Treatment of energy costs in base models

Affinity Water, Yorkshire Water, South East Water, Sutton & East Surrey Water, Thames Water, Bristol Water and Southern Water

Strictly private and confidential

May 2023

Important notice

This Report has been prepared by KPMG LLP ("we" or "KPMG") for Thames Water Limited, Yorkshire Water Limited, Bristol Water Plc, Affinity Water, South East Water Limited, Sutton and East Surrey Water Plc and Southern Water Limited, (collectively "you" or "the Companies", and individual "Company" where the context applies) in accordance with terms of engagement agreed by companies with KPMG under a private contract. This report should not be regarded as suitable to be used or relied on by any other person for any purpose.

The companies have commissioned KPMG to write a KPMG branded report on treatment of energy costs in base models to assist in their considerations regarding the PR24 price review.

In this instance, we consent the companies disclosing the report to the Water Services Regulation Authority ("Ofwat") in the context of the next price control ("PR24") subject ot the entering into of a suitable transmittal letter. .KPMG has not assisted the companies in preparation of any aspect of their PR24 business plans which remain, at all times, the sole responsibility of the companies. KPMG has not made any decisions for the companies and has not assumed any responsibility in respect of any aspect of the Business Plan including what the companies decide, or have decided to, include in their business plans.

Should anyone (other than the companies) choose to rely on this report, they do so at their own risk. Without prejudice to KPMG's liability to the companies subject to and in accordance with the terms of engagement agreed between them, KPMG will accordingly accept no responsibility or liability in respect of this report to any person. This report does not give rise to a client relationship between KPMG and any person (other than the companies). The information in the Report is based upon publicly available information and reflects prevailing conditions as of this date, all of which are accordingly subject to change.

Without prejudice to any rights that the companies may have, subject to and in accordance with the terms of engagement agreed between the companies and KPMG, no person is permitted to copy, reproduce or disclose the whole or any part of this report unless required to do so by law or by a competent regulatory authority.

KPMG does not provide any assurance as to the appropriateness or accuracy of sources of information relied upon, has not sought to establish the reliability of the sources by reference to other evidence, and KPMG does not accept any responsibility for the underlying data used in this report. For this Report the companies have not engaged KPMG to perform an assurance engagement conducted in accordance with any generally accepted assurance standards and consequently no assurance opinion is expressed.

Although we endeavour to provide accurate and timely information, there can be no guarantee that such information is accurate as of the date it is received or that it will continue to be accurate in the future.

The opinions and conclusions expressed in this report are (subject to the foregoing) those of KPMG and do not necessarily align with those of the companies.

Contents

Executive summary

On 5th of April Ofwat published its *PR24 Econometric Base Cost Models Consultation* which includes the proposed set of econometric models that Ofwat intends to use to set efficient base expenditure allowances at PR24.

PR24 base cost models build on the PR19 modelling approach and include a number of proposed changes. Ofwat is seeking views on the proposed models in response to its consultation by 12th of May.

KPMG was commissioned by a consortium of seven companies (Affinity Water, Yorkshire Water, South East Water, Sutton & East Surrey Water, Thames Water, Bristol Water and Southern Water) to provide an initial assessment as to whether recent developments in the energy markets will be adequately captured by Ofwat's PR24 base econometric models.

Energy costs represent a material component of water and sewage companies' total expenditure, equivalent to approximately 11% of base costs. Ofwat assesses the efficiency of power costs as part of its base econometric models, which use costs that are adjusted for general inflation through CPIH for modelling. Cost allowances are currently set in real terms and indexed by CPIH.

Energy prices have grown significantly faster than CPIH in recent years (35% above CPIH in Q2 2022). When energy prices increase above CPIH, the following issues can arise:

1. Cost models may fail to carry out appropriately an historical efficiency assessment.
2. Base models may not provide for efficient energy costs.

Ofwat's proposed set of PR24 cost models may not appropriately capture energy price inflation. To mitigate the risk of erroneous base cost assessment, potential remedies could include:

- Inclusion of a cost driver that reflects energy price movements.
- Inclusion of a pre-modelling adjustment for power costs based on a relevant price index.
- Introduction of year dummies to capture time variation effects.
- Exclusion of affected years from the sample.
- Inclusion of forecast costs in the wholesale base cost econometric models.

The appropriate treatment of power costs in base econometric models is crucial to ensure that *ex ante* cost allowances reflect the increased input cost pressures which water companies have faced during AMP7 due to recent developments in energy markets. If companies are not fully compensated for the future requirements, the disallowance of efficient costs will create cash-flow risks for the sector. A key objective for incentive-based regulation regimes is to facilitate robust *ex ante* estimation of allowed revenues and to incentivise efficient costs that maintain investment and service quality. Not allowing efficient power costs could introduce unintended consequences or distortions and means that water companies may seek to reduce investment to compensate for an inability to recover efficient costs. This in turn could have a negative impact on the quality of service provided to customers.

Inclusion of a cost driver that reflects energy price changes and a pre-modelling adjustment using a relevant price index are those measures which could best address potential modelling issues. The estimated impact on modelled costs in 2022-23 is an upward adjustment of c.7-10% in water and of c.7% in wastewater.

Correcting for the modelling issues in an historical benchmarking based approach can provide an appropriate starting point for the allowance, but does not mitigate all risks from future energy price pressures for the water sector. Depending on the approach to correcting for the historic modelling issue chosen, the correction should be complemented by a relevant RPE assessment as prices for energy may evolve differently from general inflation during the next price control period.

1. Introduction

Econometric modelling plays a key role in Ofwat's cost assessment framework. At PR19 Ofwat assessed approximately 70% of companies' totex using econometric models. Econometric modelling will continue to play a key role at PR24.

In December 2022, Ofwat published its Final Methodology for the PR24 price review ("PR24"). The document outlines the key principles of base cost assessment for the next price control. Ofwat has published its proposed set of econometric cost models on 5th of April 2023 as part of its *PR24 Econometric Base Cost Models Consultation* and is seeking views from the sector in response to the consultation. The sector has an opportunity to respond to the consultation by 12th May 2023 and suggest improvements to Ofwat's proposed set of cost models.

For PR24 Ofwat intends to build on the PR19 approach, which was in large part supported by the Competition and Markets Authority ("CMA") and will look to make improvements where appropriate.

Ofwat recognises that econometric models may not explain all variations in efficient base costs between companies and over time. As a result, econometric analysis is complemented with cost adjustment claims. The cost adjustment claim consultation is planned in summer 2023. Water companies are invited to submit base cost adjustment claims based on Ofwat's proposed econometric models by 9th June 2023.

1.1. Objectives of the report

Ofwat uses econometric cost models as a primary tool to determine efficient base cost allowances. The PR19 models were estimated based on companies' actual expenditure over the period 2011-12 to 2018-19 (eight years of data). The historical time series available for PR24 would increase to 13 years of data (2011-12 to 2023-24).

A longer dataset is beneficial as it can improve the precision of model estimates. At the same time, the sample period should be carefully considered to ensure there are no structural breaks, and that it sufficiently resembles the forecast period for which it sets cost allowances. A structural break may occur due to a step change in activities which is not accounted for by an exogenous cost driver within the model.

For the next price review, the water sector in England and Wales faces a series of cost challenges. Increasing energy prices represent a key concern for water companies as a result of the substantive cost pressure it has placed on them. Ofwat has published a proposed set of base cost models as part of its PR24 base cost model consultation. Although Ofwat's proposed models include multiple important changes from PR19 cost models, they do not appear to account for the step change in input prices.

KPMG was commissioned by a consortium of seven companies (Affinity Water, Yorkshire Water, South East Water, Sutton & East Surrey Water, Thames Water, Bristol Water and Southern Water) to provide an initial assessment of the impact increased energy prices have on the cost assessment framework for PR24 and in particular whether the recent increases in power costs will be adequately captured by Ofwat's base econometric models.

The report considers the appropriateness of the cost assessment framework in three steps:

- Firstly, it identifies issues that may arise if energy costs are not appropriately accounted for in base models.
- Secondly, it assesses whether the historical cost data for water, sewerage and bio-resources reflect the higher energy costs observed in recent years,
- Thirdly, it considers what type of modelling adjustment would be appropriate to ensure the sector is funded for potential high energy requirements in the future.

The scope of this report does not include any company-specific analysis. The analysis and commentary set out in this report is reflective of the entire sector for the PR24 price control period.

1.2. Structure of the report

The report is structured as follows:

- **Section 2** sets out the context and potential modelling issues which may arise if historical benchmarking data does not appropriately account for increased energy costs.
- **Section 3** assesses the extent to which the historical cost information that Ofwat uses to estimate its base models captures recent energy costs. The section also considers how the base models can robustly account for the increase in energy prices, including assessment of potential modelling amendments.
- **Section 4** discusses the results and sets out key implications for PR24. The section also discusses limitations of the analysis and sets out additional approaches that can be further considered.

2. Context

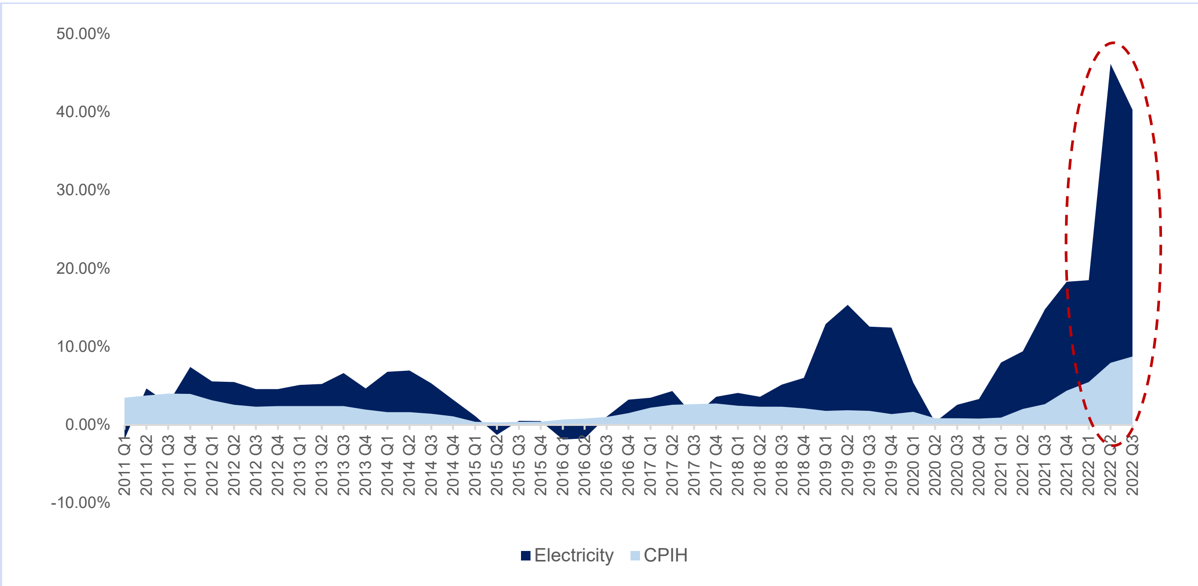
2.1. Recent trends in energy prices

The economic uncertainty in recent years driven by the impacts of the Covid-19 pandemic, climate change, the conflict in Ukraine and Brexit, has led to increased macroeconomic volatility. Overall consumer price inflation (CPIH) in the UK reached a record high in 2022, peaking at nearly 10% (9.6% in Oct-22) - the first time since Dec-90, according to the Office for National Statistics.

A significant driver of high inflation has been an unprecedented increase in global energy prices. Companies' revenues and RCV are to some extent protected against these energy cost increases through general CPIH indexation applied by Ofwat. The energy component of CPIH is 4.5% of the total (as of Dec-22), of which electricity, gas and other fuels make up 2.9%, with the rest largely relating to petrol.

However, energy prices have increased significantly faster than general inflation. Russia's invasion of Ukraine led to large increases in the price of gas, which has directly affected the price of electricity (as the cost of gas tends to set the market price of electricity in UK), pushing up retail electricity bills as well as retail gas bills. Electricity prices increased by 35% above CPIH in Q2 2022, the highest increase in real terms across the whole sample period that Ofwat considers for its base cost models (Figure 1).

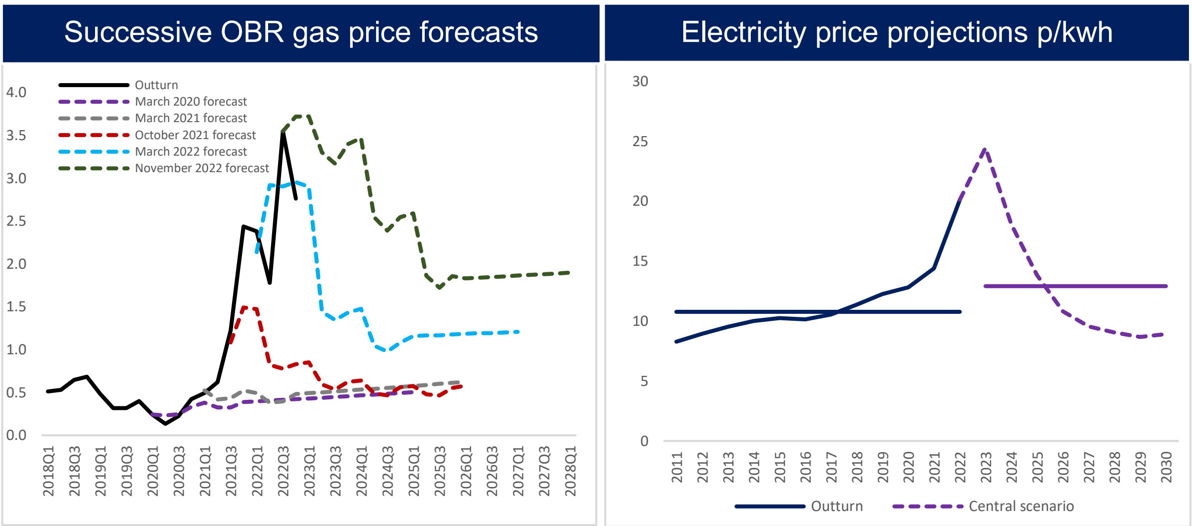
Figure 1: Year-on-year increase in the electricity price index and CPIH



Source: BEIS and ONS data, KPMG analysis

The political and economic landscape in the UK and globally is likely to have a continued impact on the energy market and sustain prices at record highs. These political and economic events have also created unusually high and sustained volatility and uncertainty in future gas prices (Figure 2). Although there is a general expectation that energy prices will start to gradually decrease from the second half of 2023, energy prices may continue to remain high compared to historical levels. There is also a risk that energy prices could rise further and will remain volatile. The uncertainties regarding gas supply in Europe over the coming years undermine the reliability of future price estimates. A relatively mild European winter in 2022 with downward pressure on electricity consumption, could be a potential source of “optimism bias” in forecasts.

Figure 2: Future trends in energy prices



Source: OBR, BEIS, electricity price projection by Cornwall Insight on behalf of Water companies, KPMG analysis

2.2. Treatment of power costs in base econometric models - key issues

Water companies use energy to abstract, transport and treat water and wastewater.

Energy costs represent a material component of water and sewage companies’ total expenditure, approximately 11%[1] of base costs according to Ofwat’s PR24 base cost dataset. Ofwat assesses the efficiency of power costs as part of its base econometric models, which use costs that are adjusted for inflation through CPIH for modelling. Additionally, cost allowances are set in real terms and indexed to CPIH.

While CPIH captures some movements in energy prices, the extent to which these movements are reflected in overall inflation is limited. Energy costs comprise of only 2.9% (excluding petrol) in the CPIH. As a result, changes in CPIH are unlikely to sufficiently reflect the energy price exposures that water companies face.

<u>When energy prices *increase above CPIH*, three main issues may arise in terms of their capture in the models:</u>

1. **Deflating nominal energy costs by CPIH may not remove the effect of inflation entirely**. If all inflationary pressures are not excluded from the sample, values will not be comparable across years. Energy prices have grown above general inflation in recent periods. In consequence, CPIH-deflated costs may continue to carry part of the inflation and costs will appear ‘higher’. Consequently, the sector may look ‘artificially’ less efficient in recent periods compared to the past.
2. **Not capturing the energy input inflation appropriately may have a disproportionate impact on energy intensive water companies.** As a result, companies that are more energy intensive (i.e., have a larger share of energy costs in

[1] 2012-2022 average

their base costs) may appear less efficient relative to those who are less energy intensive.

3. **A model based on historical data, including periods when energy costs were significantly lower than current/future costs, may result in cost allowances for the future that are too low.** Ofwat's base cost models, based on historical information, will likely generate allowances for the future that are insufficient to meet the efficient energy costs actually incurred by companies.

These three issues can have the following modelling implications:

1. **Cost models may fail to appropriately conduct historical efficiency assessment.** The first two issues (set out above) could undermine the robustness of econometric models, due to a misshape in the model performance. As a result, this can lead to biased coefficients which may distort Ofwat's comparative efficiency assessment and estimation of a robust historical catch-up benchmark.
2. **Lack of provision of efficient energy costs through base model.** The third issue (set out above) is critical for the setting of efficient allowances for the next price control. Ofwat's econometric models are based on historical cost data. If there is a discontinuity triggering a step change in power costs which is not appropriately accounted for, modelled allowances will fail to adequately reflect the future power requirements for the sector. Contrary to this, even if energy prices start to fall, there is no mechanism that ensures provision of efficient energy costs (in both directions) via Ofwat's models.

Ofwat's historical base cost dataset[2], includes 11 years of data until 2021-22. The recent spike in energy prices is only captured by the last two years of the data, 2020-21 and 2021-22. More than 80% of the sample period reflects a lower energy price scenario. This means that if Ofwat set cost allowances for the future, based on data from 2011-12 to 2021-22, significantly more weight would be placed on a period of low energy cost than the recent period of high energy cost, and consequently a lower allowance than would be appropriate given current energy costs.

[2] Dataset (v3) published in November 2022.

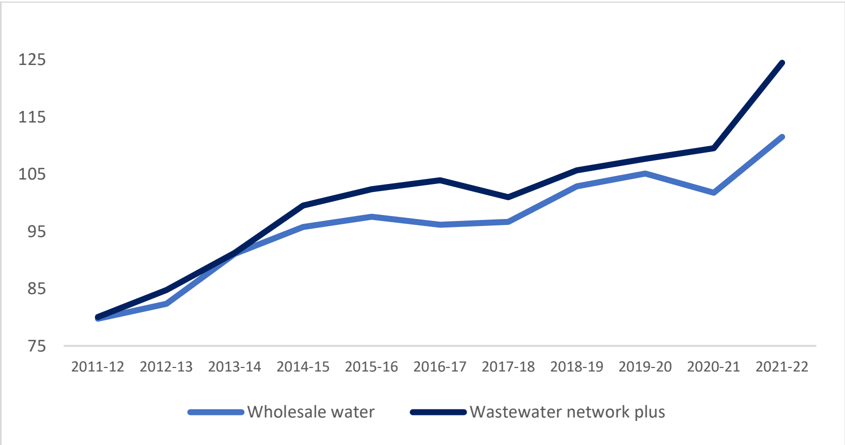
3. Treatment of energy costs in base models – analysis

3.1. Increased energy costs for water companies

Power costs have increased notably in recent years for water and sewage companies in the UK. In 2021-22, the sector incurred energy costs of £447m in wholesale water (in 2017-18 prices), which is a 27% increase from the 10-year historical average[3]. In 2021-22, sewage companies have spent in total 28% more (£387m in 2017-18 prices) on energy compared to the 10-year average (£303m, 2017-18 prices). Overall, in 2021-22 the water sector has witnessed highest year to year rate (c.12%) in power costs in the last 10 years. This high energy inflation was not anticipated at PR19; it is not included in cost allowances nor is there an RPE indexation mechanism to recover it.

Power costs in real terms may increase because of an inefficient use of energy, and therefore an increase in energy consumption. However, figure 3 shows that the unit price of energy per MWh has also increased over time with a significant upward growth in the recent period. In 2021-22, industry average power cost per MWh energy consumed in water has increased by 17% and in wastewater network plus by 26% from 10-year historical average (2011-12 to 2020-21). This suggests that power cost increases for water companies can be largely explained by the upward movement in the energy prices.

Figure 3: Power costs (£) per MWh energy consumed, 2017-18 prices



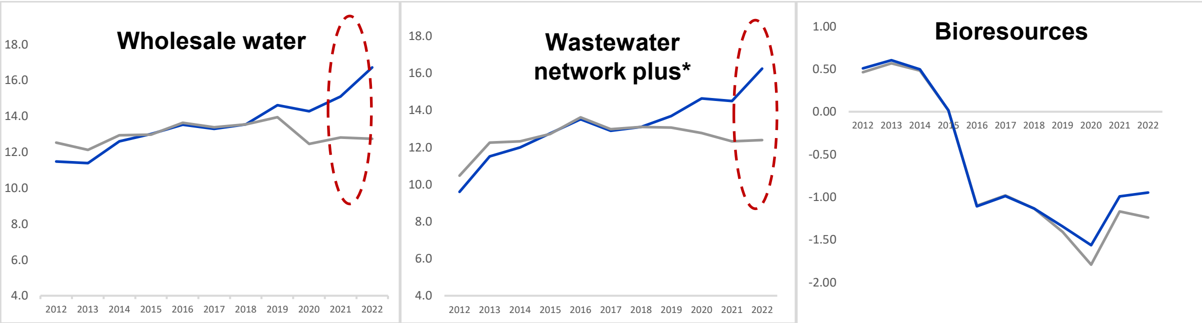
Note: *Network plus comprises of sewage treatment and sewage collection controls

Source: PR24 Ofwat's PR24 base dataset (V3, November), KPMG analysis

Power costs can also grow because of overall activity growth in the water sector. However, unit costs per connected property in CPIH terms for wholesale water and wastewater network plus have also significantly increased in the recent periods. Figure 4 compares power costs per connected property when deflated by the CPIH and when deflated by the BEIS index for electricity prices. When the same unit costs are deflated by BEIS electricity index (instead of CPIH), the trend for unit costs stabilises across the modelling period. Deflating nominal power costs using electricity price index could potentially correct for modelling issues 1 and 2 (see section 2.2).

[3] average over 2011-21 period is £351m, in 2017-18 prices

Figure 4: Power costs (£) per connected property



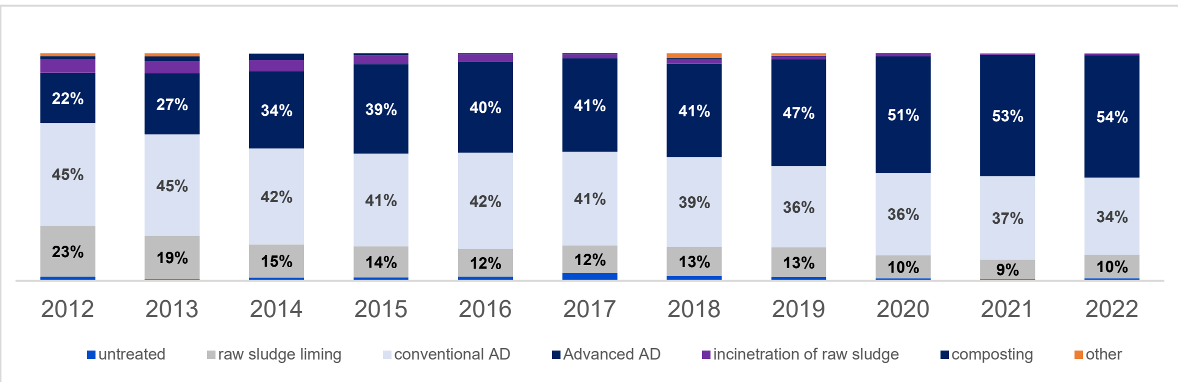
Note: **Blue line denotes unit costs adjusted for CPIH**, grey line denotes unit costs adjusted by BEIS electricity price index

Source: Ofwat's PR24 base dataset (V3, November) and BEIS electricity index data, KPMG analysis

In bioresources activities, power costs per connected property decrease over time. As part of the sludge treatment process, companies generate energy and income is deducted from these costs[4]. Negative unit cost values indicate that the sector, in aggregate, generates more energy than it uses internally. A decreasing trend for power costs per connected property in the bioresources control is reflective of the water sector switching to treat a higher proportion of sludge. This has been enabled due to more cost-efficient treatment technologies which generate more energy from the treatment process (Figure 5).

Technologies adopted by sewage companies vary significantly (Figure A1, annex A). Energy generation is particularly high for companies which use advanced anaerobic digestion (AD) technologies to treat sludge. A few firms can take some steps to improve energy generation over time, but the level of improvement that the sector can achieve over the next price control period is limited. As energy generation is only applicable to the bioresources control, significant energy cost revisions due to expected changes in energy generation for other activities (e.g., wholesale water and wastewater network plus) are not expected. For the sector as a whole the impact of recent increases in energy prices will have a more prominent impact on wholesale water and network plus wastewater activities, thus analysis in the rest of the report will primarily focus on those areas.[5]

Figure 5: Proportion of sludge treated by different technologies, sector average



Source: Ofwat's PR24 base cost dataset, v3, KPMG analysis

[4] Netting of energy income/savings from treatment opex is in accordance with Ofwat's Regulatory Accounting Guidance (RAGs). See RAGs, RAG-4.10-—Guideline-for-the-table-definitions-in-the-annual-performance-report, page 137.
[5] There may be individual companies where energy costs for bioresources are a concern.

Ofwat's econometric models are based on historical information. When new outturn data becomes available through Annual Performance Reports (APRs), Ofwat is expected to include it in the base econometric models. PR24 cost assessment models will be based on more years of data than is currently available. At a minimum, econometric models will include one more year of data, e.g., 2022-23 year.

The inclusion of 2022-23 may further distort the efficiency assessment as energy prices are expected to increase further in 2022-23. Additionally, the impact of the peak rise in prices in 2022 may take time to fully materialise in the water sector due to companies' hedging strategies. As current forward contracts expire, the new contract would incorporate future levels of expected inflation and uncertainty.

3.2. Modelling considerations to account for an increase in energy prices

To mitigate the risk of erroneous base cost assessment due to the identified step change in power cost data, potential remedies include:

- Inclusion of a cost driver that reflects energy price movements.
- Inclusion of a pre-modelling adjustment for power costs based on a relevant price index.
- Introducing year dummies to capture time variation effects.
- Exclusion of affected years from the sample.
- Inclusion of forecast costs in the wholesale base cost econometric models.

We discuss each potential approach in detail.

Inclusion of a cost driver that reflects energy price movements

To capture movements in energy prices we have tested the inclusion of BEIS electricity price index as an additional cost driver in Ofwat's base econometric models.

In its PR24 Final Methodology, Ofwat stated that the PR19 wholesale base cost drivers and corresponding explanatory variables provide a good starting point for PR24, but that it is also open to considerng additional or alternative cost drivers that can improve econoemtric models.

To introduce a new explanatory factor in base models, it has previously been suggested that the following conditions should be met[6]:

- Suggested cost driver should align with Ofwat's cost assessment principles (e.g. clear engineering, operational and economic rationale and outside the control of the company in the short term);
- Suggested cost driver should improve the performance of wholesale base econometric cost models;
- Robust historical data is available or can be collected for all water companies back to 2011-12 on a consistent basis (between companies and over time).

Input prices directly affect costs and changes in them are key drivers of companies' expenditure. Ofwat has used input prices as cost drivers previously in water and sewage cost assessment models. At PR14, regional BCIC index and average regional wage index based on ONS ASHE SOC surveys were included in the model to capture regional price differences.

[6] Assessing base costs at PR24, Ofwat, 2021 December

At PR14, CEPA (on behalf of Ofwat) defined input prices as "*one of the most important cost drivers*[7]."

BEIS' electricity price index can potentially reflect movements in energy prices over time. A key benefit of using an external price index is that it meets Ofwat's cost driver selection criteria, specifically that it is outside of direct management control.

Estimation results for water models show that the coefficient for the electricity price index has, as expected, a positive sign in all models. The driver is statistically significant in the treated water distribution model and in the wholesale water models[8]. The electricity price index has an expected positive sign in all sewage treatment, sewage collection and network plus (wastewater) models and is statistically significant in some of collection and treatment models (Annex B1).

Modelling results suggest that performance of the models for water and wastewater (sewage collection and sewage treatment models) remain robust. Other coefficients have the same signs and significance levels as PR19 models, with negligible movements in magnitudes. The models' predictive power and the range of efficiency scores remain broadly the same across all water and sewage models (Annex C).

When comparing efficiency ranking of the companies based on the last five year with and without inclusion of additional cost driver, we find that comparative efficiency positions for multiple companies have changed (Annex C).

After including the BEIS electricity price index as an additional cost driver in water models, we find that the sector's overall modelled costs for wholesale water, over the last five years, have increased by 1.4% and for wastewater network plus by 0.9%[9]. Meanwhile, the impact based on the last year is higher, modelled costs for the last year have increased by 5% for water and 3.4% for wastewater network plus. When estimating an impact on modelled costs for 2022-23 year[10], we find that modelled costs have increased by 10.4% in water and by 7.2% in wastewater.

For the purpose of generating an expected allowance for energy costs, there is an important role which future energy price forecasts can play to setting efficient costs, provided the determination is supported by a true-up mechanism to protect against future uncertainties.

Pre-modelling adjustment for power costs based on a relevant price index

Establishing a valid starting point for econometric models where costs are comparable and consistent across companies and years is the key for robust benchmarking. To ensure that Ofwat's econometric assessment is carried out on a comparable basis and the estimated efficient allowances are appropriate, power costs can be adjusted prior to the modelling, using energy price indices.

Pre-modelling adjustment of power costs based on the difference between CPIH and the energy price index (BEIS) can potentially solve for the series of modelling issues identified in *section 2.2.* We make the correction for the wedge between energy prices and CPIH for power costs after inflation adjustment and before modelling, and refer to it as a 'wedge adjustment factor' (Figure 6). The 'wedge adjustment factor' accounts for an additional inflationary

[7] Cost assessment – advanced econometric models, CEPA (developed for Ofwat), 2014

[8] with p-values of 0.16 and 0.13, respectively

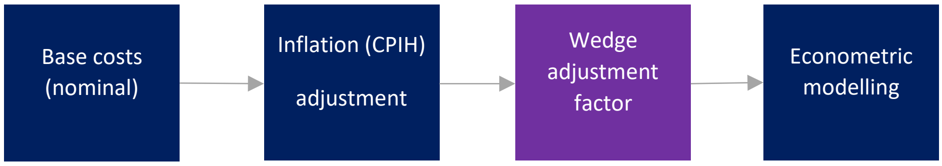
[9] We note that the figure is based on the triangualted model results of the last five years of the histroical period (2017-18 to 2021-22) and does not reflect the impact from efficiency challenges.

[10] Using PR19 business plan forecast drivers and outturn electricity price index and CPIH index for 2022-23 Q2 and Q3.

pressure on energy costs which is embedded in nominal values on top of general inflation and which should be removed before modelling to enable a comparision of costs, as if prices of energy had not changed on average.

The ‘wedge adjustment factor’ is an annual correction and is applied to all companies. However, the value of the pre-modelling adjustment differs across the sector, due to the variation in the reported proportion of power costs in the base expenditure by companies[11].

Figure 6: Pre-modelling adjustment



Source: KPMG analysis

Pre-modelling adjustment is a well-established tool in cost assessment approaches in regulated sectors. The general CPIH Inflation adjustment applied by Ofwat is a pre-modelling adjustment which is already used by Ofwat to correct for the variation in costs across years, due to economy-wide inflationary factors. Ofgem applies pre-modelling adjustments to network companies’ costs to reflect factors not incorporated within econeomtric model cost functions. The main adjustment applied by Ofgem at RIIO2 price controls is to account for the regional wage differences based on relevant labour indices[12].

We use Ofwat’s PR24 base cost datasets for wholesale water and wastewater to apply a pre-modelling adjustment. With a pre-modelling adgustment, the sector’s reported total power costs in real terms (2017-18 prices) are lower than the values used in Ofwat’s econometric models. This implies that Ofwat’s current benchmarking results would have overstated the inefficiency of the sector, reflecting modelling issue 1 (see section 2.2).

We have estimated Ofwat’s base econometric models after making the pre-modelling adjustment. Modelling results suggest that performance of the models for water and wastewater (sewage collection and sewage treatment models) remain robust. Coefficients have same the signs and significance levels as the PR19 models, with slight movements in magnitudes (Annex B2). The models’ predictive power and the range of efficiency scores remain broadly the same across all water and sewage models.

When comparing the efficiency rankings of the companies based on the last five year with and without pre-modelling adjustment, we find that comparative efficiency positions for multiple companies have changed (Annex C). The impact is not very significant. Shifts in efficiency rankings are more pronounced in sewage models. Changes in efficiency positions across companies can be explained by pre-modelling adjustments to have corrected for the modelling issue 2 (see section 2.2).

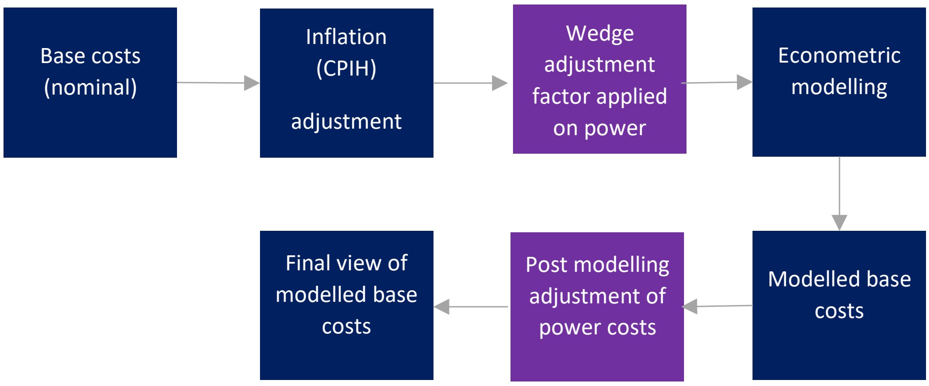
The key challenge with the pre-modelling adjustment is the robust implementation of the approach as it requires a post-modelling uplift of modelled power costs back to CPIH terms (Figure 7). If the pre-modelling approach is applied at PR24, then modelled allowances for

[11] Applying an adjustment on company’s own power share of costs instead of to a power share of notional company more accurately controls for the actual price pressures that companies face. However, applying an adjustment on notional share of power costs may better reflect efficiency incentives.

[12] RIIO-ED2 Final Determinations Core Methodology Document, [RIIO-ED2 Final Determinations Core Methodology.pdf]

power costs should be first adjusted back by the ‘wedge adjustment factor’ to incorporate input price pressures which were removed before modelling.

Figure 7: Pre-modelling adjustment with a post modelling uplift of power costs

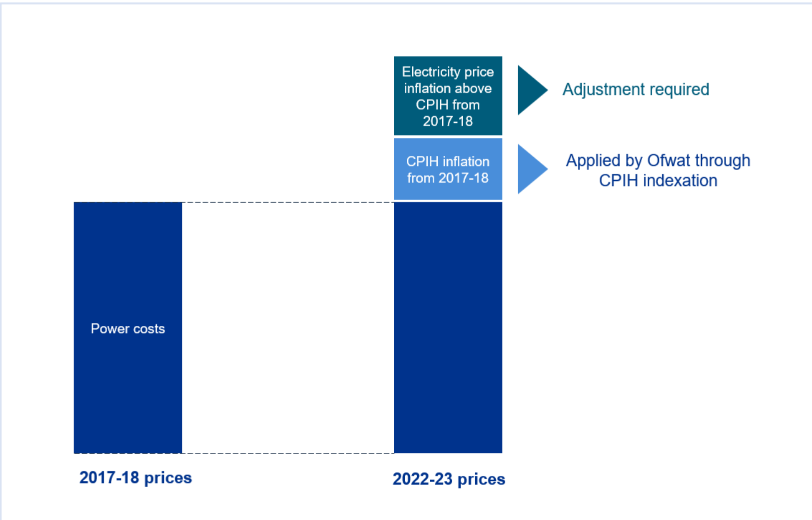


Source: KPMG analysis

Ofwat’s final cost allowances are set for total base costs. Estimated modelled costs from econometric benchmarking do not distinguish between different cost areas. To adjust the power cost component of modelled allowances with the ‘wedge adjustment factor’, it should first be estimated how much of the power cost in the sample period has been directed back to the modelled allowance. In theory, this can be achieved through two approaches:

> **1. The company proportion approach**, where the value of the modelled power costs for a company is the proportion of its power costs out of the company’s dependent variable, multiplied by the modelled costs of a company.
>
> **2.The sector proportion approach**, where the value of the modelled power costs for a company is the proportion of the sector’s power cost out of the sector’s dependent variable, multiplied by the modelled costs of a company.

Figure 8: Post modelling uplift of power costs using the ‘wedge adjustment factor’



Source: KPMG analysis

To derive modelled costs, the post-modelling adjustment should be applied based on the ‘wedge adjustment factor’ between the price base in which econometric modelling is employed and the year for which modelled costs are estimated. At PR19, base costs were modelled in 2017-18 prices and then indexed to CPIH inflation to provide allowances in nominal values. Modelled allowances for 2022-23 are indexed to the CPIH inflation, thus 2017-18 values are uplifted by observed inflation between 2017-18 and 2022-23. To reflect energy price movements above headline inflation, power costs should be first converted using 'wedge adjustment factor' between 2017-18 and 2022-23 year and then indexed to CPIH (Figure 8).

After applying the post-modelling adjustment through the company proportion approach, we find that sector's overall modelled costs over the last five years of histroical period for the wholsesale water and network plus wastewater have increased by 0.7% and 1.0%, respectively[13]. The sector's modelled costs in 2021-22 (the last year in the sample) have increased by 3.1% in water and by 4.3% in wastewater. The estimated impact in 2022-23 year is more pronounced due to electricity prices being significantly higher than CPIH inflation in 2022-23. These result in a 6.9% increase in modelled power costs in water and a 6.5% increase in wastewater for 2022-23.

When modelled costs are estimated over an historical period (e.g. over last 5 years, or for the last year in the sample), the post-modelling adjustment can be applied using outturn electricity index (e.g. inflating power costs by 'the wedge adjsutment factor"). When modelled costs are estimated over the next period where outturn indices are not yet published, the post modelling adjustment can be applied based on the forecast wedge between general inflation and energy prices and then trued-up alongside the CPIH reconciliation. The post modelling adjustment can potentially correct for modelling issue 3.

Estimation of modelled power costs adds an additional layer of complexity to the overall cost assessment approach, which should be carefully considered when considering the pre-modelling adjustment of power costs based on a relevant index.

Introducing year dummies to capture time variation effects

Inclusion of year dummies can potentially explain the step change in energy prices that the water sector faced in recent years and/or expects to see at PR24. Year dummies can be used to control for atypical periods in the sample and capture time-related effects that are not already in the model. We have included a 2021-22 year dummy in Ofwat's econometric models as the spike in energy prices is most pronounced in this year.

At the PR19 redetermination, the CMA put a high bar in using a year dummy to capture year-specific effects. The CMA consulted on whether to include 2019/20 data in the base cost models and considered using a year dummy for 2019-2020 to account for the potential atypicality of the year. At the time, it chose not to include a dummy year in its final decision, as the estimated coefficiencts were not stable in terms of significance across models[14].

Estimation results (Annex B3 and annex C) indicate that the 2021-22 year dummy does not have a statistically significant coefficient in any of the water models, but shows the expected positive sign, implying higher costs in 2021-22 year relative to the other periods. In sewage models, the year dummy also has an expected positive sign, and is statistically significant in the treatment models. After including the year dummy for 2021-22 year in water models, we find that modelled costs for the sector have increased by 0.2%. In wastewater network plus,

[13] We note that the figure is based on the triangualted model results of the last five years of the histroical period (2017-18 to 2021-22) and does not reflect the impact from efficiency challenges.

[14] Working paper – 2019/20 data for base cost models, The PR19 CMA,

the sector's total modelled costs have increased by 0.4%[15]. Modelled costs based on the last year have increased in water by 2.0% and in wastewater by 6.3%.

The year dummy in the model can potentially be picking up other cost explanatory factors than just increased energy prices which might be a key obstacle in applying this approach.

Exclusion of affected years from the sample

Exclusion of affected years from the sample can be a pragmatic solution to avoid distortion of the sample due to the high energy prices in recent years, compared to the past. However, reducing a sample size should be carefully considered in line with potential benefits that 2021-22 year exclusion can provide.

We have estimated models without 2021-22 year. The models performance across water and wastewater controls remain broadly stable (Annex B4). When comparing the efficiency rankings of the companies with and without the exclusion of 2021-22 year, we find that comparative efficiency positions for multiple companies have changed (Annex C4). After excluding the 2021-22 year, we find that modelled costs for the sector have decreased by 0.5% in water and by 1.0% in wastewater[16].

Exclusion of an atypical year can only correct for modelling issues 1 and 2 (see section 2.2). If the 2021-22 year were excluded, the models will likely still generate allowances that are insufficient to meet the efficient energy costs faced by companies. To also correct for modelling issue 3, the exclusion of 2021-22 year can be considered with a post-modelling uplift of power costs (see section on pre-modelling adjustment).

If energy prices remain high over the next few years, the number of atypical years in the sample that need to be excluded will increase. This will significantly understate the increased requirements of the sector in the recent period and may not be a plausible solution given the possible implications for the models being estimated.

Inclusion of forecast costs in the wholesale base cost econometric models

Ofwat has previously relied on historical cost information to set future allowances for base costs for the water sector. Due to a step change identified in power costs, the historical period may not be a good reflection of the future and an inclusion of business plan forecasts in the wholesale base cost econometric models at PR24 could be a reasonable option to consider for the next price control period.

Besides potentially capturing the step change in costs, the inclusion of business plan forecasts could also provide other benefits to the cost assessment framework. The use of forecast information will increase the sample size, thus may improve the models' explanatory power and precisions or level of confidence in sample estimates.

There are also risks associated with using forecast information which should be carefully considered. The inclusion of PR24 business plan forecasts may reduce the independence of

---

[15] We note that the figure is based on the triangulated model results of the last five years of the histroical period (2017-18 to 2021-22) and does not reflect the impact from efficiency challenges.

[16] We note that 0.8% does not reflect the impact from efficiency challenges.

the benchmarking process. Forecast information may reflect differences in risk appetite between companies and therefore distort setting the appropriate benchmark.

In its PR24 Final Methodology, Ofwat has expressed an intention to consider business plan forecasts in its base cost assessment and pointed to precedent in the energy sector. Although it is noted that Ofgem uses the combination of historical and forecast information to estimate cost allowances for network companies, the RIIO regulatory framework is substantially different from the one in the water sector. Risks associated with using business plan data for cost assessment in the water industry could be significantly different and forecast information should be used cautiously in models.

An inclusion of business plan forecasts may partially solve issue 3 (see section 2.2.), but the first two issues (on comparative efficiency) could still undermine the robustness of econometric models and distort the efficiency assessment.

To appropriately capture the change in power costs, Ofwat may also consider estimating models using a reduced/truncated historical sample period focused on the most recent evidence.

3.3. Summary of results

The report has considered a number of modelling amendments to adequately treat power costs at PR24. Figure 9 below summarises findings for each approach and an estimated impact on the sector's overall modelled costs (pre RPE and efficiency challenge) for water and wastewater network plus controls.

Modelling remedies that could potentially correct for all three issues identified in the report are:

- Inclusion of a cost driver that reflects energy price movements in base costs models.
- Inclusion of a pre-modelling adjustment for power costs based on a relevant price index with a post-modelling adjustment of power costs.

Other approaches considered in the report only partially capture power costs movements. Inclusion of a year dummy may capture other factors different from energy price pressures. Excluding atypicial years from the modelling will potentially further understate the power cost requirements actually faced by companies. Inclusion of business plan forecasts in the assessment can partially correct modelling issue 3, but it is unable to solve for issues related to comparative efficiency benchmarking. As a result, the most suitable approaches to capture movements in energy costs in PR24 base costs models are an off-model (pre-modelling) adjsutment (with post-modelling uplift) or an inclusion of relevant cost driver.

Incorporating an energy price factor as a cost driver in the models rather than an off-model adjustment provides number of benefits. Under the pre-modelling adjustment approach, submitted power costs by companies are shifted up or down before benchmarking assessment to improve comparability across companies. This approach requires the pre-modelling adjustment to be reversed after econometric modelling. Including a measure of energy prices as a cost driver in the econometric models could allow models to estimate the extent (the weight) to which total costs are driven by energy price pressures. It will not be necessary to estimate the proportion of costs affected by the price variation. Estimation of modelled allowances is automatic (through estimated coefficients) and does not require a post-modelling adjustment of power costs.

Both approaches have a material influence on modelled costs. The estimated impact (an increase in modelled costs by c.7-10% in water and by c.7% in wastewater) in 2022-23 is notably higher compared to the historical period. This arises as a result of energy prices growing significantly above inflation in 2022-23. Electricity prices increased by 32% (Q2 and Q3 average) in 2022-23, which is highest increase in real terms across the whole sample period that Ofwat uses for its base econometric models.

The impact of the spike in prices in 2022-23 may materialise in the water sector with a lag period as some companies may have taken forward positions or hedged their energy costs in the past[17]. While companies can reduce power costs with effective hedging strategies, this would represent a gain through efficiency improvement which under Ofwat's cost assessment framework should be rewarded. Long-term contract and hedging can constitute sensible management action to improve energy cost efficiency in the short term or to avoid a basic level of cost escalation in the future. However, hedging is a costly and a limited management tool. Companies cannot be expected as a base case to have hedged against energy cost increases experienced in the recent period. Therefore, high energy prices may put significant input cost pressures for water companies over the PR24 price control period. If energy prices are going to remain high over future periods, the impact may become more material.

Figure 9: Summary of results from considered modelling amendments

Approach		Inclusion of electricity price index in models as a cost driver	Pre-modelling adjustment with post modelling uplift of power costs	Introducing a dummy year in the models as a cost driver	Excluding the affected years from the sample (e.g., 2021-22)	Inclusion of business plan forecasts
Impact on modelled costs (last 5 years)	Wholesale water	**1.4%**	**0.7%**	**0.2%**	**-0.5%**	
	Wastewater network plus	**0.9%**	**1.0%**	**0.4%**	**-1.0%**	
Impact on modelled costs (2021-22)	Wholesale water	**5.0%**	**3.1%**	**2.0%**	**-0.5%**	
	Wastewater network plus	**3.4%**	**4.3%**	**6.3%**	**-1.2%**	
Impact on modelled costs (2022-23)	Wholesale water	**10.4%**	**6.9%**			
	Wastewater network plus	**7.2%**	**6.5%**			
Suitability	Wholesale water					
	Wastewater network plus					
Comment		May correct for issues 1, 2 and 3.	May correct for issues 1, 2 and 3 but requires modelled power costs to be estimated	May capture other factors different from movement in energy prices.	May further increase the issue 3	May only partially address issue 3. It does not correct for issues 1 and 2.

Can potentially correct for all modelling issues.
Can potentially correct only some modelling issues.
Cannot correct for any modelling issues.
Source: KPMG analysis

[17] Hedging is a risk contract for the party providing the hedge and is therefore also driven by current energy prices, as well as the future expectation of price movements.

4. Conclusions and implications for PR24

In 2021-22, the water sector has shown an approximately 12% increase in power costs, which is the largest year on year growth rate for the last 10 years. This is reflective of high energy prices as a result of the recent political and macroeconomic developments, both globally and in the UK. Individual water companies' exposure to energy prices may vary, depending on the hedging arrangements. Some companies are fully hedged for the current period but have open positions for the next few years. It is not however expected that companies will be hedged for the entire price control period nor should a hedged position necessarily represent the appropriate starting point or base case for the sector at PR24.

High energy prices may have shifted the water sector's future energy cost requirements significantly higher compared to the historical average. This means that historical trends may no longer be sufficient to determine future energy costs and PR24 cost assessment models should be designed to reflect the step change on energy market.

Ofwat uses CPIH-deflated cost data in its econometric models to conduct an efficiency assessment on a comparable basis. The report has identified three modelling issues that arise when energy prices move differently from general inflation. These could distort Ofwat's historical comparative cost efficiency assessment and result in future efficient costs being disallowed.

The magnitude of the adjustment that may be required to ensure sufficient funding over PR24 period will depend on the number of unknowns, including the PR24 econometric cost model specifications.

To mitigate risks from not accounting for rising power costs at PR24, the report has considered a number of modelling amendments. We have found that controlling for energy price movements in econometric assessment has a material impact on the sector's overall modelled costs in the recent period.

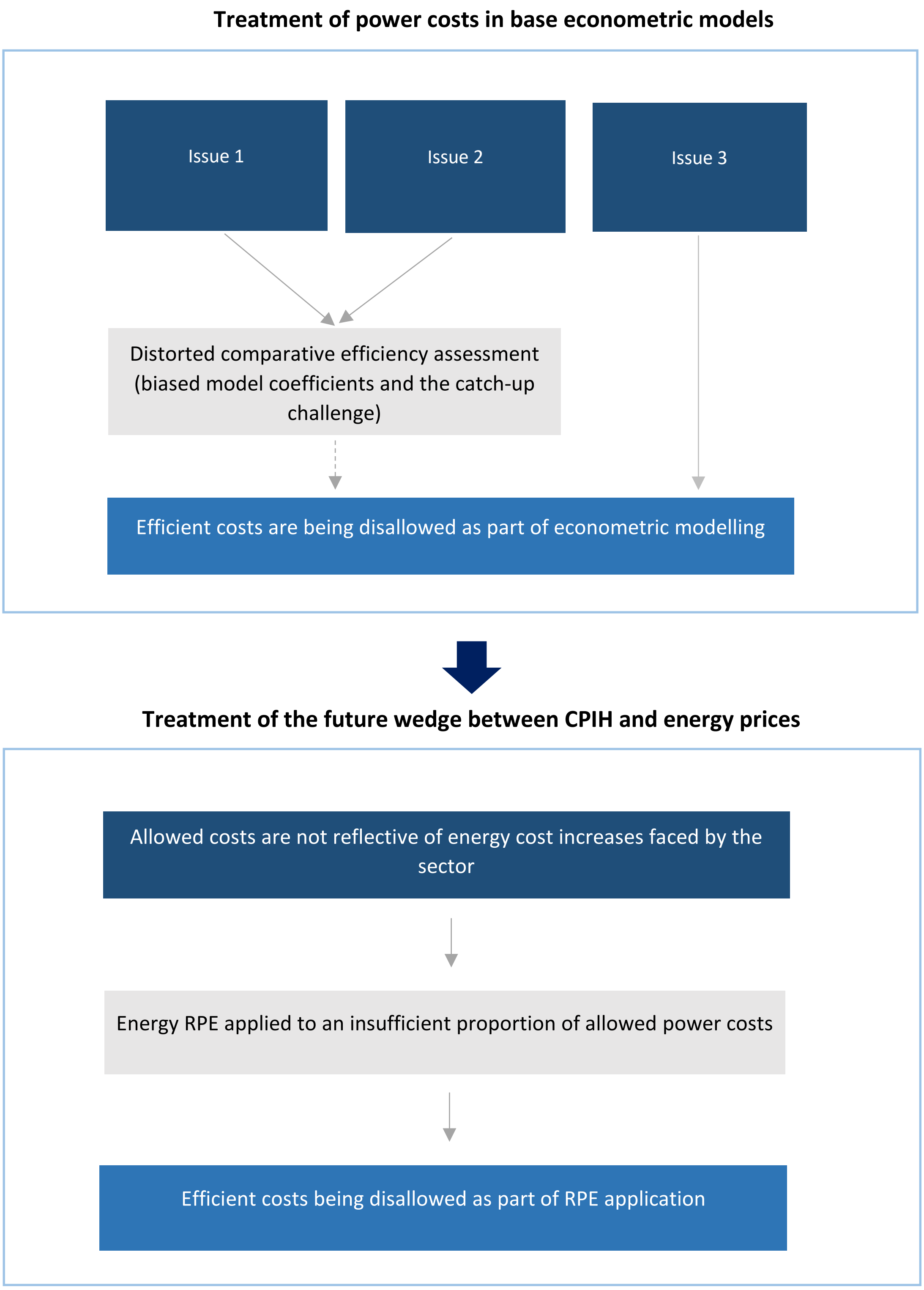
Correcting for the modelling issues in the historical benchmarking is a first and crucial step to account for the risks the sector faces from an increased power cost. It provides an appropriate starting point for the cost allowance, but it does not mitigate all the risks from future energy price pressures for the water sector.

The impact of rising (or changing) energy prices can be fully captured only if the modelling correction is complemented by a relevant RPE assessment as prices for energy may evolve differently from general inflation during the next price control period.

Accounting for power cost increases in econometric models and the application of an RPE are two different but closely interlinked mechanisms. They do not serve as substitutes but are to be applied together (Figure 10). The former should ensure that allowed efficient costs already reflect the higher energy prices which the water sector currently faces. Only then the latter may provide an adequate protection for the future wedge.

This report has focused on the treatment of power costs within PR24 econometric models. However, there may be other cost items which display similar tendencies (e.g. chemicals, materials etc.), that should also be considered to ensure water companies are sufficiently funded for their requirements in the next price control period.

Figure 10: Implications of not accounting for rising power costs at PR24



Source: KPMG analysis

The key aim for incentive based regulatory regimes is to facilitate robust *ex ante* estimation of allowed revenues in order to continue to incentivise efficient costs that maintain investment and service quality. To not provide for efficient costs creates both financeability problems and problems in the continued investment in the network as an efficient notional company cannot recover efficiently incurred costs.

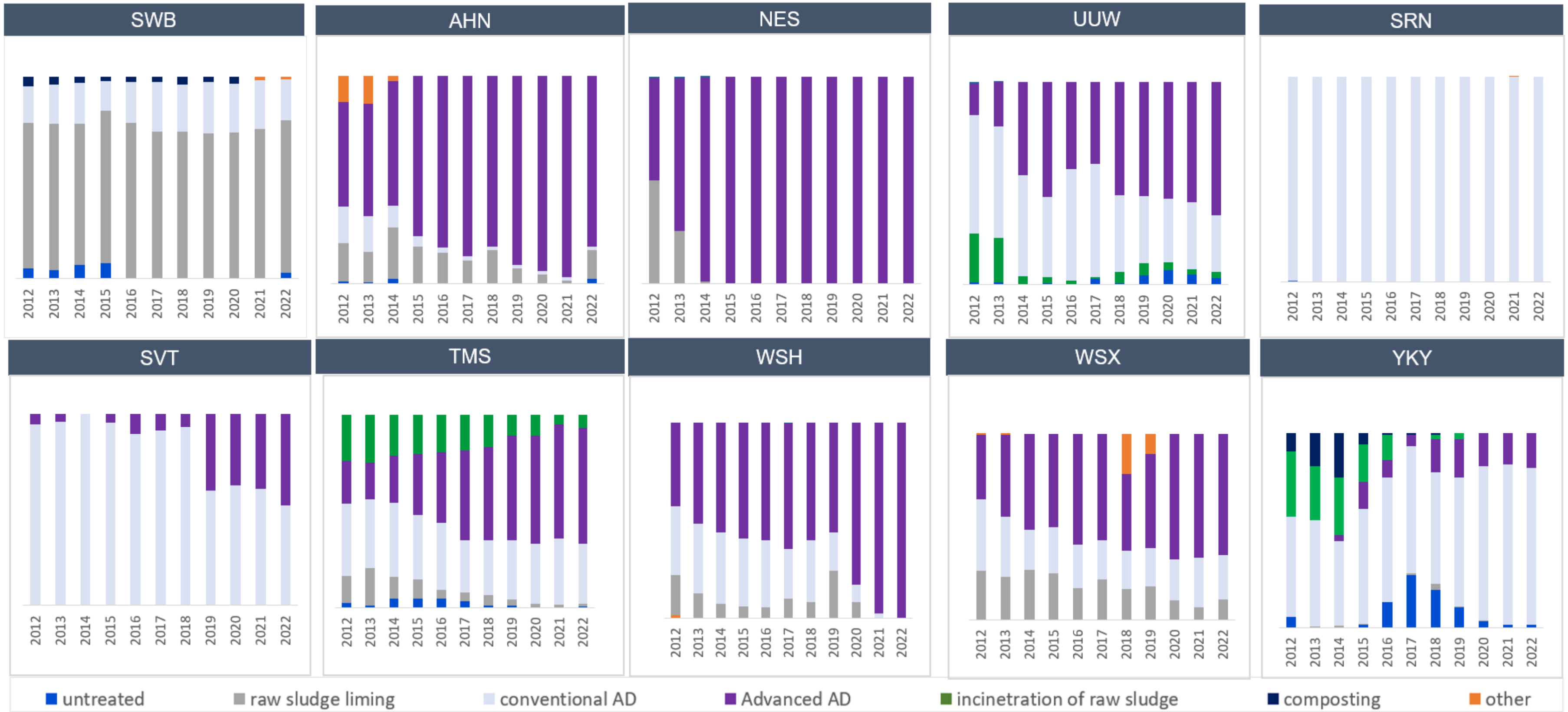
The appropriate treatment of power costs in base econometric models is crucial to ensure that cost allowances reflect the increased input cost pressures which water companies will face over next price control period due to recent developments in energy market. If companies are not fully compensated for the future requirements, then the disallowance of those efficient costs will create risks for the entire sector.

Owing to the Covid-19 pandemic, the conflict in Ukraine, climate challenges and Brexit, the water sector faces a potentially significant increase in cash-flow volatility and fluctuations in capital requirements over the next price control period. Even though the exact effect of all these is still unknown, the high volatility of prices and increased uncertainty is clear. If risks from increased energy prices are not mitigated, then the water sector will face an even riskier environment than during the previous price controls.

Water companies may not manage to earn their allowed rate of return on an expected basis if efficient energy costs are not recognised – breaching the ‘fair bet’ regulatory principle. The sector would then potentially have insufficient resources to provide adequate investment which could be reflected in the quality of service received by customers.

Annex A: Sludge treatment technology across the sector

Figure A1: Sludge by treatment technology from 2012 to 2022, by company



Annex B: Modelling results

Figure B1: Modelling results with an inclusion of energy price driver

Water resource plus and treated water distribution

	WRP						TWD					
	re1	re2	re3	re4	re5	re6	re7	re8	re9	re10	re11	re12
BEIS electricity price index (log)	0.184	0.193	0.207	0.214	0.208	0.215	0.228***	0.199**	0.181**	0.221***	0.196**	0.183**
	{0.323}	{0.243}	{0.267}	{0.198}	{0.257}	{0.187}	{0.005}	{0.016}	{0.029}	{0.007}	{0.017}	{0.033}
Connected properties (log)	1.071***	1.072***	1.059***	1.063***	1.028***	1.030***						
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}						
Water treated at complexity levels 3 to 6 (%)	0.004**		0.003		0.003**							
	{0.039}		{0.157}		{0.040}							
Weighted average density - LAD from MSOA (log)	-1.395**	-1.365*					-2.546***			-2.811***		
	{0.025}	{0.058}					{0.000}			{0.000}		
Weighted average density - LAD from MSOA (log) squared	0.086**	0.083*					0.205***			0.217***		
	{0.032}	{0.073}					{0.000}			{0.000}		
Weighted average treatment complexity (log)		0.194		0.149		0.204						
		{0.363}		{0.520}		{0.335}						
Weighted average density – MSOA (log)			-4.888**	-5.037**				-5.300***			-6.284***	
			{0.030}	{0.044}				{0.000}			{0.000}	
Weighted average density – MSOA (log) squared			0.293**	0.302**				0.373***			0.427***	
			{0.031}	{0.046}				{0.000}			{0.000}	
Properties per length of mains (log)					-6.911*	-6.842*			-14.072***			-15.748***
					{0.072}	{0.091}			{0.000}			{0.000}
Properties per length of mains (log) squared					0.741*	0.731			1.789***			1.948***
					{0.098}	{0.121}			{0.000}			{0.000}
Length of mains (log)							1.063***	1.025***	1.068***	1.057***	1.017***	1.043***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Booster pumping stations per length of mains (log)							0.444***	0.393***	0.451***			
							{0.003}	{0.005}	{0.005}			
Average pumping head TWD (log)										0.332***	0.387***	0.336***
										{0.000}	{0.000}	{0.000}
Constant	-6.515***	-6.655***	8.31	8.864	4.381	4.215	2.46	13.701**	22.448***	0.542	14.822***	23.570***
	{0.001}	{0.003}	{0.328}	{0.352}	{0.586}	{0.619}	{0.143}	{0.016}	{0.000}	{0.739}	{0.000}	{0.000}
Number of observations	187	187	187	187	187	187	187	187	187	187	187	187
R_squared	0.906	0.899	0.899	0.894	0.908	0.902	0.957	0.954	0.96	0.962	0.966	0.966
RESET_P_value	0.771	0.633	0.846	0.765	0.768	0.612	0.814	0.479	0.767	0.797	0.892	0.683

Wholesale water

	WW											
	re13	re14	re15	re16	re17	re18	re19	re20	re21	re22	re23	re24
BEIS electricity price index (log)	0.177*	0.157*	0.184*	0.166*	0.177*	0.155*	0.175*	0.162*	0.191**	0.179**	0.182*	0.166*
	{0.074}	{0.091}	{0.064}	{0.072}	{0.071}	{0.092}	{0.060}	{0.053}	{0.037}	{0.032}	{0.052}	{0.053}
Connected properties (log)	1.069***	1.062***	1.056***	1.051***	1.043***	1.037***	1.063***	1.058***	1.046***	1.044***	1.025***	1.022***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Water treated at complexity levels 3 to 6 (%)	0.002**		0.002		0.002**		0.002		0.001		0.002	
	{0.037}		{0.175}		{0.032}		{0.141}		{0.425}		{0.105}	
Weighted average density - LAD from MSOA (log)	-1.741***	-1.612***					-2.039***	-1.955***				
	{0.001}	{0.002}					{0.000}	{0.000}				
Weighted average density - LAD from MSOA (log) squared	0.123***	0.114***					0.138***	0.131***				
	{0.000}	{0.001}					{0.000}	{0.000}				
Weighted average treatment complexity (log)		0.257**		0.211*		0.263**		0.19		0.137		0.208*
		{0.028}		{0.086}		{0.021}		{0.136}		{0.281}		{0.082}
Weighted average density – MSOA (log)			-4.704***	-4.422***					-6.003***	-5.856***		
			{0.002}	{0.004}					{0.000}	{0.000}		
Weighted average density – MSOA (log) squared			0.299***	0.281***					0.372***	0.363***		
			{0.001}	{0.002}					{0.000}	{0.000}		
Properties per length of mains (log)					-10.705***	-10.093***					-11.938***	-11.525***
					{0.000}	{0.000}					{0.000}	{0.000}
Properties per length of mains (log) squared					1.245***	1.169***					1.363***	1.313***
					{0.000}	{0.000}					{0.000}	{0.000}
Length of mains (log)												
Booster pumping stations per length of mains (log)	0.439***	0.428***	0.468***	0.456***	0.342**	0.326*						
	{0.008}	{0.006}	{0.005}	{0.006}	{0.049}	{0.051}						
Average pumping head TWD (log)							0.329***	0.323***	0.337***	0.334***	0.267**	0.259**
							{0.002}	{0.003}	{0.003}	{0.004}	{0.033}	{0.042}
Constant	-3.089**	-3.576**	9.564*	8.424	13.745**	12.411**	-4.844***	-5.120***	11.999**	11.430**	14.500***	13.648***
	{0.039}	{0.018}	{0.099}	{0.145}	{0.015}	{0.024}	{0.007}	{0.004}	{0.018}	{0.030}	{0.001}	{0.001}
Number of observations	187	187	187	187	187	187	187	187	187	187	187	187
R_squared	0.965	0.966	0.963	0.965	0.965	0.967	0.965	0.965	0.963	0.963	0.966	0.966
RESET_P_value	0.696	0.49	0.74	0.53	0.689	0.42	0.978	0.989	0.873	0.933	0.936	0.898

Sewage collection, sewage treatment and wastewater network plus

	SWC								SWT			NP					
	re1	re2	re3	re4	re5	re6	re7	re8	re9	re10	re11	re12	re13	re14	re15	re16	re17
BEIS electricity price index (log)	0.054	0.115	0.100	0.054	0.106	0.09	0.240*	0.248*	0.230*	0.097	0.101	0.102	0.104	0.091	0.095	0.097	0.097
	{0.666}	{0.327}	{0.395}	{0.666}	{0.359}	{0.437}	{0.067}	{0.061}	{0.055}	{0.254}	{0.231}	{0.228}	{0.208}	{0.289}	{0.270}	{0.259}	{0.254}
Sewer per length (log)	0.812***	0.880***	0.863***	0.850***	0.889***	0.874***											
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}											
Pumping capacity per length	0.341***	0.528***	0.496***	0.356***	0.516***	0.481***				0.328***	0.340***	0.314***	0.254***	0.322***	0.337***	0.310***	0.248***
	{0.008}	{0.000}	{0.000}	{0.010}	{0.000}	{0.000}				{0.000}	{0.000}	{0.000}	{0.003}	{0.000}	{0.000}	{0.000}	{0.000}
Properties per sewer length (log)	0.985***			0.915***													
	{0.000}			{0.001}													
Weighted average density - LAD from MSOA (log)		0.193**			0.225***												
		{0.038}			{0.000}												
Weighted average density – MSOA (log)			0.314**			0.353***											
			{0.019}			{0.000}											
Urbain rainfall per length				0.114***	0.149***	0.147***								0.072**	0.073**	0.077**	0.085**
				{0.000}	{0.000}	{0.000}								{0.024}	{0.017}	{0.018}	{0.016}
Load (log)							0.709***	0.790***	0.830***	0.657***	0.743***	0.707***	0.730***	0.661***	0.747***	0.726***	0.738***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Load treated in size bands 1 to 3 (%)							0.036				0.025*				0.024**		
							{0.206}				{0.075}				{0.030}		
Load treated with ammonia permit ≤ 3mg/l							0.004***	0.004***	0.004***	0.004***	0.004***	0.004***	0.005***	0.005***	0.004***	0.005***	0.005***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Load treated in STWs ≥ 100,000 people (%)								-0.009***				-0.003**				-0.003***	
								{0.001}				{0.046}				{0.010}	
Weighted average treatment size									-0.239***				-0.097***				-0.098***
									{0.000}				{0.010}				{0.001}
Constant	-8.082***	-6.928***	-7.743***	-7.912***	-6.758***	-7.682***	-5.596***	-6.003***	-4.641***	-3.551***	-4.767***	-4.068***	-3.558***	-3.370***	-4.572***	-4.027***	-3.365***
N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
R_squared	0.917	0.892	0.892	0.919	0.911	0.91	0.866	0.88	0.917	0.948	0.953	0.95	0.957	0.954	0.959	0.957	0.964
RESET_P_value	0.371	0.452	0.382	0.134	0.449	0.381	0.04	0.151	0.303	0.345	0.234	0.413	0.5	0.149	0.05	0.002	0.078

Notes: *** indicates 1% significance level; ** indicates 5% significance level; * indicates 10% significance level. The results are based on a ‘random effects’ estimation for the panel data

Figure B2: Modelling results with pre-modelling adjustment

Water resource plus and treated water distribution

	WRP						TWD					
	re1	re2	re3	re4	re5	re6	re7	re8	re9	re10	re11	re12
Connected properties (log)	1.072***	1.073***	1.055***	1.059***	1.029***	1.029***						
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}						
Water treated at complexity levels 3 to 6 (%)	0.004***		0.004**		0.004***							
	{0.006}		{0.027}		{0.003}							
Weighted average density - LAD from MSOA (log)	-1.462**	-1.410**					-2.684***			-2.936***		
	{0.013}	{0.039}					{0.000}			{0.000}		
Weighted average density - LAD from MSOA (log) squared	0.091**	0.087**					0.216***			0.226***		
	{0.017}	{0.048}					{0.000}			{0.000}		
Weighted average treatment complexity (log)		0.276		0.244		0.297						
		{0.276}		{0.351}		{0.227}						
Weighted average density – MSOA (log)			-4.933**	-5.045**				-5.471***			-6.473***	
			{0.022}	{0.038}				{0.000}			{0.000}	
Weighted average density – MSOA (log) squared			0.298**	0.304**				0.386***			0.441***	
			{0.022}	{0.038}				{0.000}			{0.000}	
Properties per length of mains (log)					-7.578**	-7.340**			-14.517***			-16.287***
					{0.034}	{0.047}			{0.000}			{0.000}
Properties per length of mains (log) squared					0.825**	0.794*			1.848***			2.015***
					{0.049}	{0.065}			{0.000}			{0.000}
Length of mains (log)							1.068***	1.025***	1.071***	1.061***	1.017***	1.045***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Booster pumping stations per length of mains (log)							0.458***	0.425***	0.483***			
							{0.002}	{0.001}	{0.001}			
Average pumping head TWD (log)										0.351***	0.405***	0.352***
										{0.000}	{0.000}	{0.000}
Constant	-5.503***	-5.712***	9.339	9.737	6.63	6.098	4.008**	15.301***	24.230***	1.893	16.360***	25.457***
	{0.000}	{0.003}	{0.243}	{0.288}	{0.368}	{0.426}	{0.012}	{0.003}	{0.000}	{0.232}	{0.000}	{0.000}
Number of observations	187	187	187	187	187	187	187	187	187	187	187	187
R_squared	0.908	0.9	0.899	0.894	0.909	0.903	0.956	0.953	0.959	0.961	0.965	0.966
RESET_P_value	0.539	0.499	0.858	0.821	0.462	0.359	0.124	0.166	0.586	0.414	0.706	0.676

Wholesale water

	WW											
	re13	re14	re15	re16	re17	re18	re19	re20	re21	re22	re23	re24
Connected properties (log)	1.071***	1.061***	1.053***	1.048***	1.044***	1.037***	1.065***	1.059***	1.043***	1.040***	1.025***	1.021***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Water treated at complexity levels 3 to 6 (%)	0.003***		0.002**		0.003***		0.002**		0.002		0.003**	
	{0.004}		{0.024}		{0.002}		{0.040}		{0.122}		{0.020}	
Weighted average density - LAD from MSOA (log)	-1.807***	-1.634***					-2.130***	-2.011***				
	{0.000}	{0.001}					{0.000}	{0.000}				
Weighted average density - LAD from MSOA (log) squared	0.128***	0.116***					0.144***	0.136***				
	{0.000}	{0.001}					{0.000}	{0.000}				
Weighted average treatment complexity (log)		0.313**		0.277**		0.322**		0.244		0.209		0.273*
		{0.022}		{0.047}		{0.011}		{0.102}		{0.159}		{0.050}
Weighted average density – MSOA (log)			-4.686***	-4.355***					-6.117***	-5.908***		
			{0.001}	{0.002}					{0.000}	{0.000}		
Weighted average density – MSOA (log) squared			0.301***	0.278***					0.381***	0.367***		
			{0.001}	{0.002}					{0.000}	{0.000}		
Properties per length of mains (log)					-11.036***	-10.210***					-12.483***	-11.832***
					{0.000}	{0.000}					{0.000}	{0.000}
Properties per length of mains (log) squared					1.289***	1.186***					1.431***	1.351***
					{0.000}	{0.000}					{0.000}	{0.000}
Length of mains (log)												
Booster pumping stations per length of mains (log)	0.454***	0.440***	0.498***	0.477***	0.367**	0.343**						
	{0.007}	{0.005}	{0.003}	{0.003}	{0.036}	{0.037}						
Average pumping head TWD (log)							0.339***	0.331***	0.351***	0.344***	0.273**	0.261**
							{0.001}	{0.002}	{0.002}	{0.003}	{0.026}	{0.038}
Constant	-2.055	-2.792*	10.345*	8.907	15.231***	13.338**	-3.828**	-4.282**	13.168***	12.302**	16.385***	14.969***
	{0.188}	{0.068}	{0.063}	{0.109}	{0.007}	{0.013}	{0.028}	{0.014}	{0.009}	{0.020}	{0.000}	{0.000}
Number of observations	187	187	187	187	187	187	187	187	187	187	187	187
R_squared	0.965	0.966	0.963	0.965	0.965	0.967	0.965	0.965	0.962	0.962	0.966	0.966
RESET_P_value	0.243	0.148	0.285	0.17	0.313	0.148	0.878	0.911	0.807	0.881	0.869	0.793

Sewage collection, sewage treatment and network plus

	SWC								SWT			NP					
	re1	re2	re3	re4	re5	re6	re7	re8	re9	re10	re11	re12	re13	re14	re15	re16	re17
Sewer per length (log)	0.813*** {0.000}	0.889*** {0.000}	0.865*** {0.000}	0.852*** {0.000}	0.896*** {0.000}	0.876*** {0.000}											
Pumping capacity per length	0.346*** {0.009}	0.574*** {0.000}	0.531*** {0.001}	0.361** {0.012}	0.550*** {0.000}	0.508*** {0.001}				0.340*** {0.001}	0.353*** {0.002}	0.329*** {0.003}	0.268** {0.011}	0.331*** {0.001}	0.347*** {0.001}	0.322*** {0.001}	0.256*** {0.001}
Properties per sewer length (log)	0.995*** {0.000}			0.926*** {0.000}													
Weighted average density - LAD from MSOA (log)		0.205** {0.027}			0.234*** {0.000}												
Weighted average density – MSOA (log)			0.340*** {0.008}			0.372*** {0.000}											
Urban rainfall per length				0.115*** {0.000}	0.152*** {0.000}	0.149*** {0.000}								0.073** {0.016}	0.074*** {0.010}	0.079** {0.011}	0.086*** {0.010}
Load (log)							0.684*** {0.000}	0.758*** {0.000}	0.814*** {0.000}	0.656*** {0.000}	0.740*** {0.000}	0.704*** {0.000}	0.727*** {0.000}	0.661*** {0.000}	0.745*** {0.000}	0.724*** {0.000}	0.736*** {0.000}
Load treated in size bands 1 to 3 (%)							0.033 {0.213}				0.024* {0.076}				0.024** {0.031}		
Load treated with ammonia permit ≤ 3mg/l							0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}	0.005*** {0.000}
Load treated in STWs ≥ 100,000 people (%)								-0.009*** {0.002}				-0.003* {0.096}				-0.003** {0.033}	
Weighted average treatment size									-0.242*** {0.000}				-0.095** {0.013}				-0.097*** {0.002}
Constant	-7.876*** {0.000}	-6.569*** {0.000}	-7.494*** {0.000}	-7.711*** {0.000}	-6.393*** {0.000}	-7.424*** {0.000}	-4.123*** {0.002}	-4.463*** {0.000}	-3.318*** {0.000}	-3.086*** {0.000}	-4.255*** {0.000}	-3.549*** {0.000}	-3.048*** {0.000}	-2.932*** {0.000}	-4.092*** {0.000}	-3.540*** {0.000}	-2.885*** {0.000}
N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
R_squared	0.917	0.89	0.891	0.919	0.91	0.909	0.859	0.873	0.914	0.948	0.953	0.95	0.957	0.954	0.959	0.957	0.965
RESET_P_value	0.27	0.144	0.114	0.08	0.213	0.188	0.115	0.326	0.914	0.495	0.437	0.667	0.866	0.095	0.025	0.001	0.115

Notes: *** indicates 1% significance level; ** indicates 5% significance level; * indicates 10% significance level. The results are based on a ‘random effects’ estimation for the panel data

Figure B3: Modelling results with 2021-22-year dummy

Water resource plus and treated water distribution

	WRP						TWD					
	re1	re2	re3	re4	re5	re6	re7	re8	re9	re10	re11	re12
2021-22 year dummy	0.022	0.021	0.025	0.024	0.027	0.026	0.037	0.03	0.019	0.035	0.03	0.021
	{0.712}	{0.687}	{0.666}	{0.643}	{0.636}	{0.609}	{0.313}	{0.406}	{0.583}	{0.303}	{0.367}	{0.532}
Connected properties (log)	1.076***	1.075***	1.054***	1.056***	1.029***	1.028***						
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}						
Water treated at complexity levels 3 to 6 (%)	0.005***		0.004**		0.005***							
	{0.003}		{0.012}		{0.001}							
Weighted average density - LAD from MSOA (log)	-1.555***	-1.490**					-2.712***			-2.955***		
	{0.006}	{0.025}					{0.000}			{0.000}		
Weighted average density - LAD from MSOA (log) squared	0.098***	0.093**					0.218***			0.227***		
	{0.007}	{0.029}					{0.000}			{0.000}		
Weighted average treatment complexity (log)		0.322		0.294		0.343						
		{0.188}		{0.244}		{0.149}						
Weighted average density – MSOA (log)			-5.050**	-5.130**				-5.510***			-6.498***	
			{0.017}	{0.033}				{0.000}			{0.000}	
Weighted average density – MSOA (log) squared			0.307**	0.311**				0.390***			0.442***	
			{0.017}	{0.032}				{0.000}			{0.000}	
Properties per length of mains (log)					-7.947**	-7.685**			-14.734***			-16.471***
					{0.016}	{0.026}			{0.000}			{0.000}
Properties per length of mains (log) squared					0.872**	0.839**			1.877***			2.037***
					{0.024}	{0.036}			{0.000}			{0.000}
Length of mains (log)							1.069***	1.026***	1.072***	1.061***	1.017***	1.045***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Booster pumping stations per length of mains (log)							0.466***	0.434***	0.495***			
							{0.002}	{0.001}	{0.001}			
Average pumping head TWD (log)										0.353***	0.407***	0.352***
										{0.000}	{0.000}	{0.000}
Constant	-5.275***	-5.556***	9.689	9.936	7.298	6.69	4.114***	15.457***	24.680***	1.944	16.438***	25.826***
	{0.001}	{0.003}	{0.220}	{0.274}	{0.288}	{0.354}	{0.008}	{0.002}	{0.000}	{0.223}	{0.000}	{0.000}
Number of observations	187	187	187	187	187	187	187	187	187	187	187	187
R_squared	0.908	0.901	0.9	0.895	0.91	0.904	0.955	0.952	0.958	0.961	0.965	0.966
RESET_P_value	0.486	0.42	0.762	0.662	0.459	0.341	0.169	0.193	0.626	0.438	0.749	0.745

Wholesale water

	WW											
	re13	re14	re15	re16	re17	re18	re19	re20	re21	re22	re23	re24
2021-22 year dummy	0.02	0.015	0.021	0.016	0.018	0.013	0.019	0.015	0.021	0.017	0.02	0.015
	{0.618}	{0.686}	{0.607}	{0.666}	{0.654}	{0.725}	{0.614}	{0.663}	{0.570}	{0.617}	{0.611}	{0.666}
Connected properties (log)	1.072***	1.061***	1.052***	1.046***	1.044***	1.037***	1.065***	1.058***	1.042***	1.038***	1.025***	1.020***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Water treated at complexity levels 3 to 6 (%)	0.003***		0.003**		0.003***		0.003**		0.002*		0.003**	
	{0.002}		{0.014}		{0.001}		{0.031}		{0.091}		{0.016}	
Weighted average density - LAD from MSOA (log)	-1.840***	-1.645***					-2.153***	-2.011***				
	{0.000}	{0.001}					{0.000}	{0.000}				
Weighted average density - LAD from MSOA (log) squared	0.131***	0.117***					0.146***	0.136***				
	{0.000}	{0.000}					{0.000}	{0.000}				
Weighted average treatment complexity (log)		0.347**		0.313**		0.352***		0.287*		0.251		0.306**
		{0.013}		{0.026}		{0.007}		{0.064}		{0.101}		{0.035}
Weighted average density – MSOA (log)			-4.689***	-4.322***					-6.107***	-5.860***		
			{0.001}	{0.002}					{0.000}	{0.000}		
Weighted average density – MSOA (log) squared			0.302***	0.277***					0.381***	0.365***		
			{0.000}	{0.001}					{0.000}	{0.000}		
Properties per length of mains (log)					-11.233***	-10.354***					-12.694***	-11.992***
					{0.000}	{0.000}					{0.000}	{0.000}
Properties per length of mains (log) squared					1.316***	1.206***					1.458***	1.372***
					{0.000}	{0.000}					{0.000}	{0.000}
Length of mains (log)												
Booster pumping stations per length of mains (log)	0.458***	0.444***	0.508***	0.486***	0.382**	0.355**						
	{0.008}	{0.005}	{0.003}	{0.003}	{0.033}	{0.033}						
Average pumping head TWD (log)							0.342***	0.332***	0.356***	0.348***	0.281**	0.268**
							{0.001}	{0.002}	{0.002}	{0.003}	{0.021}	{0.032}
Constant	-1.974	-2.795*	10.330*	8.74	15.614***	13.600***	-3.805**	-4.344**	13.060**	12.036**	16.734***	15.203***
	{0.199}	{0.065}	{0.057}	{0.108}	{0.003}	{0.007}	{0.032}	{0.014}	{0.010}	{0.023}	{0.000}	{0.000}
Number of observations	187	187	187	187	187	187	187	187	187	187	187	187
R_squared	0.965	0.967	0.963	0.965	0.965	0.967	0.965	0.965	0.961	0.962	0.966	0.967
RESET_P_value	0.213	0.111	0.246	0.126	0.323	0.142	0.853	0.889	0.781	0.87	0.927	0.849

Sewage collection, sewage treatment and wastewater network plus

	SWC								SWT			NP					
	re1	re2	re3	re4	re5	re6	re7	re8	re9	re10	re11	re12	re13	re14	re15	re16	re17
2021-22 year dummy	0.03	0.048	0.044	0.046	0.066	0.062	0.109**	0.112**	0.108**	0.059	0.059	0.061	0.061	0.069*	0.069*	0.072*	0.072*
	{0.595}	{0.389}	{0.418}	{0.426}	{0.230}	{0.253}	{0.034}	{0.028}	{0.031}	{0.147}	{0.145}	{0.134}	{0.128}	{0.087}	{0.088}	{0.073}	{0.067}
Sewer per length (log)	0.808***	0.883***	0.859***	0.851***	0.889***	0.870***											
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}											
Pumping capacity per length	0.341***	0.559***	0.518***	0.354***	0.528***	0.486***				0.337***	0.350***	0.325***	0.265***	0.320***	0.337***	0.309***	0.247***
	{0.008}	{0.000}	{0.000}	{0.009}	{0.000}	{0.001}				{0.000}	{0.001}	{0.001}	{0.005}	{0.000}	{0.000}	{0.001}	{0.001}
Properties per sewer length (log)	1.011***			0.923***													
	{0.000}			{0.000}													
Weighted average density - LAD from MSOA (log)		0.206**			0.237***												
		{0.024}			{0.000}												
Weighted average density – MSOA (log)			0.341***			0.374***											
			{0.007}			{0.000}											
Urbain rainfall per length				0.125***	0.167***	0.163***								0.090***	0.091***	0.096***	0.101***
				{0.000}	{0.000}	{0.000}								{0.002}	{0.001}	{0.001}	{0.001}
Load (log)							0.660***	0.741***	0.798***	0.645***	0.727***	0.693***	0.718***	0.651***	0.734***	0.718***	0.729***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Load treated in size bands 1 to 3 (%)							0.03				0.024*				0.023**		
							{0.217}				{0.079}				{0.035}		
Load treated with ammonia permit ≤ 3mg/l							0.006***	0.006***	0.006***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Load treated in STWs ≥ 100,000 people (%)								-0.009***				-0.003				-0.003**	
								{0.005}				{0.108}				{0.019}	
Weighted average treatment size									-0.241***				-0.096**				-0.100***
									{0.000}				{0.013}				{0.002}
Constant	-7.880***	-6.506***	-7.441***	-7.659***	-6.289***	-7.328***	-3.822***	-4.266***	-3.130***	-2.957***	-4.094***	-3.414***	-2.922***	-2.759***	-3.900***	-3.401***	-2.732***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.002}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
R_squared	0.917	0.891	0.891	0.919	0.912	0.911	0.86	0.874	0.915	0.948	0.953	0.95	0.957	0.955	0.961	0.959	0.966
RESET_P_value	0.41	0.367	0.311	0.138	0.483	0.425	0.105	0.358	0.569	0.463	0.332	0.573	0.689	0.229	0.029	0.005	0.072

Notes: *** indicates 1% significance level; ** indicates 5% significance level; * indicates 10% significance level. The results are based on a ‘random effects’ estimation for the panel data

Figure B4: Modelling results when 2022 year is excluded

Water resource plus and treated water distribution

	WRP						TWD					
	re1	re2	re3	re4	re5	re6	re7	re8	re9	re10	re11	re12
Connected properties (log)	1.065***	1.065***	1.046***	1.051***	1.021***	1.021***						
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}						
Water treated at complexity levels 3 to 6 (%)	0.006***		0.005***		0.006***							
	{0.000}		{0.003}		{0.000}							
Weighted average density - LAD from MSOA (log)	-1.467***	-1.377**					-2.709***			-3.030***		
	{0.009}	{0.035}					{0.000}			{0.000}		
Weighted average density - LAD from MSOA (log) squared	0.091**	0.084**					0.218***			0.233***		
	{0.012}	{0.044}					{0.000}			{0.000}		
Weighted average treatment complexity (log)		0.354		0.324		0.384*						
		{0.122}		{0.176}		{0.083}						
Weighted average density – MSOA (log)			-4.684**	-4.794**				-5.537***			-6.762***	
			{0.020}	{0.042}				{0.000}			{0.000}	
Weighted average density – MSOA (log) squared			0.282**	0.288**				0.392***			0.459***	
			{0.020}	{0.043}				{0.000}			{0.000}	
Properties per length of mains (log)					-7.076**	-6.500*			-15.306***			-17.545***
					{0.029}	{0.057}			{0.000}			{0.000}
Properties per length of mains (log) squared					0.762**	0.690*			1.943***			2.161***
					{0.046}	{0.083}			{0.000}			{0.000}
Length of mains (log)							1.066***	1.023***	1.070***	1.059***	1.015***	1.042***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Booster pumping stations per length of mains (log)							0.515***	0.474***	0.520***			
							{0.001}	{0.001}	{0.001}			
Average pumping head TWD (log)										0.341***	0.398***	0.347***
										{0.000}	{0.000}	{0.000}
Constant	-5.481***	-5.834***	8.383	8.762	5.636	4.381	4.319***	15.731***	26.036***	2.291	17.561***	28.201***
	{0.001}	{0.002}	{0.268}	{0.326}	{0.400}	{0.535}	{0.007}	{0.003}	{0.000}	{0.191}	{0.000}	{0.000}
Number of observations	170	170	170	170	170	170	170	170	170	170	170	170
R_squared	0.912	0.904	0.904	0.898	0.916	0.909	0.954	0.952	0.957	0.959	0.963	0.964
RESET_P_value	0.421	0.342	0.739	0.716	0.32	0.163	0.087	0.12	0.488	0.432	0.699	0.838

Wholesale water

	WW											
	re13	re14	re15	re16	re17	re18	re19	re20	re21	re22	re23	re24
Connected properties (log)	1.065***	1.055***	1.045***	1.040***	1.037***	1.029***	1.060***	1.053***	1.036***	1.033***	1.019***	1.015***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Water treated at complexity levels 3 to 6 (%)	0.004***		0.003***		0.004***		0.003**		0.003**		0.003***	
	{0.000}		{0.004}		{0.000}		{0.010}		{0.038}		{0.005}	
Weighted average density - LAD from MSOA (log)	-1.840***	-1.633***					-2.211***	-2.059***				
	{0.000}	{0.001}					{0.000}	{0.000}				
Weighted average density - LAD from MSOA (log) squared	0.131***	0.116***					0.150***	0.139***				
	{0.000}	{0.001}					{0.000}	{0.000}				
Weighted average treatment complexity (log)		0.368***		0.335**		0.391***		0.302**		0.269*		0.339**
		{0.005}		{0.010}		{0.001}		{0.038}		{0.061}		{0.012}
Weighted average density – MSOA (log)			-4.632***	-4.288***					-6.230***	-6.002***		
			{0.002}	{0.003}					{0.000}	{0.000}		
Weighted average density – MSOA (log) squared			0.298***	0.274***					0.389***	0.373***		
			{0.001}	{0.002}					{0.000}	{0.000}		
Properties per length of mains (log)					-11.658***	-10.659***					-13.437***	-12.562***
					{0.000}	{0.000}					{0.000}	{0.000}
Properties per length of mains (log) squared					1.360***	1.236***					1.541***	1.434***
					{0.000}	{0.000}					{0.000}	{0.000}
Length of mains (log)												
Booster pumping stations per length of mains (log)	0.477***	0.459***	0.523***	0.495***	0.366**	0.338**						
	{0.003}	{0.003}	{0.001}	{0.002}	{0.015}	{0.020}						
Average pumping head TWD (log)							0.319***	0.312***	0.331***	0.324***	0.248**	0.236**
							{0.002}	{0.003}	{0.002}	{0.004}	{0.022}	{0.043}
Constant	-1.846	-2.717*	10.224*	8.714	16.602***	14.326***	-3.458*	-4.031**	13.714**	12.765**	18.566***	16.669***
	{0.259}	{0.086}	{0.070}	{0.121}	{0.001}	{0.003}	{0.075}	{0.034}	{0.013}	{0.024}	{0.000}	{0.000}
Number of observations	170	170	170	170	170	170	170	170	170	170	170	170
R_squared	0.965	0.967	0.963	0.965	0.967	0.969	0.965	0.965	0.961	0.962	0.967	0.968
RESET_P_value	0.168	0.076	0.183	0.077	0.204	0.071	0.846	0.824	0.903	0.932	0.774	0.607

Sewage collection, sewage treatment and wastewater network plus

	SWC								SWT			NP					
	re1	re2	re3	re4	re5	re6	re7	re8	re9	re10	re11	re12	re13	re14	re15	re16	re17
Sewer per length (log)	0.820***	0.896***	0.874***	0.867***	0.903***	0.885***											
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}											
Pumping capacity per length	0.334***	0.552***	0.512***	0.349***	0.521***	0.480***				0.344***	0.356***	0.334***	0.265***	0.327***	0.340***	0.313***	0.240***
	{0.001}	{0.000}	{0.000}	{0.001}	{0.000}	{0.000}				{0.000}	{0.000}	{0.000}	{0.006}	{0.000}	{0.000}	{0.000}	{0.001}
Properties per sewer length (log)	0.967***			0.867***													
	{0.000}			{0.001}													
Weighted average density - LAD from MSOA (log)		0.195**			0.225***												
		{0.047}			{0.001}												
Weighted average density – MSOA (log)			0.323**			0.354***											
			{0.022}			{0.001}											
Urbain rainfall per length				0.130***	0.164***	0.161***								0.088***	0.089***	0.094***	0.099***
				{0.000}	{0.000}	{0.000}								{0.003}	{0.002}	{0.002}	{0.002}
Load (log)							0.660***	0.745***	0.794***	0.649***	0.736***	0.700***	0.722***	0.656***	0.741***	0.725***	0.733***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Load treated in size bands 1 to 3 (%)							0.03				0.025*				0.024**		
							{0.199}				{0.091}				{0.045}		
Load treated with ammonia permit ≤ 3mg/l							0.006***	0.006***	0.006***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***
							{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
Load treated in STWs ≥ 100,000 people (%)								-0.009**				-0.003				-0.003*	
								{0.010}				{0.159}				{0.052}	
Weighted average treatment size									-0.242***				-0.097**				-0.099***
									{0.000}				{0.015}				{0.003}
Constant	-7.845***	-6.574***	-7.457***	-7.607***	-6.355***	-7.338***	-3.826***	-4.311***	-3.088***	-3.012***	-4.210***	-3.502***	-2.975***	-2.830***	-4.001***	-3.497***	-2.792***
	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.002}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
N	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
R_squared	0.918	0.888	0.888	0.921	0.911	0.91	0.86	0.874	0.915	0.947	0.952	0.949	0.956	0.955	0.961	0.959	0.966
RESET_P_value	0.337	0.305	0.253	0.163	0.399	0.359	0.055	0.269	0.849	0.538	0.445	0.664	0.887	0.239	0.04	0.003	0.22

Notes: *** indicates 1% significance level; ** indicates 5% significance level; * indicates 10% significance level. The results are based on a ‘random effects’ estimation for the panel data

Annex C: Efficiency scores

Triangulated Water

Ofwat		Inclusion of a driver		Pre-modelling adjustment		Inclusion of a 2021-22 year dummy		excluding 2021-22 year	
PRT	0.79	PRT	0.76	PRT	0.78	PRT	0.79	PRT	0.79
SSC	0.83	SSC	0.81	SSC	0.82	SSC	0.83	SSC	0.84
SWB	0.91	SWB	0.89	SWB	0.90	SWB	0.91	SWB	0.91
AFW	1.01	AFW	1.00	ANH	1.03	AFW	1.01	AFW	1.01
SVE	1.04	SEW	1.01	SEW	1.02	SVE	1.03	HDD	1.02
SEW	1.04	ANH	1.01	AFW	1.00	SEW	1.03	SEW	1.04
TMS	1.05	SVE	1.01	SVE	1.03	ANH	1.04	SVE	1.05
ANH	1.05	HDD	1.02	NWT	1.05	HDD	1.05	ANH	1.05
HDD	1.05	NWT	1.03	HDD	1.04	TMS	1.05	NES	1.06
NWT	1.06	NES	1.04	NES	1.05	NWT	1.05	NWT	1.06
NES	1.06	TMS	1.08	TMS	1.06	NES	1.06	TMS	1.06
YKY	1.11	YKY	1.09	YKY	1.11	YKY	1.11	YKY	1.11
WSH	1.15	WSH	1.12	BRL	1.16	WSH	1.14	WSH	1.13
BRL	1.16	BRL	1.15	WSH	1.14	BRL	1.16	BRL	1.15
WSX	1.26	WSX	1.19	WSX	1.24	WSX	1.25	WSX	1.26
SES	1.32	SES	1.30	SES	1.31	SES	1.31	SES	1.31
SRN	1.36	SRN	1.34	SRN	1.36	SRN	1.36	SRN	1.36
Average	1.07	Average	1.05	Average	1.06	Average	1.07	Average	1.07
UQ	1.02	UQ	1.00	UQ	1.01	UQ	1.02	UQ	1.01
Range	0.57	Range	0.58	Range	0.58	Range	0.57	Range	0.57

Triangulated wastewater (network plus)

Ofwat		Inclusion of a driver		Pre-modelling adjustment		Inclusion of a 2021-22 year dummy		excluding 2021-22 year	
WSX	0.93	WSX	0.90	WSX	0.92	WSX	0.90	WSX	0.93
TMS	0.97	ANH	0.98	TMS	0.97	ANH	0.98	TMS	0.99
SWB	1.00	SWB	0.98	SWB	0.98	SWB	0.98	SWB	1.01
NES	1.00	NES	0.98	NES	0.99	NES	0.98	ANH	1.01
ANH	1.01	TMS	0.99	ANH	0.99	TMS	0.99	NES	1.01
NWT	1.04	NWT	1.03	NWT	1.04	NWT	1.03	NWT	1.05
YKY	1.06	WSH	1.04	WSH	1.05	WSH	1.04	YKY	1.07
WSH	1.07	YKY	1.05	YKY	1.06	YKY	1.05	WSH	1.07
SRN	1.09	SRN	1.09	SRN	1.09	SRN	1.09	SRN	1.12
Average	1.02	Average	1.01	Average	1.01	Average	1.01	Average	1.03
UQ	0.99	UQ	0.98	UQ	0.98	UQ	0.98	UQ	1.00
Range	0.16	Range	0.19	Range	0.18	Range	0.19	Range	0.19

www.kpmg.com