PR24 focused range'*; and (iii) the *'sensitivity analysis range'*.

13A. Plausible range

Table 33: Gross output TFP estimates (plausible range)

Comparator	2010-2019	1995-2019	1970-2007
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Information and communication	3.7%	4.0%	1.8%
Financial and insurance activities	-0.6%	-0.3%	-0.2%
Real estate activities	1.3%	0.5%	-0.5%
Professional, scientific and technical activities; administrative and support service activities	-0.1%	-0.3%	
Other service activities	-0.3%	-1.2%	
Final results (average)	**0.6%**	**0.4%**	**0.3%**

Source: Economic Insight analysis of EU KLEMS data

13B. PR24 focused range

Table 34: Gross output TFP estimates (PR24 focused range)[124]

Comparator	2010-2019	1970-2019 (weighted average of 1970-2007; 1995-2019)
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.1%
Information and communication	3.7%	2.9%
Financial and insurance activities	-0.6%	-0.3%
Real estate activities	1.3%	0.0%
Professional, scientific and technical activities; administrative and support service activities	-0.1%	-0.3%
Other service activities	-0.3%	-1.2%
Final results (average)	**0.6%**	**0.4%**

Source: Economic Insight analysis of EU KLEMS data

[124] *We note that, for some comparators in NACE II, there is no NACE I equivalent (e.g. "Other service activities"), hence there is no TFP estimate for these comparators in the 1970-2007 period. Therefore, for these comparators, the TFP estimate for 1970-2019 is equal to the 1995-2019 average. As such, the average across comparators in 1970-2019 may not equate to the average of the individual comparator TFP estimates, as it is calculated using a weighted average of the total averages across comparators in 1995-2019 and 1970-2007.*

13C. Sensitivity analysis range

Time period

We firstly present the results of using the **1992-2007 (NACE I)** period on our *'preferred set'* of comparators. We include it in our *'sensitivity analysis range'* as it includes (almost) the entirety of the business cycle prior to the financial crisis (which we consider to be 1992-2009), noting that data is unavailable beyond 2007 in the NACE I database. It is not included in our *'plausible range'* or our *'PR24 focused range'* as it does not utilise all the data available in the NACE I database.

Table 35: Gross output TFP estimates – 1992-2007 (NACE I)

Comparator	1992-2007
Wholesale And Retail Trade	0.7%
Post And Telecommunications	3.2%
Financial Intermediation	0.9%
Real Estate, Renting And Business Activities	-0.1%
Final results (average)	**1.2%**

Source: Economic Insight analysis of EU KLEMS data

Comparator choice

We have also included different comparators in our assessment in order to test modifications to our *'preferred set'* of comparators.

As was detailed in Section 8A, we have included **Sensitivity 1**, which adds "Total industries" to our *'preferred set'* of comparators. This tests whether the inclusion of a metric that captures productivity changes across the entire UK 'on average' affects our results.

Table 36: Gross output TFP estimates (Sensitivity 1)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.2%	0.2%	0.2%
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Information and communication	3.7%	4.0%	1.8%
Financial and insurance activities	-0.6%	-0.3%	-0.2%
Real estate activities	1.3%	0.5%	-0.5%
Professional, scientific and technical activities; administrative and support service activities	-0.1%	-0.3%	
Other service activities	-0.3%	-1.2%	
Final results (average)	**0.6%**	**0.4%**	**0.3%**

Source: Economic Insight analysis of EU KLEMS data

Furthermore, as was detailed in Section 8A, we have included **Sensitivity 2**, where the assessment under Criterion 1 strengthened. Specifically, this only includes comparators for which Criterion 1 is defined as "Green" (and thus places more weight on the similarity of sectors).

Table 37: Gross output TFP estimates (Sensitivity 2)

Comparator	2010-2019	1995-2019	1970-2007
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Information and communication	3.7%	4.0%	1.8%
Financial and insurance activities	-0.6%	-0.3%	-0.2%
Professional, scientific and technical activities; administrative and support service activities	-0.1%	-0.3%	
Final results (average)	**0.7%**	**0.8%**	**0.6%**

Source: Economic Insight analysis of EU KLEMS data

Furthermore, as was detailed in Section 8A, we have included **Sensitivity 3**, where: the assessment under Criterion 2 is strengthened. Specifically, only comparators for which the adjusted HHI in Figure 14 is less than 2,000 are included.

Table 38: Gross output TFP estimates (Sensitivity 3)

Comparator	2010-2019	1995-2019	1970-2007
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Real estate activities	1.3%	0.5%	-0.5%
Professional, scientific and technical activities; administrative and support service activities	-0.1%	-0.3%	
Final results (average)	**0.4%**	**0.0%**	**-0.2%**

Source: Economic Insight analysis of EU KLEMS data

In addition, as is detailed in Section 8A, we have included a **Sensitivity 4**, where Criterion 3 is strengthened. Specifically, this only includes comparators for which at least one of Criteria 3a-3c is defined as "Green" (and thus places more weight on the similarity of sectors as regards economies of scale).[125]

Table 39: Gross output TFP estimates (Sensitivity 4)

Comparator	2010-2019	1995-2019	1970-2007
Total industries	0.2%	0.2%	0.2%
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.1%	-0.2%	0.1%
Financial and insurance activities	-0.6%	-0.3%	-0.2%
Real estate activities	1.3%	0.5%	-0.5%
Professional, scientific and technical activities; administrative and support service activities	-0.1%	-0.3%	
Other service activities	-0.3%	-1.2%	
Final results (average)	**0.0%**	**-0.2%**	**-0.1%**

Source: Economic Insight analysis of EU KLEMS data

[125] *We also include "Total industries" on this basis.*

14 Annex 5: Geometric vs arithmetic mean

To estimate an annual rate of frontier shift, we have calculated the average growth rate of TFP over the time period under consideration for each of our comparators. When calculating the average growth rate in TFP (or MFP) over a period of time, two different methodologies can be selected. We have detailed each below.

- **Geometric mean.** This is the product of a series of numbers raised to the inverse of the length of the series.
- **Arithmetic mean.** This is the sum of a series of numbers divided by the count of that series of numbers.

Both methods have advantages and disadvantages. Arithmetic means are an appropriate measure when the values in a series are independent of one another; but do produce less reliable results when values are not independent. Geometric means can reliably be used when series values are not independent from one another. This means that geometric means can take account of the impact of variation that occurs in one year on future years. This is a common occurrence when analysing economic data. However, geometric means suffer from a higher degree of sensitivity to the start date selected than arithmetic means. This is because the geometric calculation requires values to be compounded based upon the start value, whereas the arithmetic calculation does not require compounding.

Based upon the advantages and disadvantages of each approach, our view is that the use of geometric (as opposed to arithmetic) means should be considered in order to assess productivity over longer time periods (e.g. about 10 years) – we note that this threshold should be taken as a guide rather than a set rule.

- When analysing TFP over a short time period, the estimate will be sensitive to the start date; and it is beneficial to examine the effect of year-on-year volatility. This points towards an **arithmetic mean** being the most suitable method.
- When calculating TFP growth over a long time period, it is beneficial to strip out year-on-year volatility in order to determine the actual long-run productivity rate. Furthermore, over a long time period, the calculation should be less sensitive to any small amount of variance in the start date. Therefore, this suggests the use of a **geometric mean** for longer time periods.

As was discussed in Chapter 7 of the main report, all our results in Chapter 7 (and in Annex 3) for the total water value chain were presented using the arithmetic mean. However, to allow for a comparison between the two approaches, we present the

results of the time periods in our *'plausible range'* that exceed 10 years (1995-2019 and 1970-2007) using the geometric in addition to the arithmetic mean. As can be seen in the tables below, the estimates using the geometric mean are either the same or fractionally different to those using the arithmetic mean. As we have stated above, we believe that the geometric mean results are more suitable when considering longer time periods since, over these longer periods, a geometric mean can take account of the compounding effect on productivity growth.

Table 40: Comparison between geometric and arithmetic mean

Comparator	1995-2019		1970-2007	
	Arithmetic	Geometric	Arithmetic	Geometric
Total industries	0.2%	0.2%	0.2%	0.2%
Agriculture, forestry and fishing	1.2%	1.0%	1.0%	0.9%
Manufacturing	1.1%	1.1%	0.7%	0.7%
Chemicals; basic pharmaceutical products	1.9%	1.8%	1.3%	1.3%
Manufacture of rubber and plastic products and other non-metallic mineral products	0.9%	0.9%	0.9%	0.9%
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	1.0%	1.0%		
Wholesale and retail trade; repair of motor vehicles and motorcycles	-0.2%	-0.3%	0.1%	0.2%
Transportation and storage	-0.1%	-0.1%	1.1%	1.0%
Final results (average)	**0.7%**	**0.7%**	**0.8%**	**0.7%**

Source: Economic Insight analysis of EU KLEMS data

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