12th January 2023

By email:
CostAssessment@ofwat.gov.uk

Dear Ofwat cost assessment team,

Wessex Water submission – Base Econometric Cost Models for Consultation

Thank you for the opportunity to propose models for the forthcoming cost model consultation. Our templates and supporting files have been provided alongside this response.

Econometric benchmarking models are a useful tool to inform what efficient future base expenditure allowances could be for PR24. In applying these tools, a few fundamentals need careful consideration:

1. What does a good cost model look like?
2. What does a base cost model fund?

These considerations have steered the development of models we have ultimately submitted for consultation. We provide further detail below.

Overall, we recommend using a relatively short backward-looking time period and controlling for dynamic factors as within-model methods to increase the relevancy of backward-looking relationships to inform future allowances. We recognise that other mechanisms which are outside of a set of base models, such as cost adjustment claims, choice and calculation of catch-up challenge, and enhancement dives, can enable a more comprehensive assessment of what efficient forward-looking totex allowances should be.

We have sought to take a proportionate and at times a more principle-based approach to this model submission. This reflects resource and time constraints, a degree of selectivity on the data included in the Ofwat published datasets and, perhaps most importantly, the reality that come final determination a different suite of models may be appropriate given the extra data for 22/23 and 23/24 and business plan information that Ofwat will have available.

Please do not hesitate to get in touch if you would like to discuss any aspect of our submission further or have any questions.

Yours sincerely,

Harriet Cutts

Regulatory Finance Manager

Our submission:

- WSX – Submission of Base Econometric Cost Models 12.01.23 [pdf]
- WSX – Water Template [word]
- WSX – Water do file [Stata]
- WSX – Water results [excel]
- WSX – Wastewater Template [word]
- WSX – Waste do file [Stata]
- WSX – Waste results [excel]
- WSX – Retail Template [word]
- WSX – Retail data do file [Stata]
- WSX – Retail models do file [Stata]
- WSX – Retail results [excel]
- WSX – Retail input data IncomeScoreSq [excel]

Wessex Water submission – Base Econometric Cost Models for Consultation

This cover note, discusses the following:

Contents

Purpose of econometrics

Econometric models, in this regulatory application, estimate the relationship between expenditure and one or more explanatory variables (or cost drivers). They perform best when there are a good number of company observations, expenditure is routinely occurred in most years and by most companies, and there is consistency and comparability of model inputs.

This may lend itself reasonably well to modelling base expenditure, which is further underpinned by well-established reporting of routine base expenditure and cost drivers through the APR. For models estimated using historical data only, this approach is appropriate as long as the historical relationship between costs and cost drivers is a good proxy for the expected future relationship, which needs to be carefully considered in the context of PR24 and the business plans submitted by companies.

Benchmarking generally, including econometric benchmarking, and more specifically benchmarking which uses historical data, is more challenging for some types of expenditure, such as:

- **Enhancement expenditure**, which is lumpy and company specific and may differ to past enhancements. We continue to disagree on trying to benchmark enhancements
- **Growth and network reinforcement**, which is company and site specific (a cost adjustment claim could be a more appropriate method to assess and funded this type of expenditure)
- **Expenditure for new or increased obligations**, for example additional or increased base opex, capital maintenance or enhancement opex, where this is not reflected in historical data
- **Expenditure that is unique to one or a few companies,** i.e. cost adjustments

There are other relevant tools that are more fit for the purpose of assessing the above expenditures, such as deep dives and bottom-up assessment, that can help assess efficient costs in these areas instead of benchmarking.

What does a good model look like?

Model robustness and model quality are key considerations when assessing and selecting models, including:

- Engineering and rationale for cost drivers and model specification, and consistency of results to operational insight
- Goodness of fit between the data and the model
- Statistical significance of cost drivers and predicted costs (estimation results) and stability of these to sensitivities in the data set
- Results from diagnostic tests
- Quality and consistency of model input data, over time and between companies
- Potential implications for water companies' incentives

We have been working with Reckon LLP to develop more enhanced techniques to inform the assessment and selection of models, which we briefly introduce below. This has been initially applied to help our assessment and selection of retail models submitted to this consultation, however the tools developed can be equally useful and applicable to wholesale models.

Tailored measure of goodness of fit

The main measure of goodness of fit Ofwat used at PR19 was R-squared. R-squared, whilst a reasonable measure of goodness of fit, is not directly comparable across models with different dependent variables. For example, R2 metrics on an aggregate model such as total retail cost models and on a disaggregate model such as bad debt are not comparable because the dependent cost variable is not the same. Reckon have developed a measure which enables direct comparison across models where the dependent variable is different.

Robustness of predicted costs

In regulatory applications of econometric benchmarking models there has been a focus on precision of the estimated coefficients, but little focus on precious of the predicted cost values, i.e. precision of the model. As the primary purpose of these models is to provide a view of efficient historical costs this seems an area for greater focus.

By running the same model(s) on different variations of the dataset (e.g. dropping individual years and companies), Reckon have developed a metric that measures the statistical variance in the predicted costs from the model estimation process, on a normalised basis across companies and years.

We would like to further engage with you on these metrics.

Wholesale

Scope of wholesale base cost models

From a starting point of the PR19 scope of wholesale modelled base costs, we consider the following adjustments are justified. We discuss each in turn.

1. Exclude all capital enhancement expenditure
2. Include all enhancement operating expenditure
3. Exclude growth and network reinforcement

Enhancement expenditure

<u>We have excluded all capital enhancement expenditure from our submitted models</u>

The models we propose exclude all capital enhancement expenditure as reported in APR.

Enhancement expenditure can be company, timing and site-specific and historical costs are not always a good indicator of future costs (e.g. due to diminishing returns) and therefore benchmarking, whether included in a base cost econometric model or otherwise benchmarked is not like-for-like.

<u>There are better ways of assessing capital enhancement expenditure</u>

Shallow and deep dives using company-specific data on the proposed enhancements may be more appropriate methods of assessment to account for the company and timing-specific circumstances in which they are proposed (e.g. multiple drivers of investment, site-specific needs etc.), which are often ‘lost in the noise’ of econometric / benchmarking models but can have a fundamental bearing on efficient costs of delivery.

We envisage most of the large enhancements for PR24 will be on the wastewater network. This is also where benchmarking is constrained further by the number of company observations, making shallow/deep dives potentially more practical alternative methods of assessment.

In addition, shallow/deep dives provide greater opportunity to assess the impact of enhancements on future ongoing running and capital maintenance requirements. It is not initially clear if and how this could be understood from econometrics.

Left unaddressed, there is still 'hidden capital enhancement' expenditure in base models

Across the industry, there were unfunded capital enhancement obligations which have been booked to base expenditure to ensure compliance with the RAGs. We disagree with how Ofwat have funded this in the past and we will continue to argue this is enhancement (even if hidden in base). We consider there to be a significant proportion of 'hidden capital enhancement' in base reporting.

The existence of 'hidden capital enhancement' expenditure in the base cost models without relevant cost drivers of this expenditure, risks this expenditure being treated as inefficiency which could cause under-funding of base allowances. We recommend a series of company-level adjustments to resolve this.

What then do the true base cost models actually buy?

True base cost models (with no explicit or hidden capital enhancements) is that which funds the maintenance of current performance. If differences in performance across companies are not accounted for in base models as a driver of costs, those companies that spend more from base to deliver a higher level of service will be considered less efficient (all else being equal). Absent a cost driver for service, companies are in effect funded for a level of service consistent with average service over the historical time series of the model.

This suggests:

- The potential for significant past underfunding and therefore the potential for continued significant underfunding if a simple roll-forward of historical costs is used to set future allowances. That is to say these models self-perpetuate the cycle of underfunding. This underfunding is heightened where companies are targeted or commit to do more in the future than in the past. Ideally, Ofwat need a mechanism that 'resets' base expenditure with reference to the new prevailing level of 'current service', for example that achieved in the previous AMP
- A strong case for symmetrical cost adjustments for performance where companies have over/under performed compared to the average historically to recognise modelling limitations

Enhancement operating expenditure

It is important that cost assessment sufficiently accounts for the additional opex and capital maintenance requirements that arises over time due to enhancements previously implemented, as these will not be recognised in a simple roll-forward of historical expenditure in the base totex models.

"Enhancement operating expenditure can be classified as: expenditure incurred in the creation and running of new capital assets; and expenditure on operating solutions instead of (or alongside) capital solutions to deliver service enhancements." (RAG 4.10)

Whilst we support Ofwat's decision in the final methodology to include enhancement opex to modelled base costs, we do not think their position goes far enough in two key ways:

Ofwat propose to include a subset of enhancement opex lines

We think all enhancement opex should be included in the base cost models, as this recognises the new opex associated with a growing asset base and increasing obligations, commitments and service levels. In addition, including a subset of lines only will further muddy the boundary of what is / isn't included in the base models over time (see above) and stifle future regulatory change in the scope of enhancement opex.

Ofwat's published Stata code includes 2 years of enhancement opex

Whilst we recognise enhancement opex has only been collected in the APR for 2 years, including 2 years of data in models which are regressed over up to 11 years will only ever fund a minor portion of this. By its nature, e.g. of supporting the creating and running of new assets, enhancement opex will increase over time. Using backward looking econometric models will not fund the requirements going forward. Ofwat further need to consider this with regard to how to translate what is a backward looking view of efficient expenditure into forward looking allowances, including with regard to enhancement opex.

Therefore, whilst Ofwat's final methodology position is a step in the right direction we think it is appropriate to include all enhancement in the base models. We recognise data limitations in distinguishing what may have been 'pre-existing base expenditure' from that attributable to past implemented enhancements and therefore, to support consistency of benchmarking, recommend using a shortened time period (by the final determination data for 19/20 to 23/24 should be available) and ask companies to provide 1 year back-stated view of enhancement opex for 19/20.

We note that Ofwat have not included in the published master data sets the enhancement opex lines except for those they propose including in the Final Methodology. This appears pre-emptive and may well mean companies do not include enhancement opex in their submitted models to this consultation due to the non-inclusion of these lines in the published dataset. We recommend Ofwat publish this data.

Our submitted models include the few enhancement opex lines Ofwat did publish, however our intention is that the dependent cost variable includes all enhancement opex. We emphasis this in our submitted templates.

Growth and network reinforcement

Providing sufficient and efficient allowances for growth is important to ensure sustainability of our services and performance levels to new customers without detriment to existing customers.

Ofwat sets out in the final methodology, "for the spring 2023 modelling consultation, we intend to exclude site-specific developer services and growth at wastewater treatment works costs from the scope of modelled base costs. But include network reinforcement and reducing risk of sewer flooding enhancement expenditure. We will reassess these assumptions at draft determinations." We agree with the need to reassess the assumptions on including network reinforcement and reducing risk of sewer flooding, but do not think this need wait until draft determinations.

We agree with the exclusion of site-specific developer services and growth at wastewater treatment works costs, as these are company and site-specific, future requirements are not likely reflective of past requirements and neither are the costs incurred, especially for wastewater treatment works, routine over time. Our submitted models exclude site-specific developer services and growth at wastewater treatment works costs, which is consistent with how the dependent cost variable was defined at PR19.

We recognise Ofwat's assumption to include network reinforcement and reducing risk of sewer flooding enhancement expenditure as one of the recommendations made by Arup for each of these cost areas respectively.

Network reinforcement as strategic growth-related expenditure must be assessed in the context of the company's network configuration and capacity at a local level taking account of inter-related drivers of expenditure; none of which readily lends itself to sector level quantitative benchmarking as part of base cost assessment models. The same is true for growth at sewerage treatment works. We have therefore excluded network reinforcement and growth at sewerage treatment works from our submitted models, as these elements of cost do not support benchmarking on a like-for-like basis.

We recall that Arup's conclusion for including sewer flooding costs in the base models is because the costs of these activities are driven by a similar set of cost drivers used in the (PR19) base models. Firstly, the specification of these models may differ at PR24. Second, a distinction needs to be made as to what is modellable and what the purpose of the expenditure is. This relates back to the question of what base buys and what expenditure is required to maintain existing service levels (see above). Expenditure to reduce the risk of sewer flooding to properties improves service performance and therefore is not true base, by definition. Just because there is similarity in the drivers between the PR19 base models and ARUP's causal analysis of what drives expenditure on sewer flooding, does not preclude it should all be in a single model. Also, if the drivers are the same it should be possible to estimate a separate model for growth costs. It is also important to note, that companies will have invested different amounts historically and therefore any interpretation of the allowances needs to reflect and acknowledge this.

This provides further justification to exclude reducing risk of sewer flooding from the base models, in addition to this also being an enhancement (see above).

Data sources

We have used the Ofwat wholesale water and wastewater published datasets.

As set out above, the water dataset does not include enhancement opex and the waste dataset only includes only a subset of enhancement opex. Given this resource limitation, our models do not include the full set of enhancement opex but the inclusion if the full set of these costs is recommended.

Time series of the modelled relationship between costs and cost drivers

Our submitted models use a short, backward-looking time series 16/17 to date (6 years) to inform the historical relationship between costs and cost drivers.

For PR24 modelling we recommend Ofwat use 19/20 to 23/24 (5 years). This is because:

- Breadth of the panel data set, i.e., number of companies, is far more of a constraining factor that length. We are supportive of a shorter, more consistent time series data set.

- It will be the most recent past data. The further back you look, the less relevant and definitionally comparable the past is to the future. We would not say 2011/12 is comparable to 2029/30.
- It will remove the need to rely on backcast data or data re-stated to align with new assumptions which is likely to be less accurate
- Reflecting dynamic changes in the sector some variables drop in or out of significance over time or become more or less significant[1].

Our views here reflect those previously provided in our base cost consultation response and also Draft methodology response[2], although we note we are not explicitly listed as a company that supports this in the final methodology, however we most certainly are!

Level of model aggregation

In addition to the level of model aggregations used at PR19, Ofwat should also consider aggregate WWW models as we think these are an important a cross check on the cost allocation changes / improvements being made in bioresources and wastewater. We have not found a model that performs well at the aggregate level for inclusion in this submission.

We do not think network plus models are worth pursuing given the trade offs involved, for example between water resources and treatment.

Wholesale Water Cost drivers

Summary

Overall, we have found that the PR19 WRP models continue to work well (with short time period and changes to the dependent variable as specified above) and we have therefore submitted the PR19 model specifications for the consultation.

We find the inclusion of year dummy variables and a time trend for the TWD and WW models intuitive and economically helpful in the models. We find that the statistical significance of boosters per length of mains in the TWD models becomes less significant compared to PR19, but do find that the average capacity of boosters is helpful in our submitted TWD models (but weren't helpful in the WWW models we tested) as a driver of asset running and maintenance costs.

Dynamics (time trends and year dummies)

There are a number of 'within model' dynamic factors to consider when developing a backward-looking cost model, for examples changes in significance of variables over time, persistent effects and year-specific effects.

We have sought to capture some of these dynamic effects in the backward-looking models via time trends and dummy variables. We have included year dummy variables to pick-up any year specific effects, e.g. COVID related impacts. We have included the time trends to pick-up any long-term trends, such as productivity and performance improvements and / or a persistent underlying increase in input prices.

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[1] For example, when we re-run the water models, we find that booster pumping stations become insignificant in the WW models (in more recent time period). As does ammonia less than 3mgl in sewerage treatment and bioresources plus models.

[2] Wessex Water Appendix 9 commentary, section 1.4

Specifically, we have separately tested the inclusion of a time trend, year dummy variables for 19/20, 20/21 and 21/22, and both time trend and the three dummy variables on a range of different model specifications, including the PR19 models.

In summary we find for TWD, WNP and WW the inclusion of both a time trend and two year dummies for 20/21 and 21/22 are statistically significant. For WRP models we find that dynamic effects appear less relevant.

We have found the coefficient on the time trend in the water models to be positive, implying that over time there are other effects having a net positive impact on costs.

We find that the year dummy variables included for 20/21 and 21/22 are negative, which is consistent with expectations of a slowdown in capital expenditure seen in those years due to reductions in planned work, e.g. due to the 2metre rule associated with reducing the spread of COVID-19.

The inclusion of time trends and year dummy variables feature heavily in the models we have submitted for this consultation.

We strongly recommend Ofwat test the inclusion of a year dummy variable for 22/23 when the data becomes available to test for the heightened input price pressures, e.g. energy, materials etc. as result of global economic and political pressures affecting supply chains.

Density

Building on gains made at PR19, we support continued combined use of WAD and WAD2 measures in the water models to capture the non-linear relationship between density and cost.

Booster pumping stations and average pumping head (APH)

In our re-running of the PR19 models with the dependent variable and sample period as defined above, we find booster pumping stations per length of mains becomes statistically insignificant in WW models and the significance of the variable becomes less significant in the TWD models. We do not find that average pumping head performs any better as an alternative. Therefore, we do not think either variable should be considered for inclusion in the PR24 models.

We find average capacity of booster pumping stations to be a good driver of TWD costs and is included in one of our submitted TWD model(s), although this appears less relevant when tested at a wholesale water level which also makes sense (we would not expect it to be a relevant driver of water resource or treatment costs).

Regional labour differences

We do not consider regional labour differences to be a material driver of differences in cost between companies, this is supported by its poor performance across a range of models as evidenced at PR19, and have not sought to re-open that debate.

Water Treatment Complexity

Reflecting on the PR19 model specifications, we continue to find that the proportion of water treated at works with complexity 3 to 6 and the weighted average treatment complexity variable continue to perform well.

We have tested alternative variables to capture the type of raw water source, for example the share of surface water sourced, share of water from reservoirs, share of water from rivers and found these to either not be statistically significant or have a sign counter to intuition. We have similarly tested the share of water being received at surface water treatment works and again reached a similar conclusion.

Wholesale Wastewater Cost drivers

Summary

We find re-running the PR19 SWC collection models (with the above amends to the dependent variable and time period) work well. We agree with the addition of the squared term by the CMA to the PR19_SWC2 model and we have submitted this sewage collection model to the consultation.

We find on re-running the PR19 models for SWT and bioresources plus that variables capturing economies of scale, complexity and consent drivers, are not significant. We find that population equivalent is an intuitive and statistically significant scale driver of both SWT and BRP costs, however of the variables we have tested we have typically struggled to find anything else significant (economies at works, consents and complexity drivers of those we have tested (reference). Our submitted models in these areas are therefore quite simple (PE as a driver of treatment costs, and PE and pctbands6 as drivers of BRP costs), although we would welcome ideas on additional drivers as part of the consultation.

For bioresources, we have proposed two additional models. These include the pctbands6 variable as a means of capturing economies of scale at treatment works, which is a material driver of costs.

We have not submitted a network plus models given the trade-offs that exist between sewerage treatment and bioresources.

Scale drivers

The PR19 models used the variable total load as a scale driver for sewage treatment and bioresources plus models. We note in the more recently published Stata code, the variable referred to as load is actually looking up the amount of load receiving phosphorus[3]. We have amended the Stata code we have submitted with our submission such that the load variable is looking up total load received (ID: STWD128_21), not total load receiving phosphorus (ID: STWDP125_21).

Our submitted models include **population equivalent (pe)** as a variable we find both intuitive and statistically significant driver of costs sewage treatment and bioresources plus models and removes the additional assumption and potential inconsistency around converting pe to load.

Density

For the weighted average measure of density, at PR19 Ofwat used both the WAD and WAD squared-term in the water models, but only the linear WAD term in the waste models.

We agree with the addition of the squared term by the CMA to the PR19_SWC2 model and we have submitted this sewage collection model to the consultation.

We do not find that the joint co-existence of the WAD and WAD squared-terms is as statistically significant in the waste models compared to water and this might be because some of the effect on

[3] As load is also used as the denominator of the constructed variables, the following variables were also impacted: % of load with ammonia consent below 3mg, % of load treated at bands 1-3, % of load treated at bands 6.

cost is being picked up by variables which capture the economies of scale at treatment works, such as the percentage of load treated in STWs band 6.

Economies of scale at treatment works

We find the % of load treated at bands 6 to be a relevant driver of economies of scale at treatment works in the bioresources and also the bioresources plus models submitted.

Complexity at treatment works

We have not found much support for complexity and consent variables, despite the engineering and operational logic of including these variables. We have identified this as an area for further investigation.

Dynamics (time trends and year dummies)

In comparison to our submitted wholesale water models, year time dummies and time trends appear less relevant for wholesale waste models.

Residential Retail

Data sources

We have used the Ofwat residential retail published dataset.

We also include in our submission a dataset of the values we use for the variable 'squared income deprivation score unadjusted' in the bad debt models. This variable is derived from the ONS income deprivation score. We provide more detail on the metric further below.

We have made an adjustment to the revenue figures for South West Water, to acknowledge the £50/customer government contribution made to South West Water customers which we understand is not captured in APR reported data, and thus in the revenue data published in the residential retail cost assessment dataset. Given the merger between South West Water and Bournemouth, this adjustment has taken the form of:

- For SWT we deducted £50 per customer.
- For SWB, (i) for each of the years from 2013/14 to 2015/16, we deducted (£50 *Number of SWT customers); (ii) for each of the years from 2016/17, we deducted (£50* Number of SWB customers* *ratio*), where *ratio* is the average of the ratio of SWT customers to the sum of SWT and BWH customers in the years from 2013/14 to 2015/16.

This adjustment to the revenue figures, impacts the dependent variable for three of our bad debt models where the dependent variable is defined as the ratio between real bad debt costs and total billed revenue; and also on the independent variable revenue per household (equivalently average bill) which is used as a driver of bad debt costs in the bad debt models where the dependent variable is specified as bad debt per household.

Time series of the modelled relationship between costs and cost drivers

Our submitted models use a time series 13/14 to date (9 years) to inform the historical relationship between costs and cost drivers. We consider there to be less change in retail functions and greater stability compared to wholesale, such that a longer time period does not appear inappropriate.

Level of model aggregation

Our submitted models are disaggregated only, at the level of bad debt and other residential retail costs. Drawing upon the enhanced techniques of assessing and selecting models introduced above, we have not included any total residential retail costs because the aggregate models we tried did not perform as well. Variables that were intuitive and worked well in the disaggregate models did not appear relevant or had lower t-ratios on the coefficients when included in the aggregate models.

Given our finding we are pleased to see Ofwat is more open to disaggregate retail models for PR24 in the final methodology[4] compared to the draft methodology[5].

Scope of retail base costs

We submit two sets of models for bad debt related costs. One set has a dependent variable defined as real bad debt related costs per household and other set as the ratio of real bad debt related costs to total billed revenue[6].

Ofwat used a per household dependent variable at PR19. We see there is merit in considering both specifications of the dependent variable. We consider the second specification worth exploration because household retail revenue seems an appropriate scale variable of bad debt costs and thus an appropriate normaliser, as alternative to the number of households. We think this is intuitive because typically the level of bad debt provisions (as a component of bad debt related costs) made by companies is related to the amount of retail revenue at risk. In addition, with regard to debt management costs (the other component of bad debt related costs) it makes sense that the costs of these activities are also driven by the size of revenue at risk.

In the real bad debt related cost models we use the measure of "smoothed" doubtful debt.

For other retail costs, the dependent variable is defined as and real other retail costs per household.

We note in Ofwat's PR19 models, all depreciation and recharges are allocated to the 'other retail costs' which may not technically be true (as some of this may relate to bad debt costs). However, for the purpose of this submission and a proportion approach to the submission, we retain Ofwat's PR19 allocation, although suggest it may be worthwhile for Ofwat and companies to look into the allocation of deprecation and recharges.

At PR19, Ofwat smoothed depreciation. For this submission we have used outturn, not smoothed depreciation. We do not consider the smoothing of depreciation necessary. This is because the core purpose of depreciation, as an accounting concept, is to smooth expenditure which is incurred at a single point in time over the duration of time benefits from the expenditure are realised.

Cost drivers

Relevant explanatory variables are similarly to the dependent variable, are expressed in real terms.

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[4] Final Methodology (Ofwat) Appendix 9 – Setting Expenditure Allowances, p10
[5] Draft Methodology (Ofwat) Appendix 9 – Setting Expenditure Allowances, p14
[6] See adjustment made to SWEST revenue data in section 'Residential Retail – Data Sources'

Dynamics (time trends and year dummies)

Similar to the wholesale models, we have separately tested the inclusion of a time trend, year dummy variables for 19/20, 20/21 and 21/22, year dummy variables for the full time period, and both time trend and year dummy variables for 19/20, 20/21 and 21/22 on a range of different model specifications.

Our submitted bad debt models have both a time trend and year dummy variables for 19/20, 20/21 and 21/22. We note, that whilst we tested the three dummy year variables in the wholesale models, we only found 20/21 and 21/22 to be significant. Whilst we recognise COVID impacted one week of 19/20 and this therefore had limited impact on our wholesale operations, we do consider the inclusion of 19/20 dummy year variable in the bad debt models both intuitive and statistically significant because of the action by auditors which necessitated a drastic increase in the provision of bad debt, despite there being limited operational cost impact on retail in 19/20.

Our submitted other retail cost models include either a time trend or year dummy variables for each year of the sample period. Whilst we did not find the same level of support for year specific dummies for 19/20, 20/21 and 21/22 as with the bad debt models, we found controlling for dynamics as per our submitted models, better than models which include only a constant term, as per those used at PR19.

We note a positive coefficient on the year dummy variables included in the retail models and a negative coefficient on the time trend. We note that this is the opposite to observations made for wholesale, although we consider these observations consistent with business insight of the retail function. The negative time trend suggests over time there are other effects having a reducing impact on cost. This negative time trend in real panel data set, could highlight the frontier efficiencies that are apparent in the historical data. The positive year dummy variables, in particular for the covid years, are no doubt picking up the increased bad debt provision and other retail costs associated with supporting customers. We would recommend Ofwat test the inclusion of dummy year variables for 22/23 when the data is available to capture any cost of living crisis related costs.

Deprivation and credit risk (bad debt)

Our submitted bad debt models rely on one of the following three variables that capture deprivation and credit risk:

- *Credit risk score (Equifax variable RGC102)* – of the Equifax variables we have found RGC102 to be both the most intuitive and statistically significant. Whilst it is not the Equifax variable used by Ofwat at PR19, this variable was discussed as part of previous PR19 work by United Utilities.
- *Income deprivation score unadjusted (ONS)*
- *Squared income deprivation score unadjusted (using above ONS source data)* – we found there to be reasonable intuition and statistical basis for a squared term of the income deprivation measure to capture the non-linear relationship between deprivation and bad debt costs. For example, a company with an LSOA of 40% deprivation and another of 60% deprivation, is likely to have a higher risk of default compared to a company with two LSOA areas of 50% deprivation. In aggregating LSOA data to a company level, we have therefore used a square term to give more weight to areas of higher deprivation within a company's area.

Whilst we did look into the possibility of models that combine both the Equifax and ONS variables, these weren't successful.

Customer transience (bad debt)

We found the customer transience variables used in the PR19 bad debt models no longer work well.

Revenue per household (bad debt)

Revenue per household[7], equivalently average bill makes sense as a driver of bad debt related costs for cost models where the dependent variable is per household, and it performs well in our submitted bad debt models. As with the dependent variable, this is expressed as a CPIH adjusted measure.

Approach and Assumptions

Interpretation and application of RAG sensitivities

We support the inclusion of model sensitivity testing to the removal of the most and least efficient company and the removal of the first and last year of sample period as part of the model assessment process and the Ofwat template. Models should be robust to such changes in the dataset. We have set a high bar for how we have interpreted the results of these sensitivities.

For the purposes of deriving the RAG rating of models, we have made the following assumptions:

We have excluded the estimated coefficients on the year-specific dummy variables within the set of coefficients. This is because, in particular with regard to the other retail cost models which include year dummy variables for the full sample period, we do not have a priori view on the sign of those dummy variables for all, or most, years. In addition, analysis of changes in their statistical significance would be complex to disentangle: it would be necessary to go beyond inspection of the Stata output from the regressions as the results will depend on which of the year is taken as a reference year in the regression.

In terms of changes in statistical significance of coefficients, we 'marked-down' changes of coefficients being significant when: (i) they are significant at the 5% (or lower) level when estimated on the full dataset, and become significant at the 10% or higher level under the dataset variation; OR (ii) they are significant at the 10% level in the full dataset, and become significant at a higher level in a variant of the dataset. An implication of this is that we did not mark-down a model where one or more coefficient changes from being significant at the 1% to being significant at the 5% level.

Following from the above, we also did not penalise improvements in the statistical significance of models when going from using a full dataset to using a variant of the dataset.

[7] See adjustment made to SWEST revenue data in section 'Residential Retail – Data Sources'

Template for submission of econometric models for consultation

Econometric model formula:

Please see also our cover note to this submission.

Water Resource Plus (WRP) Models

WSXWRP1
ln(real WRP botex excluding enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(properties) + B2*pctwatertreated36 + B3 ln(WAD_LAD) + B4 ln(WAD_LAD2) + e

WSXWRP2
ln(real WRP botex excluding enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(properties) + B2 ln(wac) + B3 ln(WAD_LAD) + B4 ln(WAD_LAD2) + e

Treated Water Distribution (TWD) Models

WSXTWD1
ln(real TWD botex excluding capital enhancement, growth, network reinforcement and including enhancement opex) = α + β1 ln(lengthsofmain) + B3 ln(WAD_LAD) + B4 ln(WAD_LAD2) + B5*timetrend + B6*dummyyear10 + B7*dummyyear11 + e

WSXTWD2
ln(real TWD botex excluding capital enhancement, growth, network reinforcement and including enhancement opex) = α + β1 ln(lengthsofmain) + B3 ln(WAD_LAD) + B4 ln(WAD_LAD2) + B5*timetrend + B6*dummyyear10 + B7*dummyyear11 B8 ln(avcapboosters) + e

Wholesale Wastewater (WW) Models

WSXWW1
ln(real WW botex excluding capital enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(properties) + B2*pctwatertreated36 + B3 ln(WAD_LAD) + B4 ln(WAD_LAD2) + B5*timetrend + B6*dummyyear10 + B7*dummyyear11 + e

WSXWW2
ln(real WW botex excluding capital enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(properties) + B2 ln(wac) + B3 ln(WAD_LAD) + B4 ln(WAD_LAD2) + B5*timetrend + B6*dummyyear10 + B7*dummyyear11 + e

WSXWW3
ln(real WW botex excluding capital enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(lengthsofmain) + B2 ln(wac) + B3 ln(WAD_LAD) + B4 ln(WAD_LAD2) + B5*timetrend + B6*dummyyear10 + B7*dummyyear11 + e

Please see below for further information on the dependent variable.

Description of the dependent variable

The dependent variable is defined as the natural logarithm of costs for the respective area of the value chain (WRP, TWD, WW), in CPIH-adjusted real terms (2017/18 reference price level).

Taking the PR19 scope of the dependent as a starting point we have made a series of adjustments to the costs defined and also recommend other further adjustments be made by Ofwat. In summary:

We take the PR19 dependent variable and:

- Exclude capital enhancement expenditure
- Include enhancement operating expenditure
- Exclude growth and network reinforcement

We discuss each in turn, although further information is provided in our cover note to this submission).

Exclude enhancement expenditure

The models we propose exclude all capital enhancement expenditure as reported in APR.

Enhancement expenditure can be company, timing and site-specific and historical costs are not always a good indicator of future costs (e.g. due to diminishing returns) and therefore benchmarking, whether included in a base cost econometric model or otherwise benchmarked is not like-for-like.

We discuss in our cover note that there are better ways assessing capital enhancement expenditure and the existence of 'hidden capital enhancement expenditure' in the base cost models.

Include enhancement operating expenditure

It is important that cost assessment sufficiently accounts for the additional opex and capital maintenance requirements that arises over time due to enhancements previously implemented, as these will not be recognised in a simple roll-forward of historical expenditure in the base totex models.

Whilst we support Ofwat's decision in the final methodology to include enhancement opex to modelled base costs, we do not think their position goes far enough in two key ways:

<u>Ofwat propose to include a subset of enhancement opex lines (none of which relate to water)</u>

We think all enhancement opex should be included in the base cost models, as this recognises the new opex associated with a growing asset base and increasing obligations, commitments and service levels.

<u>Ofwat's published Stata code (for waste) includes 2 years of enhancement opex, however given we support including all water enhancement opex in the base models, the following is conceptually relevant</u>

Whilst we recognise enhancement opex has only been collected in the APR for 2 years, including 2 years of data in models which are regressed over up to 11 years will only ever fund a minor portion of this. By its nature, e.g. of supporting the creating and running of new assets, enhancement opex will increase over time. Using backward looking econometric models will not fund the requirements going forward. Ofwat further need to consider this with regard to how to translate what is a backward looking view of efficient expenditure into forward looking allowances, including with regard to enhancement opex.

Therefore, whilst Ofwat's final methodology position is a step in the right direction we think it is appropriate to include all enhancement in the base models. We recognise data limitations in distinguishing what may have been 'pre-existing base expenditure' from that attributable to past implemented enhancements and therefore, to support consistency of benchmarking, recommend using a shortened time period (by the final determination data for 19/20 to 23/24 should be available) and ask companies to provide 1 year back-stated view of enhancement opex for 19/20.

We note that Ofwat have not included in the published master data sets the enhancement opex lines except for those they propose including in the Final Methodology (for a subset of waste costs only). This appears pre-emptive and may well mean companies do not include enhancement opex in their submitted models to this consultation due to the non-inclusion of these lines in the published dataset. We recommend Ofwat publish this data.

Our submitted models for water at this time do not include any enhancement opex, however our intention is that the dependent cost variable includes all enhancement opex.

Exclude growth and network reinforcement

Providing sufficient and efficient allowances for growth is important to ensure sustainability of our services and performance levels to new customers without detriment to existing customers.

Ofwat sets out in the final methodology, "for the spring 2023 modelling consultation, we intend to exclude site-specific developer services and growth at wastewater treatment works costs from the scope of modelled base costs. But include network reinforcement and reducing risk of sewer flooding enhancement expenditure. We will reassess these assumptions at draft determinations." We agree with the need to reassess the assumptions on including network reinforcement but do not think this need wait until draft determinations.

We agree with the exclusion of site-specific developer services, as these are company and site-specific, future requirements are not likely reflective of past requirements and neither are the costs incurred, especially for wastewater treatment works, routine over time. Our submitted models exclude site-specific developer services, which is consistent with how the dependent cost variable was defined at PR19.

We recognise Ofwat's assumption to include network reinforcement as one of the recommendations made by Arup.

Network reinforcement as strategic growth-related expenditure must be assessed in the context of the company's network configuration and capacity at a local level taking account of inter-related drivers of expenditure; none of which readily lends itself to sector level quantitative benchmarking as part of base cost assessment models. We have therefore excluded network reinforcement from our submitted models, as these elements of cost do not support benchmarking on a like-for-like basis.

Description of the explanatory variables

All explanatory variables are sourced or constructed from published wholesale dataset:

- Total properties (code: properties)
- % proportion of water treated in water treatment works with complexity levels 3-6 (code: pctwatertreated36)
- Length of mains (code: lengthsofmain)
- Density (code: WAD_LAD)
- Density squared (code: WAD_LAD2)
- Weighted average level of treatment complexity (code: wac)
- Time trend (code: timetrend)
- Year dummy variables for 20/21 and 21/22 (code: dummyyear10, dummyyear11)
- Average capacity of booster pumping stations (code: avcapboosters)

Dynamics (time trends and year dummies)

There are a number of 'within model' dynamic factors to consider when developing a backward-looking cost model, for examples changes in significance of variables over time, persistent effects and year-specific effects.

We have sought to capture some of these dynamic effects in the backward-looking models via time trends and dummy variables. We have included year dummy variables to pick-up any year specific effects, e.g. COVID related impacts. We have included the time trends to pick-up any long-term trends, such as productivity and performance improvements and / or a persistent underlying increase in input prices.

Specifically, we have separately tested the inclusion of a time trend, year dummy variables for 19/20, 20/21 and 21/22, and both time trend and the three dummy variables on a range of different model specifications, including the PR19 models.

In summary we find for TWD, WNP and WW the inclusion of both a time trend and two year dummies for 20/21 and 21/22 are statistically significant. For WRP models we find that dynamic effects appear less relevant.

We have found the coefficient on the time trend in the water models to be positive, implying that over time there are other effects having a net positive impact on costs.

We find that the year dummy variables included for 20/21 and 21/22 are negative, which is consistent with expectations of a slowdown in capital expenditure seen in those years due to reductions in planned work, e.g. due to the 2metre rule associated with reducing the spread of COVID-19.

The inclusion of time trends and year dummy variables feature heavily in the models we have submitted for this consultation.

We strongly recommend Ofwat test the inclusion of a year dummy variable for 22/23 when the data becomes available to test for the heightened input price pressures, e.g. energy, materials etc. as result of global economic and political pressures affecting supply chains.

Density

Building on gains made at PR19, we support continued combined use of WAD and WAD2 measures in the water models to capture the non-linear relationship between density and cost.

Booster pumping stations and average pumping head (APH)

In our re-running of the PR19 models with the dependent variable and sample period as defined above, we find booster pumping stations per length of mains becomes statistically insignificant in WW models and the significance of the variable becomes less significant in the TWD models. We do not find that average pumping head performs any better as an alternative. Therefore, we do not think either variable should be considered for inclusion in the PR24 models.

We find average capacity of booster pumping stations to be a good driver of TWD costs and is included in one of our submitted TWD model(s), although this appears less relevant when tested at a wholesale water level which also makes sense (we would not expect it to be a relevant driver of water resource or treatment costs).

Regional labour differences

We do not consider regional labour differences to be a material driver of differences in cost between companies, this is supported by its poor performance across a range of models as evidenced at PR19, and have not sought to re-open that debate.

Water Treatment Complexity

Reflecting on the PR19 model specifications, we continue to find that the proportion of water treated at works with complexity 3 to 6 and the weighted average treatment complexity variable continue to perform well.

We have tested alternative variables to capture the type of raw water source, for example the share of surface water sourced, share of water from reservoirs, share of water from rivers and found these to either not be statistically significant or have a sign counter to intuition. We have similarly tested the share of water being received at surface water treatment works and again reached a similar conclusion.

Brief comment on the models

Please see also our cover note to this submission.

Time series

Our submitted models use a short, backward-looking time series 16/17 to date (6 years) to inform the historical relationship between costs and cost drivers.

For PR24 modelling we recommend Ofwat use 19/20 to 23/24 (5 years). This is because:

- Breadth of the panel data set, i.e., number of companies, is far more of a constraining factor that length. We are supportive of a shorter, more consistent time series data set.
- It will be the most recent past data. The further back you look, the less relevant and definitionally comparable the past is to the future. We would not say 2011/12 is comparable to 2029/30.
- It will remove the need to rely on backcast data or data re-stated to align with new assumptions which is likely to be less accurate
- Reflecting dynamic changes in the sector some variables drop in or out of significance over time or become more or less significant.

Commentary on models

Overall, we have found that the PR19 WRP models continue to work well (with short time period and changes to the dependent variable as specified above) and we have therefore submitted the PR19 model specifications for the consultation.

We find the inclusion of year dummy variables and a time trend for the TWD and WW models intuitive and economically helpful in the models. We find that the statistical significance of boosters per length of mains in the TWD models becomes less significant compared to PR19, but do find that the average capacity of boosters is helpful in our submitted TWD models (but weren't helpful in the WWW models we tested) as a driver of asset running and maintenance costs.

Interpretation and application of RAG sensitivities to removal of most and least efficient company and removal of first and last year of sample period

We support the inclusion of these sensitivities as part of the model assessment process. Models should be robust to such changes in the dataset. We have set a high bar for how we have interpreted the results of these sensitivities.

Guidance on how to complete the table below is included in section 4 of this document. The first column in the table has been filled in with an illustrative example. Numbers are fictional.

		WSXWRP1	WSXWRP2	WSXTWD1	WSXTWD2	WSXWW1	WSXWW2	WSXWW3
Dependent variable		lnrealbotexwrp	lnrealbotexwrp	lnrealbotextwd	lnrealbotextwd	lnrealbotexww	lnrealbotexww	lnrealbotexww
		real botex excluding capital enhancement, growth, network reinforcement and including enhancement opex						
Var. description	Var. code							
ln Number of connected properties	lnproperties	1.079***	1.062***			1.069***	1.059***	
		{0.000}	{0.000}			{0.000}	{0.000}	
% proportion of water treated in water treatment works with	pctwatertreated36	0.010***				0.006***		0.004**
		{0.001}				{0.001}		{0.035}
ln Weighted average population density based on LAD	lnWAD_LAD	-1.670***	-1.326**	-3.307***	-3.225***	-2.548***	-2.361***	-2.666***
		{0.010}	{0.028}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
ln Weighted average population density based on LAD squared	lnWAD_LAD2	0.104**	0.078**	0.251***	0.242***	0.172***	0.158***	0.202***
		{0.012}	{0.041}	{0.000}	{0.000}	{0.000}	{0.000}	{0.000}
ln Water treatment complexity index	lnwac		0.970*				0.680***	
			{0.060}				{0.007}	
Ln Lenghts of main	lnlengthsofmain			1.063***	1.049***			1.050***
				{0.000}	{0.000}			{0.000}
Time trend	timetrend			0.055***	0.047***	0.039***	0.036**	0.042***
				{0.000}	{0.005}	{0.005}	{0.012}	{0.002}
Dummy variable 2020/21	dummyyear10			-0.165***	-0.151***	-0.121***	-0.118***	-0.122***
				{0.001}	{0.004}	{0.006}	{0.006}	{0.005}
Dummy variable 2021/22	dummyyear11			-0.215***	-0.201**	-0.166***	-0.161***	-0.164***
				{0.005}	{0.011}	{0.007}	{0.009}	{0.008}
ln average capacity of booster pumping stations	lnavcapboosters				0.117***			
					{0.000}			
Constant	_cons	-5.227***	-6.792***	4.380***	3.858***	-1.416	-2.419**	2.775*
		{0.008}	{0.002}	{0.002}	{0.001}	{0.114}	{0.011}	{0.079}
Estimation_method		RE	RE	RE	RE	RE	RE	RE
N		102	102	102	102	102	102	102
Model robustness tests								
R_squared		0.914	0.901	0.967	0.973	0.976	0.975	0.972
RESET_P_value		0.422	0.281	0.292	0.386	0.459	0.345	0.41
VIF_statistic								
Pooling								
Normality								
Heteroskedasticity								
LM		0	0	0	0	0	0	0
Efficiency ratios								
Min		0.54	0.48	0.72	0.73	0.77	0.78	0.75
Max		1.98	1.91	1.33	1.26	1.41	1.38	1.42
Sensitivity of estimated coefficients to removal of most and least efficient company		G	A	G	G	A	A	A
Sensitivity of estimated coefficients to removal of first and last year of the sample		A	A	G	A	A	A	A

Efficiency scores distribution

	WSXWRP1	WSXWRP2	WSXTWD1	WSXTWD2	WSXWW1	WSXWW2	WSXWW3
AFW	0.78	0.77	1.18	1.17	0.96	0.94	1.00
ANH	0.76	0.69	1.01	0.96	0.92	0.86	0.89
BRL	1.08	1.00	1.33	1.26	1.18	1.11	1.18
HDD	0.88	0.92	0.99	1.02	1.00	1.01	0.86
NES	0.99	1.01	0.95	0.97	0.93	0.93	0.97
NWT	1.13	1.15	0.83	0.83	0.93	0.95	0.96
PRT	0.80	0.78	0.76	0.86	0.77	0.78	0.75
SES	1.57	1.69	0.97	0.97	1.20	1.26	1.13
SEW	0.94	0.93	1.10	1.04	0.97	0.97	1.05
SRN	1.98	1.91	1.05	1.08	1.41	1.38	1.42
SSC	0.54	0.48	1.13	1.05	0.88	0.83	0.88
SVE	1.02	1.09	0.99	1.00	0.99	1.04	0.98
SWB	1.07	1.08	0.72	0.73	0.94	0.95	0.78
TMS	1.02	1.01	1.05	1.01	1.02	1.00	1.05
WSH	1.01	0.98	1.18	1.24	1.14	1.11	1.04
WSX	1.39	1.33	0.94	0.95	1.12	1.13	1.13
YKY	0.95	1.00	1.22	1.22	1.01	1.05	1.13

Comments

- Please indicate the units of the explanatory variable, and whether it was expressed in logs.
- Use asterisks to denote significance level: *** (1%), ** (5%) and * (10%)
- P values should be based on cluster robust standard errors
- In the case of random effects please report Stata's output "R2 overall"
- Please use the following naming convention to assign a name to each model: company acronym, level of aggregation, model number (eg for Anglian Water's wholesale water model number 1: ANHWW1). Please refer to the table below for company acronyms and level of aggregation acronyms.

Company acronyms	Level of aggregation acronyms
Anglian Water: ANH Hafren Dyfrdwy: HDD Northumbrian Water: NES Southern Water: SRN Severn Trent England: SVE South West Water: SWB Thames Water: TMS United Utilities: UUW Dŵr Cymru: WSH Wessex Water: WSX Yorkshire Water: YKY Affinity Water: AFW Bristol Water: BRL Portsmouth Water: PRT SES Water: SES	**Wholesale water** Treated water distribution: TWD Water resources plus: WRP Water network plus: WWNP Wholesale water: WW **Wholesale wastewater** Sewage collection: SWC Sewage treatment: STW Bioresources: BR Wastewater network plus: WWWNP Bioresources plus: BRP **Residential retail** Bad debt related costs: RDC

South East Water: SEW South Staffs Water: SSC	Other costs: ROC Total costs: RTC

Template for submission of econometric models for consultation

Econometric model formula:

Please see also our cover note to this submission.

We find re-running the PR19 SWC collection models (with the above amends to the dependent variable and time period) work well. We agree with the addition of the squared term by the CMA to the PR19_SWC2 model and we have submitted this sewage collection model to the consultation.

Sewage Collection (SWC) Models

WSXSWC1
ln(real SWC botex excluding enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(sewerlength) +B2 ln(pumpingcapperlength) + B3 ln(WAD_LAD) + B4 ln(WAD_LAD2) + e

Sewage Treatment (STW) Models

WSXSTW1
ln(real TW botex excluding enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(PE) + e

Bioresources (BR) Models

WSXBR1
ln(real BR botex excluding enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(sludgeprod) +B2*pctbands6 + e

WSXBR2
ln(real BR botex excluding enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(sludgeprod) +B2*pctbands6 +B3 ln(sludge_re_BOD) + e

Bioresources Plus (BRP) Models

WSXBRP1
ln(real BRP botex excluding enhancement, growth, network reinforcement and including enhancement opex) = a + B1 ln(PE) +B2*pctbands6 + e

Please see below for further information on the dependent variable.

Description of the dependent variable

The dependent variable is defined as the natural logarithm of costs for the respective area of the value chain (SWC, STW, BR, BRP), in CPIH-adjusted real terms (2017/18 reference price level).

Taking the PR19 scope of the dependent as a starting point we have made a series of adjustments to the costs defined and also recommend other further adjustments be made by Ofwat. In summary:

We take the PR19 dependent variable and:

- Exclude capital enhancement expenditure
- Include enhancement operating expenditure
- Exclude growth and network reinforcement

We discuss each in turn, although further information is provided in our cover note to this submission).

Exclude enhancement expenditure

The models we propose exclude all capital enhancement expenditure as reported in APR.

Enhancement expenditure can be company, timing and site-specific and historical costs are not always a good indicator of future costs (e.g. due to diminishing returns) and therefore benchmarking, whether included in a base cost econometric model or otherwise benchmarked is not like-for-like.

We discuss in our cover note that there are better ways assessing capital enhancement expenditure and the existence of 'hidden capital enhancement expenditure' in the base cost models.

Include enhancement operating expenditure

It is important that cost assessment sufficiently accounts for the additional opex and capital maintenance requirements that arises over time due to enhancements previously implemented, as these will not be recognised in a simple roll-forward of historical expenditure in the base totex models.

Whilst we support Ofwat's decision in the final methodology to include enhancement opex to modelled base costs, we do not think their position goes far enough in two key ways:

<u>Ofwat propose to include a subset of waste enhancement opex lines only</u>

We think all enhancement opex should be included in the base cost models, as this recognises the new opex associated with a growing asset base and increasing obligations, commitments and service levels. In addition, including a subset of lines only will further muddy the boundary of what is / isn't included in the base models over time (see above) and stifle future regulatory change in the scope of enhancement opex.

Ofwat's published Stata code includes 2 years of enhancement opex

Whilst we recognise enhancement opex has only been collected in the APR for 2 years, including 2 years of data in models which are regressed over up to 11 years will only ever fund a minor portion of this. By its nature, e.g. of supporting the creating and running of new assets, enhancement opex will increase over time. Using backward looking econometric models will not fund the requirements going forward. Ofwat further need to consider this with regard to how to translate what is a backward looking view of efficient expenditure into forward looking allowances, including with regard to enhancement opex.

Therefore, whilst Ofwat's final methodology position is a step in the right direction we think it is appropriate to include all enhancement in the base models. We recognise data limitations in distinguishing what may have been 'pre-existing base expenditure' from that attributable to past implemented enhancements and therefore, to support consistency of benchmarking, recommend using a shortened time period (by the final determination data for 19/20 to 23/24 should be available) and ask companies to provide 1 year back-stated view of enhancement opex for 19/20.

We note that Ofwat have not included in the published master data sets the enhancement opex lines except for those they propose including in the Final Methodology. This appears pre-emptive and may well mean companies do not include enhancement opex in their submitted models to this consultation due to the non-inclusion of these lines in the published dataset. We recommend Ofwat publish this data.

Our submitted models include the few enhancement opex lines Ofwat did publish, however our intention is that the dependent cost variable includes all enhancement opex.

Exclude growth and network reinforcement

Providing sufficient and efficient allowances for growth is important to ensure sustainability of our services and performance levels to new customers without detriment to existing customers.

Ofwat sets out in the final methodology, "for the spring 2023 modelling consultation, we intend to exclude site-specific developer services and growth at wastewater treatment works costs from the scope of modelled base costs. But include network reinforcement and reducing risk of sewer flooding enhancement expenditure. We will reassess these assumptions at draft determinations." We agree with the need to reassess the assumptions on including network reinforcement and reducing risk of sewer flooding, but do not think this need wait until draft determinations.

We agree with the exclusion of site-specific developer services and growth at wastewater treatment works costs, as these are company and site-specific, future requirements are not likely reflective of past requirements and neither are the costs incurred, especially for wastewater treatment works, routine over time. Our submitted models exclude site-specific developer services and growth at wastewater treatment works costs, which is consistent with how the dependent cost variable was defined at PR19.

We recognise Ofwat's assumption to include network reinforcement and reducing risk of sewer flooding enhancement expenditure as one of the recommendations made by Arup for each of these cost areas respectively.

Network reinforcement as strategic growth-related expenditure must be assessed in the context of the company's network configuration and capacity at a local level taking account of inter-related drivers of expenditure; none of which readily lends itself to sector level quantitative benchmarking as part of base cost assessment models. The same is true for growth at sewerage treatment works. We have therefore excluded network reinforcement and growth at sewerage treatment works from our submitted models, as these elements of cost do not support benchmarking on a like-for-like basis.

We recall that Arup's conclusion for including sewer flooding costs in the base models is because the costs of these activities are driven by a similar set of cost drivers used in the (PR19) base models. Firstly, the specification of these models may differ at PR24. Second, a distinction needs to be made as to what is modellable and what the purpose of the expenditure is. This relates back to the question of what base buys and what expenditure is required to maintain existing service levels (see above). Expenditure to reduce the risk of sewer flooding to properties improves service performance and therefore is not true base, by definition. Just because there is similarity in the drivers between the PR19 base models and ARUP's causal analysis of what drives expenditure on sewer flooding, does not preclude it should all be in a single model. Also, if the drivers are the same it should be possible to estimate a separate model for growth costs. It is also important to note, that companies will have invested different amounts historically and therefore any interpretation of the allowances needs to reflect and acknowledge this.

This provides further justification to exclude reducing risk of sewer flooding from the base models, in addition to this also being an enhancement (see above).

Description of the explanatory variables

All explanatory variables are sourced or constructed from published wholesale dataset:

- Length of sewer (code: sewerlength)
- Population Equivalent (code: PE)
- Pumping capacity/km of sewer (code: pumpingcapperlength)
- Sludge produced (code: sludgeprod)
- Percentage of load treated in STWs band 6 (code: pctbands6)
- Density (code: WAD_LAD)
- Density squared (code: WAD_LAD2)
- kg BOD5/day, Total load received by STWs - Secondary Activated Sludge (code: sludge_re_BOD)

Scale drivers

The PR19 models used the variable total load as a scale driver for sewage treatment and bioresources plus models. We note in the more recently published Stata code, the variable referred to as load is actually looking up the amount of load receiving phosphorus[1]. We have amended the Stata code we have submitted with our submission such that the load variable is looking up total load received (ID: STWD128_21), not total load receiving phosphorus (ID: STWDP125_21).

Our submitted models include **population equivalent (pe)** as a variable we find both intuitive and statistically significant driver of costs sewage treatment and bioresources plus models and removes the additional assumption and potential inconsistency around converting pe to load.

Density

For the weighted average measure of density, at PR19 Ofwat used both the WAD and WAD squared-term in the water models, but only the linear WAD term in the waste models.

[1] As load is also used as the denominator of the constructed variables, the following variables were also impacted: % of load with ammonia consent below 3mg, % of load treated at bands 1-3, % of load treated at bands 6.

We agree with the addition of the squared term by the CMA to the PR19_SWC2 model and we have submitted this sewage collection model to the consultation.

We do not find that the joint co-existence of the WAD and WAD squared-terms is as statistically significant in the waste models compared to water and this might be because some of the effect on cost is being picked up by variables which capture the economies of scale at treatment works, such as the percentage of load treated in STWs band 6.

Economies of scale at treatment works

We find the % of load treated at bands 6 to be a relevant driver of economies of scale at treatment works in the bioresources and also the bioresources plus models submitted.

Complexity at treatment works

We have not found much support for complexity and consent variables, despite the engineering and operational logic of including these variables. We have identified this as an area for further investigation.

Dynamics (time trends and year dummies)

In comparison to our submitted wholesale water models, year time dummies and time trends appear less relevant for wholesale waste models.

Brief comment on the models

Please see also our cover note to this submission.

Time series

Our submitted models use a short, backward-looking time series 16/17 to date (6 years) to inform the historical relationship between costs and cost drivers.

For PR24 modelling we recommend Ofwat use 19/20 to 23/24 (5 years). This is because:

- Breadth of the panel data set, i.e., number of companies, is far more of a constraining factor that length. We are supportive of a shorter, more consistent time series data set.
- It will be the most recent past data. The further back you look, the less relevant and definitionally comparable the past is to the future. We would not say 2011/12 is comparable to 2029/30.
- It will remove the need to rely on backcast data or data re-stated to align with new assumptions which is likely to be less accurate
- Reflecting dynamic changes in the sector some variables drop in or out of significance over time or become more or less significant.

Commentary on models

We find re-running the PR19 SWC collection models (with the above amends to the dependent variable and time period) work well. We agree with the addition of the squared term by the CMA to the PR19_SWC2 model and we have submitted this sewage collection model to the consultation.

We find on re-running the PR19 models for SWT and bioresources plus that variables capturing economies of scale, complexity and consent drivers, are not significant. We find that population equivalent is an intuitive and statistically significant scale driver of both SWT and BRP costs, however of the variables we have tested we have typically struggled to find anything else significant (economies at works, consents and complexity drivers of those we have tested (reference). Our submitted models in these areas are therefore quite simple (PE as a driver of treatment costs, and PE and pctbands6 as drivers of BRP costs), although we would welcome ideas on additional drivers as part of the consultation.

For bioresources, we have proposed two additional models. These include the pctbands6 variable as a means of capturing economies of scale at treatment works, which is a material driver of costs.

We have not submitted a network plus models given the trade-offs that exist between sewerage treatment and bioresources.

Interpretation and application of RAG sensitivities to removal of most and least efficient company and removal of first and last year of sample period

We support the inclusion of these sensitivities as part of the model assessment process. Models should be robust to such changes in the dataset. We have set a high bar for how we have interpreted the results of these sensitivities.

Guidance on how to complete the table below is included in section 4 of this document. The first column in the table has been filled in with an illustrative example. Numbers are fictional.

		WSXSWC1	WSXSTW1	WSXBR1	WSXBR2	WSXBRP1
Dependent variable		lnrealbotexswc	lnrealbotexswt	lnrealbotexbr	lnrealbotexbr	lnrealbotexbrp
Var. description	Var. code	real botex excluding capital enhancement, growth, network reinforcement and including enhancement opex				
Ln Length of sewer	lnsewerlength	0.851***				
		{0.000}				
Ln Pumping capacity/km of sewer	lnpumpingcapperlength	0.643***				
		{0.000}				
ln Weighted average population density based on LAD	lnWAD_LAD	-2.882***				
		{0.000}				
ln Weighted average population density based on LAD squared	lnWAD_LAD2	0.208***				
		{0.000}				
Ln Population Equivalent	lnPE		0.755***			0.908***
			{0.000}			{0.000}
Ln Sludge produced	lnsludgeprod			1.182***	0.977***	
				{0.000}	{0.000}	
Percentage of load treated in STWs band 6	pctbands6			-0.029***	-0.030***	-0.011*
				{0.001}	{0.000}	{0.080}
ln Total load received by STWs - Secondary Activated Sludge	lnsludge_re_BOD				0.195***	
					{0.003}	
Constant	_cons	5.081*	-1.626***	0.618*	-0.584	-1.741***
		{0.053}	{0.007}	{0.072}	{0.103}	{0.000}
Estimation_method		RE	RE	RE	RE	RE
N		60	60	60	60	60
Model robustness tests						
R_squared		0.901	0.868	0.813	0.857	0.898
RESET_P_value		0.054	0.001	0.538	0.133	0.072
VIF_statistic						
Pooling						
Normality						
Heteroskedasticity						
LM		0	0	0	0.139	0
Efficiency ratios						
Min		0.86	0.81	0.77	0.82	0.84
Max		1.32	1.32	1.58	1.32	1.23
Sensitivity of estimated coefficients to removal of most and least efficient company		G	G	G	G	A
Sensitivity of estimated coefficients to removal of first and last year of the sample		G	G	G	A	G

Efficiency scores distribution

	WSXSWC1	WSXSTW1	WSXBR1	WSXBR2	WSXBRP1
ANH	0.87	1.06	0.85	0.82	0.93
NES	1.09	0.81	0.77	0.91	0.84
NWT	1.02	1.11	0.98	1.01	1.07
SRN	1.02	1.32	0.92	0.86	1.23
SVH	0.97	0.89	0.88	1.15	0.89
SWB	0.94	1.11	0.94	1.04	1.06
TMS	1.01	0.94	1.08	0.96	0.98
WSH	1.03	1	1.58	1.32	1.07
WSX	0.86	0.85	0.99	0.94	0.84
YKY	1.32	1.07	1.29	1.15	1.17

Comments

- Please indicate the units of the explanatory variable, and whether it was expressed in logs.
- Use asterisks to denote significance level: *** (1%), ** (5%) and * (10%)
- P values should be based on cluster robust standard errors
- In the case of random effects please report Stata's output "R2 overall"
- Please use the following naming convention to assign a name to each model: company acronym, level of aggregation, model number (eg for Anglian Water's wholesale water model number 1: ANHWW1). Please refer to the table below for company acronyms and level of aggregation acronyms.

Company acronyms	Level of aggregation acronyms
Anglian Water: ANH Hafren Dyfrdwy: HDD Northumbrian Water: NES Southern Water: SRN Severn Trent England: SVE South West Water: SWB Thames Water: TMS United Utilities: UUW Dŵr Cymru: WSH Wessex Water: WSX Yorkshire Water: YKY Affinity Water: AFW Bristol Water: BRL Portsmouth Water: PRT SES Water: SES South East Water: SEW South Staffs Water: SSC	**Wholesale water** Treated water distribution: TWD Water resources plus: WRP Water network plus: WWNP Wholesale water: WW **Wholesale wastewater** Sewage collection: SWC Sewage treatment: STW Bioresources: BR Wastewater network plus: WWWNP Bioresources plus: BRP **Residential retail** Bad debt related costs: RDC Other costs: ROC Total costs: RTC

Template for submission of econometric models for consultation

Econometric model formula:

Please see also our cover note to this submission.

Our submitted models are disaggregated only, at the level of bad debt and other residential retail costs. Drawing upon techniques used to assess and select models in the cover note, we have not included any total residential retail costs because the aggregate models we tried did not perform as well. Variables that were intuitive and worked well in the disaggregate models did not appear relevant or had lower t-ratios on the coefficients when included in the aggregate models.

Given our finding we are pleased to see Ofwat is more open to disaggregate retail models for PR24 in the final methodology[1] compared to the draft methodology[2].

Models of bad debt related costs

We submit two sets of models for bad debt related costs. One set has a dependent variable defined as real bad debt related costs per household and other set as the ratio of real bad debt related costs to total billed revenue.

Ofwat used a per household dependent variable at PR19. We see there is merit in considering both specifications of the dependent variable. We consider the second specification worth exploration because household retail revenue seems an appropriate scale variable of bad debt costs and thus an appropriate normaliser, as alternative to the number of households. We think this is intuitive because typically the level of bad debt provisions (as a component of bad debt related costs) made by companies is related to the amount of retail revenue at risk. In addition, with regard to debt management costs (the other component of bad debt related costs) it makes sense that the costs of these activities are also driven by the size of revenue at risk.

The two sets of three models have a similar structure and include the same set of underlying cost drivers, the main difference being (in addition to the specification of the dependent variable), is that the models where the dependent variable is specified as the ratio of bad debt related costs to billed revenue do not include the variable lnreal_revAdj_hh.

Within each set of three models, the main difference is in respect of the choice of metric to control for variation in deprivations/arrears risk.

Model WSXRDC1
lnreal_DCsdebt_hh = a + B1* lnreal_revAdj_hh + B2*incomescore_unadjusted + B3*fye +B4*t2020 + B5* t2021 + B6* t2022 + εit

Model WSXRDC2:
lnreal_DCsdebt_hh = a+ B1*lnreal_revAdj_hh +B2*eq_rgc102 + B3* fye + B4*t2020 + B5*t2021 + B6*t2022 + εit

[1] Final Methodology (Ofwat) Appendix 9 – Setting Expenditure Allowances, p10
[2] Draft Methodology (Ofwat) Appendix 9 – Setting Expenditure Allowances, p14

Model WSXRDC3:
lnreal_DCsdebt_hh = a+ B1*lnreal_revAdj_hh +B2*SqIncomeIMD2019 + B3*fye + B4*t2020 + B5*t2021 + B6*t2022 + εit

Model WSXRDC4:
ratio_smbdtorev = a + B1*incomescore_unadjusted + B2*fye +B3*t2020 + B4* t2021 + B5* t2022 + εit

Model WSXRDC5:
ratio_smbdtorev = a + B1*eq_rgc102 + B2*fye + B3*t2020 + B4*t2021 + B5*t2022 + εit

Model WSXRDC6:
ratio_smbdtorev = a+ B1*SqIncomeIMD2019 + B2*fye + B3*t2020 + B4*t2021 + B5*t2022 + εit

We also include in our submission a dataset of the values we use for the variable 'squared income deprivation score unadjusted' in the bad debt models. This variable is derived from the ONS income deprivation score. We provide more detail on the metric further below.

Models of other retail costs

We present four models for other retail costs. The specification of the four models share some common elements but differ in respect of (i) the inclusion of an explanatory variable to control for scale, and in respect of (ii) the modelling of time-related effects. In particular:

- In all four models, the dependent variable is the logarithm of other retail costs per household in real terms, which was derived using the "smoothed" measure of bad debt costs and the "unsmoothed" measure of depreciation reported in the PR24 dataset.
- All four models include explanatory variables to control for (i) the proportion of dual service household, and (ii) the proportion of metered households.
- Two of the models (models WSXROC2 and WSXROC4) control for scale through the inclusion of a variable defined as the logarithm of the number of households.
- Models WSXROC1 and WSXROC2 include a set of year-specific dummy variables for each year in the dataset, i.e. they include a dummy-variable that is defined to be 1 if the observation relates to 2013/14 and is 0 otherwise; a dummy-variable that is 1 if the observation relates to 2014/15 and is 0 otherwise, and so on. (On estimating, the dummy-variable for one of the years drops out.)
- Models WSXROC3 and WSXROC4 include a variable to capture a time trend.

WSXROC1
ln(real Other retail costs per household) = α + β1 (Proportion of dual service customers) + β_2 (Proportion of metered connections) + β3 t2014 + β4 t2015 + β5 t2016 + β6 t2017 + β7 t2018 + β8 t2019 + β9 t2020 + β10 t2021 + β11 t2022 + ε_{it}

WSXROC2
ln(real Other retail costs per household) = α + β1 (Proportion of dual service customers) + β_2 (Proportion of metered connections) + β3 Ln (Total households connected) + β4 t2014 + β5 t2015 + β6 t2016 + β7 t2017 + β8 t2018 + β9 t2019 + β10 t2020 + β11 t2021 + β12 t2022 + ε_{it}

WSXROC3
ln(real Other retail costs per household) = α + β1 (Proportion of dual service customers) + β_2 (Proportion of metered connections) + β3 timetrend + ε_{it}

WSXROC4
ln(real Other retail costs per household) = $\alpha + \beta 1$ (Proportion of dual service customers) + β_2 (Proportion of metered connections) + $\beta 3$ Ln (Total households connected) + $\beta 4$ timetrend + ε_{it}

Description of the dependent variable

Please see also our cover note to this submission.

Revenue adjustment (impacts a dependent and independent variable)

We have made an adjustment to the revenue figures for South West Water, to acknowledge the £50/customer government contribution made to South West Water customers which we understand is not captured in APR reported data, and thus in the revenue data published in the residential retail cost assessment dataset. Given the merger between South West Water and Bournemouth, this adjustment has taken the form of:

- For SWT we deducted £50 per customer.
- For SWB, (i) for each of the years from 2013/14 to 2015/16, we deducted (£50 *Number of SWT customers); (ii) for each of the years from 2016/17, we deducted (£50* Number of SWB customers* ratio), where ratio is the average of the ratio of SWT customers to the sum of SWT and BWH customers in the years from 2013/14 to 2015/16.

This adjustment to the revenue figures, impacts the dependent variable for three of our bad debt models where the dependent variable is defined as the ratio between real bad debt costs and total billed revenue; and also on the independent variable revenue per household (equivalently average bill) which is used as a driver of bad debt costs in the bad debt models where the dependent variable is specified as bad debt per household.

Models of bad debt related costs

As set out above, we have submitted two sets of models for bad debt related costs. One set has a dependent variable defined as real bad debt related costs per household and other set as the ratio of real bad debt related costs to total billed revenue.

Dependent variable: lnreal_DCsdebt_hh – defined as the natural logarithm of bad debt related costs per household in CPIH-adjusted real terms (2017/18 reference price level), using the "smoothed" measure of bad debt costs reported in the PR24 datasets, i.e. the sum of debt management costs and the "smoothed" bad debt costs. To express the variable on a real basis, we adjusted the nominal value by CPIH, using 2017/18 as reference.

The variable is identical to the one called "lnDCsdebt_hh" which is derived in the Stata do file published by Ofwat.

The variable is expressed in units of (log of) £/household.

Dependent variable: ratio_smbdtorev – defined as the ratio of smoothed bad debt costs to total billed revenue***. This is expressed in CPIH-adjusted real terms (2017/18 reference price level), using the "smoothed" measure of bad debt costs reported in the PR24 datasets, i.e. the sum of debt management costs and the "smoothed" bad debt costs. To express the variable on a real basis, we adjusted the nominal value by CPIH, using 2017/18 as reference.

Models of other retail costs

Dependent variable: lnreal_OCsdebt_hh – defined as the natural logarithm of other retail costs per household in CPIH-adjusted real terms (2017/18 reference price level), using the "smoothed" measure of bad debt costs and the "unsmoothed" measure of depreciation, reported in the PR24 datasets. To express the variable on a real basis, we adjusted the nominal value by CPIH, using 2017/18 as reference.

This variable departs from ones derived in the Stata do file published by Ofwat in that it draws on "unsmoothed" depreciation and "smoothed" bad debt costs.

The variable is expressed in units of (log of) £/household.

Description of the explanatory variables

All from published retail dataset, see additional information on SqIncomescore.

- adjusted revenue per household*** (code: real_revAdj_hh)
- Credit risk score equifax variable RGC102 (code: eq_rgc102)
- incomescore_unadjusted (code: incomescore_unadjusted)
- SqIncomescore (code: SqIncomeIMD2019)
- Proportion of dual service customers (code: hhdu_hh)
- Proportion of metered connections (code: hhm_hh)
- Total households connected (code: hh_t)
- dummy year variables (code: t2014, t2015, t2016, t2017, t2018, t2019, t2020, t2021, t2022)
- Time trend (code: fye)

Deprivation and credit risk (bad debt)

Our submitted bad debt models rely on one of the following three variables that capture deprivation and credit risk:

- *Credit risk score (Equifax variable RGC102)* – of the Equifax variables we have found RGC102 to be both the most intuitive and statistically significant. Whilst it is not the Equifax variable used by Ofwat at PR19, this variable was discussed as part of previous PR19 work by United Utilities.
- *Income deprivation score unadjusted (ONS)*
- *Squared income deprivation score unadjusted (using above ONS source data)* – we found there to be reasonable intuition and statistical basis for a squared term of the income deprivation measure to capture the non-linear relationship between deprivation and bad debt costs. For example, a company with an LSOA of 40% deprivation and another of 60% deprivation, is likely to have a higher risk of default compared to a company with two LSOA areas of 50% deprivation. In aggregating LSOA data to a company level, we have therefore used a square term to give more weight to areas of higher deprivation within a company's area.

We also include in our submission a dataset of values we use for the variable 'squared income deprivation score unadjusted' in the bad debt models. This variable is derived from the ONS income deprivation score.

Brief comment on the models

Please see also our cover note to this submission.

Time series

Our submitted models use a time series 13/14 to date (9 years) to inform the historical relationship between costs and cost drivers. We consider there to be less change in retail functions and greater stability compared to wholesale, such that a longer time period does not appear inappropriate.

Commentary on models

We consider there to be less change in retail functions and greater stability compared to wholesale, such that a longer time period does not appear inappropriate.

Interpretation and application of RAG sensitivities to removal of most and least efficient company and removal of first and last year of sample period

We support the inclusion of these sensitivities as part of the model assessment process. Models should be robust to such changes in the dataset. We have set a high bar for how we have interpreted the results of these sensitivities.

Guidance on how to complete the table below is included in section 4 of this document. The first column in the table has been filled in with an illustrative example. Numbers are fictional.

Bad debt related cost models

		Model WSXRDC1	Model WSXRDC2	Model WSXRDC3
Dependent variable		Logarithm of bad debt related costs per household in CPIH-adjusted real terms (2017/18 reference price level), using the "smoothed" measure of bad debt costs reported in the PR24 datasets. Code: lnreal_DCsdebt_hh		
Explanatory variables				
Var. description	Var. code			
Ln of wholesale and retail adjusted revenue per household, in real CPIH-adjusted terms	lnreal_revAdj_hh	0.975*** {0.000}	1.000*** {0.000}	0.959*** {0.000}

Income deprivation score	incomescore_unadjusted	0.046* {0.089}		
Equifax measure RGC102	eq_rgc102		-0.029** {0.042}	
Company-level aggregate of square of LSOA-level income deprivation score	SqIncomeIMD2019			13.286* {0.060}
Dummy variable 2019/20	t2020	0.449*** {0.000}	0.380*** {0.000}	0.385*** {0.000}
Dummy variable 2020/21	t2021	0.389*** {0.000}	0.298*** {0.000}	0.326*** {0.000}
Dummy variable 2021/22	t2022	0.270* {0.072}	0.183 {0.136}	0.209 {0.107}
Financial year ending	fye	-0.045*** {0.007}	-0.047*** {0.006}	-0.046*** {0.006}
Constant	_cons	86.357*** {0.009}	95.357*** {0.008}	89.950*** {0.008}
Estimation_method		RE	RE	RE
N		153	153	153
Model robustness tests				
R2 adjusted		0.736	0.730	0.724
RESET test		0	0	0
VIF (max)[1]		3.437	3.439	3.438
Pooling/Chow test][2]		N/A	N/A	N/A
Normality of model residuals[2]		N/A	N/A	N/A
Heteroskedasticity of model residuals[2]		N/A	N/A	N/A
Test of pooled OLS vs Random effects (LM test)		0.000	0.000	0.000
Efficiency ratios				

Min	150.67	153.52	152.16
Max	61.19	61.15	60.22
Sensitivity analysis			
Sensitivity to removal of most and least efficient company	A	A	A
Sensitivity to removal of first and last year of the sample	G	A	G

Table notes:

1. *We report the VIF (max) based on OLS estimation of the model, in line with Ofwat's approach in published Stata script file.*
2. *We do not report the test statistics relating to Pooling/Chow test, the test of normality of residuals and the test of heteroscedasticity of residuals given our models are random effects models and in light of Ofwat's response to a query raised on this.*

		Model WSXRDC4	**Model WSXRDC2**	**Model WSXRDC3**
Dependent variable		The ratio of smoothed bad debt costs to total billed revenue*** in CPIH-adjusted real terms (2017/18 reference price level), using the "smoothed" measure of bad debt costs reported in the PR24 datasets. Code: ratio_smbdtorev		
Explanatory variables				
Var. description	**Var. code**			
Income deprivation score	incomescore_unadjusted	0.002* {0.055}		
Equifax measure RGC102	eq_rgc102		-0.001** {0.044}	
Company-level aggregate of square of LSOA-level income deprivation score	SqIncomeIMD2019			0.434* {0.075}
Dummy variable 2019/20	t2020	0.019*** {0.000}	0.016*** {0.001}	0.016*** {0.001}
Dummy variable 2020/21	t2021	0.014*** {0.000}	0.011*** {0.000}	0.012*** {0.000}

Dummy variable 2021/22	t2022	0.009*** {0.008}	0.006** {0.042}	0.007** {0.023}
Financial year ending	fye	-0.002*** {0.001}	-0.002*** {0.001}	-0.002*** {0.001}
Constant	_cons	3.239*** {0.001}	3.588*** {0.001}	3.340*** {0.001}
Estimation_method		RE	RE	RE
N		153	153	153
Model robustness tests				
R2 adjusted		0.232	0.209	0.208
RESET test		0.613	0.256	0.298
VIF (max)[1]		3.429	3.429	3.429
Pooling/Chow test][2]		N/A	N/A	N/A
Normality of model residuals[2]		N/A	N/A	N/A
Heteroskedasticity of model residuals[2]		N/A	N/A	N/A
Test of pooled OLS vs Random effects (LM test)		0.000	0.000	0.000
Efficiency ratios				
Min		140.19	144.59	141.79
Max		57.21	57.34	56.02
Sensitivity analysis				
Sensitivity to removal of most and least efficient company		A	A	A
Sensitivity to removal of first and last year of the sample		G	A	A

Table notes:

1. *We report the VIF (max) based on OLS estimation of the model, in line with Ofwat's approach in published Stata script file.*
2. *We do not report the test statistics relating to Pooling/Chow test, the test of normality of residuals and the test of heteroscedasticity of residuals given our models are random effects models and in light of Ofwat's response to a query raised on this.*

Other retail cost models

	Model WSXROC1	Model WSXROC2	Model WSXROC3	Model WSXROC4

Dependent variable		Logarithm of other retail costs per household, in real CPIH adjusted terms (drawing on "smoothed" bad debt costs and "unsmoothed" depreciation). Code: lnreal_OCsdebt_hh			
Explanatory variables					
Var. description	**Var. code**				
Prop. of dual service households	**hhdu_hh**	0.208** {0.018}	0.286*** {0.000}	0.210** {0.017}	0.292*** {0.000}
Prop. of metered households	hhm_hh	0.495* {0.087}	0.509* {0.072}	0.555** {0.041}	0.577** {0.031}
Dummy variable 2013/14	t2014	0.165** {0.033}	0.165** {0.034}		
Dummy variable 2014/15	t2015	0.193*** {0.008}	0.192*** {0.008}		
Dummy variable 2015/16	t2016	0.134* {0.054}	0.134* {0.056}		
Dummy variable 2016/17	t2017	0.104* {0.075}	0.104* {0.078}		
Dummy variable 2017/18	t2018	0.127** {0.013}	0.127** {0.015}		
Dummy variable 2018/19	t2019	0.167*** {0.001}	0.166*** {0.001}		
Dummy variable 2019/20	t2020	0.132*** {0.001}	0.131*** {0.001}		
Dummy variable 2020/21	t2021	0.031 {0.426}	0.031 {0.429}		
Ln of number of households	lnhh_t		-0.033 {0.292}		-0.035 {0.273}
Financial year ending	fye			-0.020* {0.052}	-0.020* {0.051}
Constant	_cons	2.347*** {0.000}	2.770*** {0.000}	42.021** {0.038}	42.767** {0.034}

Estimation_method	RE	RE	RE	RE
N	153	153	153	153
Model robustness tests				
R2 adjusted	0.184	0.198	0.148	0.162
RESET test	0.324	0.562	0.060	0.075
VIF (max)[1]	1.875	2.12	1.103	2.119
Pooling/Chow test][2]	N/A	N/A	N/A	N/A
Normality of model residuals	N/A	N/A	N/A	N/A
Heteroskedasticity of model residuals	N/A	N/A	N/A	N/A
Test of pooled OLS vs Random effects (LM test)	0.000	0.000	0.000	0.000
Efficiency ratios				
Min	155.41	153.24	157.13	154.80
Max	75.32	76.27	75.22	76.12
Sensitivity analysis				
Sensitivity to removal of most and least efficient company	A	A	A	A
Sensitivity to removal of first and last year of the sample	A	G	A	A

Table notes:

1. *We report the VIF (max) based on OLS estimation of the model, in line with Ofwat's approach in published Stata script file.*
2. *We do not report the test statistics relating to Pooling/Chow test, the test of normality of residuals and the test of heteroscedasticity of residuals given our models are random effects models and in light of Ofwat's response to a query raised on this.*

Efficiency scores distribution

Models of bad debt related costs (bad debt cost per household): efficiency scores

Model WSXRDC1		**Model WSXRDC2**		**Model WSXRDC3**	
SEW	61.2	SEW	61.1	SEW	60.2
SVE	73.1	SVE	73.7	SVE	72.6

SWB	77.9	YKY	81.5	SWB	80.5
YKY	83.5	SWB	81.7	YKY	81.9
NES	89.5	PRT	86.0	PRT	87.5
PRT	91.1	NES	90.1	NES	87.6
SES	91.8	SES	90.1	SES	91.9
ANH	103.2	ANH	102.6	NWT	104.9
NWT	109.4	NWT	107.6	ANH	105.1
AFW	115.4	AFW	113.1	WSH	114.5
WSH	115.6	TMS	116.3	AFW	118.5
WSX	122.7	WSX	122.8	WSX	122.7
TMS	124.2	WSH	123.3	BRL	126.5
BRL	127.6	BRL	129.7	SSC	128.8
SSC	127.7	SSC	134.0	TMS	129.1
HDD	144.2	SRN	151.3	HDD	148.3
SRN	150.7	HDD	153.5	SRN	152.2

Models of bad debt related costs (ratio of bad debt to total billed revenue): efficiency scores

Model WSXRDC4		Model WSXRDC5		Model WSXRDC6	
SEW	57.2	SEW	57.3	SEW	56

SVE	69.9	SVE	70.4	SVE	69.6
SWB	72.5	YKY	76.6	SWB	73.9
YKY	79.7	SWB	78.5	YKY	78.4
NES	86	PRT	81	PRT	84.7
PRT	86.8	NES	84.4	NES	85.7
SES	86.9	SES	87.3	SES	85.9
ANH	95.9	ANH	96.4	NWT	96.8
NWT	105.9	NWT	105.1	ANH	102.8
AFW	108.9	AFW	106.4	WSH	109.6
WSH	110.8	TMS	110.8	AFW	111.8
WSX	113.6	WSX	115	WSX	112.5
TMS	116.5	WSH	117.3	BRL	119.8
BRL	120.4	BRL	121.7	SSC	120.1
SSC	124.7	SSC	127.9	TMS	126.9
HDD	138.3	SRN	142	HDD	140.5
SRN	140.2	HDD	144.6	SRN	141.8

Models of other retail: efficiency scores

Model WSXROC1	**Model WSXROC2**	**Model WSXROC3**	**Model WSXROC4**

ANH	75.3	ANH	76.3	ANH	75.2	ANH	76.1
WSX	80.5	WSX	80.6	WSX	81.2	WSX	81.3
SEW	89.0	SWB	88.8	SEW	88.6	SWB	88.3
AFW	91.0	SEW	90.9	SWB	91.4	SEW	90.4
BRL	91.2	BRL	91.8	AFW	92.2	BRL	93.1
SWB	91.6	NWT	94.4	BRL	92.4	AFW	96.2
SSC	93.9	AFW	94.8	SSC	95.8	NWT	96.2
NWT	94.9	SSC	95.6	NWT	96.7	SSC	97.8
PRT	96.4	PRT	95.7	PRT	99.3	PRT	98.7
YKY	100.3	YKY	98.9	YKY	101.6	HDD	100.1
SVE	103.9	HDD	98.9	SVE	106.0	YKY	100.1
HDD	105.3	SVE	106.0	HDD	106.9	SVE	108.4
NES	111.2	NES	112.1	SRN	112.8	SRN	113.9
SRN	112.9	SRN	114.1	NES	113.2	NES	114.2
TMS	119.4	WSH	117.3	TMS	121.3	WSH	119.5
WSH	120.1	TMS	124.1	WSH	122.3	TMS	126.4
SES	155.4	SES	153.2	SES	157.1	SES	154.8

Comments

- Please indicate the units of the explanatory variable, and whether it was expressed in logs.
- Use asterisks to denote significance level: *** (1%), ** (5%) and * (10%)
- P values should be based on cluster robust standard errors
- In the case of random effects please report Stata's output "R2 overall"
- Please use the following naming convention to assign a name to each model: company acronym, level of aggregation, model number (eg for Anglian Water's wholesale water model number 1: ANHWW1). Please refer to the table below for company acronyms and level of aggregation acronyms.

Company acronyms	Level of aggregation acronyms
Anglian Water: ANH Hafren Dyfrdwy: HDD Northumbrian Water: NES Southern Water: SRN Severn Trent England: SVE South West Water: SWB Thames Water: TMS United Utilities: UUW Dŵr Cymru: WSH Wessex Water: WSX Yorkshire Water: YKY Affinity Water: AFW Bristol Water: BRL Portsmouth Water: PRT SES Water: SES South East Water: SEW South Staffs Water: SSC	**Wholesale water** Treated water distribution: TWD Water resources plus: WRP Water network plus: WWNP Wholesale water: WW **Wholesale wastewater** Sewage collection: SWC Sewage treatment: STW Bioresources: BR Wastewater network plus: WWWNP Bioresources plus: BRP **Residential retail** Bad debt related costs: RDC Other costs: ROC Total costs: RTC