Water models

Econometric model formula:

1. UUWWR1: ln(WR botex) = α + β.ln(properties) + β.ln(impounding reservoirs per DI) + ε

2. UUWWR2: ln(WR botex) = α + β.ln(properties) + β.ln(impounding reservoirs per DI) + β.% pumped + ε

3. UUWWRP1: ln(WRP botex) = α + β.ln(properties) + β.ln(impounding reservoirs per DI) + β .% water treated in bands 1-3 + β.ln(WAD_MSOA_population) + β.ln(WAD_MSOA_population^2) + ε

4. UUWWRP2: ln(WRP botex) = α + β.ln(properties) + β.ln(impounding reservoirs per DI) + β.ln(weighted treatment complexity) + β.ln(WAD_MSOA_population) + β.ln(WAD_MSOA_population^2) + ε

5. UUWTWD1: ln(TWD botex plus network reinforcement) = α + β.ln(length of main) + β.ln(booster pumps per length) + β.ln(WAD_MSOA_population) + β.ln(WAD_MSOA_population^2) + ε

6. UUWWWNP1: ln(WWNP botex plus network reinforcement) = α + β.ln(properties) + β.ln(booster pumps per length) + β.ln(weighted treatment complexity) + β.ln(WAD_MSOA_population) + β.ln(WAD_MSOA_population^2) + ε

7. UUWWWNP2: ln(WWNP botex plus network reinforcement) = α + β.ln(properties) + β.ln(booster pumps per length) + β.% water treated in bands 1-3 + β.ln(WAD_MSOA_population) + β.ln(WAD_MSOA_population^2) + ε

8. UUWWW1: ln(WW botex plus network reinforcement) = α + β.ln(properties) + β.ln(booster pumps per length) + β.% water treated in bands 1-3 + β.ln(WAD_MSOA_population) + β.ln(WAD_MSOA_population^2) + ε

9. UUWWW2: ln(WW botex plus network reinforcement) = α + β.ln(properties) + β.ln(booster pumps per length) + β.ln(weighted treatment complexity) + β.ln(WAD_MSOA_population) + β.ln(WAD_MSOA_population^2) + ε

Description of the dependent variable

All dependent variables align to those calculated in Ofwat's do-file. We include network reinforcement costs across all specifications that include treated water distribution network costs.

Description of the explanatory variables

All data used are reported in Ofwat's published wholesale dataset. Most of the variables used are calculated in Ofwat's do-file. Where this is not the case, we provide a formula including the relevant code and calculation.

Properties: (code: properties)

Impounding reservoirs per distribution input: (BN4860S / BN1000_CA22_A)

% pumped: (BN4848 + BN4834 + BN4846 + BN4847) * 100

% water treated in bands 1-3: (code: pctwatertreated36)

Weighted treatment complexity: (code: wac)

WAD_MSOA_population: (code: WAD_MSOA_population)

WAD_MSOA_population^2: (code: WAD_MSOA_population2)

booster pumps per length: (code: boosterperlength)

Brief comment on the models

- The models reflect the full historical period covered by the dataset i.e. no years are excluded. We do consider there is some evidence of a structural break between AMP5 and AMP6, when the totex-outcomes regime began. This might justify modelling using data from AMP6 onwards, when more years of data are available in future.

- We focus upon Random Effects estimation, although we do consider this choice should not be a policy decision but rather based upon comparative statistical performance.

- All models are based upon strong engineering, operational and economic rational. Our model selection process prefers strong engineering priors over statistical performance (although this is still a relevant consideration when selecting models). This is because approaches that focus upon statistical fit are at risk of relying on chance correlations, which can break down in future periods making any modelling result unreliable. That said, our models tend to perform well statistically as well as being aligned with strong engineering priors.
- We propose water resources models that capture cost variation caused by impounding reservoir dam maintenance and pumping of water out of sources. This also facilitates Water Network Plus models, which controls for variation in asset configuration across the treatment/distribution boundary. These models perform well.
- We note that our water resources plus models have a relatively wide spread of residuals. This is due to a small number of outlier companies (that tend to be WOCs); the rest of the industry is tightly grouped. The spread under UUW's specification (i.e. including an impounding reservoir measure) is narrower than under the PR19 specification included in the do-file provided by Ofwat.
- Our treated water distribution model aligns with Ofwat's PR19 model, although we prefer to use WAD at the MSOA level. We consider that greater granularity is better able to reflect density and wider urban areas. We do not consider that pumping head is robust enough to use within cost assessment; the Turner and Townsend report noted significant inconsistencies in pumping head reporting and although T&T provided recommendations, we are not aware of any progress being made to address these points. In the context of an exogenous variable that is inconsistent across the industry, it's reasonable to assume that companies will have developed an asset base needed to overcome the influence of pumping head. Therefore, using booster pumps should appropriately reflect pumping requirements across the industry in a consistent way, which we consider makes it a compelling measure to use. It is also better able to reflect capital maintenance requirements for a company.
- Our wholesale water model aligns with the PR19 specfications, although we prefer to use WAD at the MSOA level for the reasons discussed above.

Water resources

	UUWWR1	UUWWR2			
Dependent variable	Botex	Botex			
ln(properties)	0.994*** (0.000)	1.031*** (0.000)			
ln(impounding reservoirs per DI)	0.032 (0.163)	0.073** (0.254)			
% pumped		0.004 (0.254)			
Constant	-11.166*** (0.000)	-11.727*** (0.000)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	187	187			
Model robustness tests					
R2 adjusted	0.889	0.899			
RESET test	0.16	0.028			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.65 Max: 1.57	Min: 0.68 Max: 1.57			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Water resources plus

	UUWWRP1	UUWWRP2			
Dependent variable	Botex	Botex			
ln(properties)	0.986*** (0.000)	0.982*** (0.000)			
% water treated in bands 1-3	0.004** (0.041)				
ln(WAD MSOA population)	-3.933** (0.041)	-3.851* (0.069)			
ln(WAD MSOA population)²	0.253** (0.036)	0.248* (0.06)			
ln(Impounding reservoirs per DI)	0.071** (0.029)	0.077** (0.017)			
ln(weighted average complexity)		0.283 (0.285)			
Constant	5.57 (0.438)	5.202 (0.516)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	187	187			
Model robustness tests					
R2 adjusted	0.906	0.904			
RESET test	0.666	0.661			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.51 Max: 1.89	Min: 0.49 Max: 1.98			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Treated water distribution

	UUWTWD1				
Dependent variable	Botex including network reinforcement				
ln(Length of main)	1.026*** (0.000)				
ln(Booster pumps per length of main)	0.433*** (0.001)				
ln(WAD MSOA population)	-5.561*** (0.000)				
ln(WAD MSOA population)^2	0.393*** (0.000)				
Constant	15.638*** (0.00)				
Estimation method (OLS or RE)	RE				
N (sample size)	187				
Model robustness tests					
R2 adjusted	0.952				
RESET test	0.122				
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0				
Efficiency score distribution (min and max)	Min: 0.75 Max: 1.42				
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Water Network Plus

	UUWWWNP1	UUWWWNP2			
Dependent variable	Botex including network reinforcement	Botex including network reinforcement			
ln(properties)	1.050*** (0.000)	1.056*** (0.000)			
% water treated in bands 1-3		0.003* (0.058)			
ln(WAD MSOA population)	-4.535*** (0.000)	-4.877*** (0.000)			
ln(WAD MSOA population)^2	0.291*** (0.001)	0.314*** (0.000)			
ln(weighted average complexity)	0.293* (0.074)				
Constant	9.556* (0.08)	11.047** (0.04)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	187	187			
Model robustness tests					
R2 adjusted	0.963	0.96			
RESET test	0.148	0.27			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.71 Max: 1.57	Min: 0.71 Max: 1.57			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Wholesale water

	UUWWW1	UUWWW2			
Dependent variable	Botex including network reinforcement	Botex including network reinforcement			
ln(properties)	1.052*** (0.000)	1.046*** (0.000)			
% water treated in bands 1-3	0.003** (0.011)				
ln(WAD MSOA population)	-4.684*** (0.001)	-4.308*** (0.002)			
ln(WAD MSOA population)^2	0.301*** (0.000)	0.276*** (0.001)			
ln(weighted average complexity)		0.322** (0.03)			
ln(Booster pumps per length of main)	0.509*** (0.003)	0.486*** (0.003)			
Constant	10.3* (0.056)	8.674 (0.108)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	187	187			
Model robustness tests					
R2 adjusted	0.963	0.965			
RESET test	0.178	0.075			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.73 Max: 1.53	Min: 0.74 Max: 1.53			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Wastewater models

Econometric model formula:

1. UUWSWC1: ln(swc botex plus) = α + β.ln(sewer length) + β.ln(pumping capacity per length) + β.ln(WAD_MSOA_population) + β.ln(rainfall per length) + ε

2. UUWSWC2: ln(swc botex plus) = α + β.ln(sewer length) + β.ln(pumping capacity per length) + β.ln(WAD_MSOA_population) + β.ln(rainfall per length) + β.% combined sewer + ε

3. UUWSWC3: ln(swc botex plus) = α + β.ln(sewer length) + β.ln(pumping capacity per length) + β.ln(WAD_MSOA_population) + β.ln(rainfall).% combined sewer + ε

4. UUWSWT1: ln(swt botex) = α + β.ln(load) + β.ln(UV consent days, total) + β.% load treated bands 1-3 + β.ln(rainfall per length) + ε

5. UUWSWT2: ln(swt botex) = α + β.ln(load) + β.ln(UV consent days, >30mW/s/cm) + β.% load treated above band 5 + β.ln(rainfall per length) + ε

6. UUWWWWNP1: ln(wwwnp botex plus) = α + β.ln(properties) + β.ln(UV consent days, total) + β.% load treated bands 1-3 + β.ln(rainfall per length) + ε

7. UUWWWWNP2: ln(wwwnp botex plus) = α + β.ln(properties) + β.ln(UV consent days, total) + β.% load treated above band 5 + β.ln(rainfall per length) + ε

8. UUWBR1: ln(br botex plus growth) = α + β.ln(sludge produced) + β.ln(WAD_MSOA_population) + β.% sludge produced at co-located assets + β.% load treated with a P consent < 1mg/l + ε

9. UUWBR2: ln(br botex plus growth) = α + β.ln(sludge produced) + β.ln(WwTW per property) + β.% sludge produced at co-located assets + ε

10. UUWBRP1: ln(brp botex plus bio growth) = α + β.ln(load) + β.ln(UV consent days, total) + β.% load treated bands 1-3 + β.ln(rainfall per length) + ε

11. UUWBRP2: ln(brp botex plus bio growth) = α + β.ln(load) + β.ln(UV consent days, >30mW/s/cm) + β.% load treated above band 5 + ε

Description of the dependent variable

All dependent variables align to those calculated in Ofwat's do-file. We include 'reduce flooding risk for properties' enhancement expenditure and network reinforcement costs within all specifications that include sewage collection costs. We consider that including 'reduce flooding risk for properties' within the dependent variable is legitimate if the model includes an appropriate driver that reflects variation in urban run-off across the industry.

We also include bioresources growth within our bioresources and bioresources plus models to align with Ofwat's PR24 methodology. However, we note that we were unable to identify a suitable cost driver that can appropriately explain variations in growth requirements across the industry.

Description of the explanatory variables

All data used are reported in Ofwat's published wholesale dataset. Most of the variables used are calculated in Ofwat's do-file. Where this is not the case, we provide a formula including the relevant code and calculation.

Sewer length: (code: sewerlength)

Properties: (code: properties)

Load: (code: load)

Sludge produced: (code: sludgeprod)

Pumping capacity per length: (code: pumpingcapperlength)

WAD_MSOA_population: (code: WAD_MSOA_population)

Rainfall per length: (BN4508 / sewerlength)

Combined sewer: (BN13526 / sewerlength) * 100

Rainfall x combined sewer: BN4508 * ((BN13526 / sewerlength) * 100)

UV consent days, total: STWDV003 + STWDV006 + STWDV009 + STWDV012 + STWDV015 + STWDV018

UV consent days, >30mW/s/cm: STWDV001 + STWDV004 + STWDV007 + STWDV010 + STWDV013 + STWDV016

% load treated bands 1-3: (code: pctbands13)

% load treated above band 5: (code: pctbands6)

% sludge produced at co-located assets: MP05615 * 100

% load treated with a P consent < 1 mg/l: (STWDP122_21 / STWDP125_21) * 100

Brief comment on the models

- The models reflect the full historical period covered by the dataset i.e. no years are excluded. We do consider there is some evidence of a structural break between AMP5 and AMP6, when the totex-outcomes regime began. This might justify modelling using data from AMP6 onwards, when more years of data are available in future.
- We focus upon Random Effects estimation, although we do consider this choice should not be a policy decision but rather based upon comparative statistical performance.
- All models are based upon strong engineering, operational and economic rational. Our model selection process prefers strong engineering priors over statistical performance (although this is still a relevant consideration when selecting models). This is because approaches which focus upon statistical fit are at risk of relying on chance correlations, which can break down in future periods making any modelling result unreliable. In some wastewater models, a factor has a high p score, but is of a reasonable magnitude and has an intuitive sign. In such cases, we prioritise the engineering and economic rationale by including the variable.
- Our sewer collection models have been informed by our work looking into the drivers of costs on the wastewater network[1]. This work has revealed a number of drivers of cost including urban run-off, combined sewers and the interaction of run-off and topography. Importantly, the effect of each of these factors depends upon the value of the others e.g. high levels of urban run-off will have a larger impact on cost and performance in areas with high levels of combined sewers, than the same level of urban run-off in an area with low levels of combined sewer. We reflect this interaction using an interaction term in UUWSWC3 – this variable is of the expected sign and is statistically significant. We note that all cost drivers across our sewage collection models align with engineering and operational rationale and are statistically significant.

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[1] See for example Arup and Vivid Economics (2017) *Understanding the exogenous drivers of wholesale wastewater costs in England and Wales* (Available here) and UUW (2022) *What lessons can we learn from cost assessment at PR19?* (Available here).

- Ofwat's consultation focuses upon econometric models for cost assessment. For this reason, we have submitted models that include variables that could also legitimately be used to explain variations in efficient performance. For example, we have found that urban run-off can explain variations in efficient performance for internal sewer flooding[2]. This is to align with the objectives of Ofwat's consultation, but in future it may be more appropriate to reflect these factors within performance targets.
- We add a Wastewater Network Plus modelling split to Ofwat's PR19 model suite. We consider that the WwNP models we propose align with engineering and operational rationale. While dropping 2011-12 impacts the coefficients on rainfall such that we have marked this robustness test red, the models are otherwise relatively robust.
- We incorporate a driver that reflects UV treatment in all models that include treatment costs. UV treatment increases operating and maintenance costs significantly; an engineering estimate suggests by 15% against an identical WwTW without UV treatment. These models align with engineering rationale and perform well statistically.
- We note that Ofwat has stated its aim to apply a bioresources-specific catch-up challenge. We consider that this approach is at risk of mistaking company asset configuration across the price control boundary for efficiency i.e. companies that had relatively more assets allocated to WwNP will appear more efficient, which will create an unobtainable efficiency. We appreciate Ofwat has stated companies should seek to be efficient across their entire value chain but WwNP is subject to cost sharing with customers whereas Bioresources is not – this creates an asymmetric impact across the industry that is not related to underlying efficiency. We have attempted to reflect asset configuration using a driver that reflects the co-location of WwNP and Bio assets; lower co-location requires more work to be done within the Bioresources price control, such as increased dewatering at intermediate sites with onward transportation to AD centres, which is all reported in the Bioresources price control. This activity means that % co-location will correlate more closely with the asset configuration of the Bioresources price control boundary. We note that this factor may also reflect rurality, so we have not considered Ofwat's PR19 rurality driver to maximise parsimony. While these models aren't as statistically significant as other models in our suite, we consider that they align with engineering rationale and are robust to dropping years and companies, which justifies their inclusion.
- We note that a Bioresources Plus model is also a legitimate way to control for asset configuration across the price control boundary. As such, we have included two BRP models which align to engineering rational and perform well statistically.

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[2] UUW (2022) *What lessons can we learn from cost assessment at PR19?* (Available here).

Sewage collection

	UUWSWC1	UUWSWC2	UUWSWC3		
Dependent variable	Botex including network reinforcement and ‘reduce flooding risk for properties’	Botex including network reinforcement and ‘reduce flooding risk for properties’	Botex including network reinforcement and ‘reduce flooding risk for properties’		
ln(sewer length)	0.878*** (0.000)	0.922*** (0.000)	0.9*** (0.000)		
ln(pumping capacity per length)	0.523*** (0.000)	0.618*** (0.000)	0.657*** (0.000)		
ln(WAD MSOA population)	0.38*** (0.000)	0.435*** (0.000)	0.432*** (0.000)		
ln(rainfall per length)	0.152*** (0.000)	0.132*** (0.000)			
% combined sewers		0.008* (0.065)			
ln(rainfall) x % combined sewers			0.001*** (0.001)		
Constant	-7.445*** (0.000)	-8.61*** (0.000)	-8.85*** (0.000)		
Estimation method (OLS or RE)	RE	RE	RE		
N (sample size)	110	110	110		
Model robustness tests					
R2 adjusted	0.91	0.92	0.913		
RESET test	0.31	0.249	0.264		
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0	0		
Efficiency score distribution (min and max)	Min: 0.84 Max: 1.11	Min: 0.88 Max: 1.13	Min: 0.88 Max: 1.15		
Sensitivity – most/least efficient	🟩	🟩	🟩		
Sensitivity – first/last year	🟩	🟧	🟩		

Sewage treatment

	UUWSWT1	UUWSWT2			
Dependent variable	Botex	Botex			
ln(load)	1.026*** (0.000)	1.144*** (0.000)			
ln(UV consent days total)	0.017** (0.014)				
ln(UV consent days >30mW/s/cm)		0.024*** (0.000)			
% load treated in bands 1-3	0.04** (0.027)				
% load treated above band 5		-0.016*** (0.000)			
Constant	-8.428*** (0.000)	-8.478*** (0.000)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	110	110			
Model robustness tests					
R2 adjusted	0.893	0.896			
RESET test	0.027	0.009			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.92 Max: 1.41	Min: 0.89 Max: 1.36			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Wastewater network plus

	UUWWWWNP1	UUWWWWNP2			
Dependent variable	Botex including network reinforcement and 'reduce flooding risk for properties'	Botex including network reinforcement and 'reduce flooding risk for properties'			
ln(properties)	0.967*** (0.000)	1.059*** (0.000)			
ln(UV consent days total)	0.012** (0.03)	0.014** (0.02)			
% load treated in bands 1-3		0.036* (0.066)			
% load treated above band 5	-0.003 (0.501)				
ln(rainfall per length)	0.067** (0.029)	0.068** (0.042)			
Constant	-8.147*** (0.000)	-9.894*** (0.000)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	110	110			
Model robustness tests					
R2 adjusted	0.922	0.931			
RESET test	0.049	0.064			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.91 Max: 1.28	Min: 0.87 Max: 1.32			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Bioresources

	UUWBR1	UUWBR2			
Dependent variable	Botex including BR growth	Botex including BR growth			
ln(sludge produced)	1.000*** (0.000)	1.116*** (0.000)			
ln(WAD MSOA population)	-0.22 (0.381)				
ln(WwTW per property)		0.225 (0.264)			
% sludge produced at co-located assets	-0.006 (0.14)	-0.005 (0.195)			
% load treated with a P consent <1mg/l	0.001 (0.593)				
Constant	1.105 (0.515)	1.085 (0.279)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	110	110			
Model robustness tests					
R2 adjusted	0.711	0.731			
RESET test	0.052	0.173			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.59 Max: 1.44	Min: 0.60 Max: 1.38			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Bioresources plus

	UUWBRP1	UUWBRP2			
Dependent variable	Botex including BR growth	Botex including BR growth			
ln(load)	1.033*** (0.000)	1.092*** (0.000)			
ln(UV consent days total)	0.011*** (0.007)				
ln(UV consent days >30mW/s/cm)		0.014*** (0.004)			
% load treated in bands 1-3	0.04** (0.041)				
% load treated above band 5		-0.014*** (0.000)			
Constant	-8.111*** (0.000)	-7.592*** (0.000)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	110	110			
Model robustness tests					
R2 adjusted	0.935	0.935			
RESET test	0.979	0.874			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.90 Max: 1.25	Min: 0.92 Max: 1.23			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

Residential retail models

Econometric model formula:

1. UUWRDC1: ln(smoothed bad debt per household) = $\alpha + \beta.\ln(\text{bill size}) + \beta.\%\ \text{default} + \varepsilon$

2. UUWRDC2: ln(smoothed bad debt per household) = $\alpha + \beta.\ln(\text{bill size}) + \beta.\%\ \text{income deprived} + \varepsilon$

3. UUWRDC3: ln(smoothed bad debt per household) = $\alpha + \beta.\ln(\text{bill size}) + \beta.\ln(\text{credit risk score}) + \varepsilon$

4. UUWROC1: ln(other retail costs per household) = $\alpha + \beta.\%\ \text{dual service customers} + \beta.\%\ \text{meter penetration} + \varepsilon$

5. UUWRTC1: ln(total cost (smoothed bad debt) per household) = $\alpha + \beta.\ln(\text{bill size}) + \beta.\%\ \text{default} + \varepsilon$

6. UUWRTC2: ln(total cost (smoothed bad debt) per household) = $\alpha + \beta.\ln(\text{bill size}) + \beta.\%\ \text{income deprived} + \varepsilon$

Description of the dependent variable

All dependent variables align to those calculated in Ofwat's do-file. We use the 'smoothed' bad debt cost variable. We consider that this will remove any potential over-provisioning of bad debt during the covid-19 period and therefore provide a better relationship between cost and cost driver.

Description of the explanatory variables

All data used are reported in Ofwat's published wholesale dataset. All of the variables used are calculated in Ofwat's do-file. We found that the interpolated income score factor performs better statistically than the unadjusted factor. Given both factors align with operational rationale, we choose the factor that performs best statistically.

Bill size: (code: rev_hh)

% default: (code: eq_lpcf62)

% income deprived: (code: incomescore_interpolated)

Credit risk score: (code: eq_rgc102)

% dual service: (code: hhdu_hh)

% meter penetration: (code: hhm_hh)

Brief comment on the models

- Our models are similar to Ofwat's PR19 residential retail models, although we do not utilise the economies of scale driver (total households). Unlike in wholesale, we consider scale to be within the control of residential retail businesses, for example, through joint billing operations or through outsourcing to a large service provider like Capita.
- The models are based upon operational and economic rationale. All cost drivers have intuitive signs and magnitudes according to this rationale, so we do not consider that a lack of statistical significance undermines these models. We note that the models perform relatively well on the robustness tests.
- We consider that the use of a bottom up model split (bad debt and other retail costs) is key in enabling the modelled benchmark to reflect a richer relationship between cost and cost driver and produce more appropriate outcomes overall.
- Reckon found[3] that that levels of bad debt are influenced more by levels of extreme deprivation than average deprivation. We are considering appropriate measures of extreme deprivation for cost modelling purposes and will share insight in future if these prove a more powerful explanatory of bad debt costs.
- We have not included transiency – our work in this area found that the key cost driver of interest is deprivation and that once this is accounted for, the effect of transiency on cost is immaterial i.e. transiency only tends to lead to higher costs in deprived areas.
- We note that the relatively large residual spread on some models is driven by a small number of companies (which tend to be WOCs). We consider that the triangulated retail residual spread (i.e. triangulating across all models) demonstrates that the retail models provide an appropriate outcome, despite large residual spreads in

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[3] Reckon (2018) *Deprivation and arrears risk in household retail cost assessment*. Available here.

some model specifications. This demonstrates the benefit of a diverse, appropriately triangulated model suite.

Bad debt costs

	UUWRDC1	UUWRDC2	UUWRDC3		
Dependent variable	Smoothed bad debt costs	Smoothed bad debt costs	Smoothed bad debt costs		
ln(bill size)	1.09*** (0.000)	1.038*** (0.000)	1.072*** (0.000)		
% default	0.008 (0.649)				
% income deprived		0.025 (0.313)			
ln(credit risk score)			-3.876** (0.026)		
Constant	-3.952*** (0.000)	-3.802*** (0.000)	15.437* (0.066)		
Estimation method (OLS or RE)	RE	RE	RE		
N (sample size)	153	153	153		
Model robustness tests					
R2 adjusted	0.663	0.683	0.695		
RESET test	0.057	0.026	0.107		
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0	0		
Efficiency score distribution (min and max)	Min: 0.55 Max: 1.62	Min: 0.59 Max: 1.55	Min: 0.62 Max: 1.6		
Sensitivity – most/least efficient	🟥	🟩	🟩		
Sensitivity – first/last year	🟩	🟩	🟩		

Other retail costs

	UUWROC1				
Dependent variable	Other retail costs (smoothed bad debt and smoothed deprivation)				
% dual service	0.002** (0.025)				
% meter penetration	0.0004 (0.809)				
Constant	2.718*** (0.000)				
Estimation method (OLS or RE)	RE				
N (sample size)	153				
Model robustness tests					
R2 adjusted	0.127				
RESET test	0.586				
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0				
Efficiency score distribution (min and max)	Min: 0.82 Max: 1.54				
Sensitivity – most/least efficient	🟩				
Sensitivity – first/last year	🟥				

Total retail costs

	UUWRTC1	UUWRTC2			
Dependent variable	Total retail costs (smoothed bad debt and smoothed deprivation	Total retail costs (smoothed bad debt and smoothed deprivation			
ln(bill size)	0.491*** (0.000)	0.489*** (0.000)			
% default	0.013 (0.302)				
% income deprived		0.012 (0.424)			
% meter penetration	0.002 (0.513)	0.001 (0.629)			
Constant	0.165 (0.74)	0.392 (0.274)			
Estimation method (OLS or RE)	RE	RE			
N (sample size)	153	153			
Model robustness tests					
R2 adjusted	0.624	0.62			
RESET test	0	0			
VIF (max)					
Pooling / Chow test					
Normality of model residuals					
Heteroskedasticity of model residuals					
Test of pooled OLS versus Random Effects (LM test)	0	0			
Efficiency score distribution (min and max)	Min: 0.81 Max: 1.31	Min: 0.82 Max: 1.32			
Sensitivity – most/least efficient					
Sensitivity – first/last year					

PR24

UUW econometric model submission - supporting document

January 2023

United Utilities

Water for the North West

Contents

1. Introduction

In 2021, we published a document setting out our view of the key principles of cost assessment[1] – we have used these principles when identifying suitable cost models for use at PR24, as part of this submission.

In accordance with these principles, the first step of a modelling exercise should be to identify the engineering, operational and economic drivers of costs across all elements of the water, wastewater and retail value chain. Prioritising engineering, operational and economic rationale prevents cost assessment reflecting chance correlations in the data, which is more likely when using small datasets such as those utilised within cost assessment. This means that, although we do refer to statistical indicators and performance when assessing models, alignment with strong engineering priors could outweigh any evidence of weak statistical significance or issues arising from other diagnostic tests. This should result in a modelled benchmark which is reflective and realistic of company circumstances (now and in the future), which in turn promotes appropriate incentive properties and outcomes for customers.

This document sets out the assessment carried out prior to developing UUW's submission to Ofwat's econometric model consultation. We consider that this will provide helpful context for the model specifications we have chosen to submit.

The starting point of our model submission was Ofwat's PR19 model suite. We have made alterations to this model suite where there is compelling engineering, operational and/or economic justification. We also note that we've approached this as a cost modelling exercise, and have therefore submitted a series of costs with cost drivers motivated by engineering, operation and economic rationale. In some cases, it may be more appropriate to utilise these cost drivers as performance drivers, when setting performance commitment targets during PR24. We explored this issue further in our recent submission to Ofwat's Future Ideas Lab[2].

We would be more than happy to discuss any part of our submission in more detail with Ofwat.

Contents of UUW submission

(1) UUW model submission – Ofwat template.

(2) UUW model submission – supporting document *(this document).*

(3) Stata do-files to replicate the water models within UUW's submission.

(4) Stata do-files to replicate the wastewater models within UUW's submission.

(5) Stata do-files to replicate the retail models within UUW's submission.

(6) Corrected UV treatment days data (see section 5.1). We supply corrected data as part of this submission (see file: *UV weighted average operating days – updated*). We also provide a version of Ofwat's wastewater dataset with the corrected UV data.

(7) Corrected % co-location data. The corrected data is set out in section 5.2. We also provide a version of Ofwat's wastewater dataset with the corrected % co-location data.

(8) Results of our robustness testing.

We note that the Stata do-files generate correlation matrices, coefficients and results files. We have also included these for ease although Ofwat may wish to recreate these files to validate our results.

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[1] UUW (2021) *The principles of regulatory cost assessment.* Available here.

[2] UUW (2022) *What lessons can we learn from cost assessment at PR19?* Available here.

2. Water models

2.1 Water resources

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	Companies that serve more customers require more water resources. A higher number of sources can lead to increased complexity of the supply system.	Properties, which aligns with Ofwat's PR19 WRP models.
Reservoir dam maintenance	Companies must ensure that each dam in their impounding reservoir fleet meets safety standards. Since the Toddbrook dam safety incident of 2019 these dam safety regulations have been enforced with increasing rigour. Compliance with legal requirements drives high maintenance requirements per dam and leads to increased costs for companies with large dam fleets. This factor will also reflect pumping requirements to an extent as a higher relative number of impounding reservoirs will lead to lower pumping requirements, all else equal.	Number of impounding reservoirs per unit of distribution input. We have normalised this variable to prevent correlation with scale. We have used total number of impounding reservoirs, which counts each individual reservoir in a chain separately. This is better able to reflect the maintenance requirements associated with each dam.
Pumping	Certain water resources types will be associated with higher pumping requirements, for example boreholes. This increases associated operating and maintenance costs. A reflection of pumping is required in a water resources split because there is no related treatment complexity measure like in Ofwat's PR19 water resources plus models that is capable of reflecting pumping requirements. In dry weather conditions, companies with a large proportion of surface water may need to increase pumping within water resources to ensure sufficiency across their region.	Percentage of distribution derived from groundwater sources. We exclude river abstractions from this measure because the pumping requirement is minimal when compared to groundwater sources.

2.2 Water resources plus

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	Companies that serve more customers require more water resources. A higher number of sources can lead to increased complexity of the supply system.	Properties, which aligns with Ofwat's PR19 WRP models

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Treatment complexity	Companies that source a large proportion of their DI from surface water sources will need to engage in more complex treatment to remove all contaminants that enter surface water sources from the environment. This is because surface water sources are heavily susceptible to environmental factors. During storm events debris and material can be washed into the reservoir/river, affecting levels of turbidity, colour and chemical composition. Similarly, during hot weather, rivers and reservoirs can be affected by algae and cyanobacteria (blue/green algae) which can generate compounds which affect the taste and smell of the water for customers. Surface water therefore requires more complex treatment processes, to accommodate the variable water quality. This driver will also reflect pumping requirements as groundwater is associated with less complex treatment requirements.	% of water treated in bands 1-3 and weighted average complexity, which aligns with Ofwat's PR19 models.
Reservoir dam maintenance	Companies must ensure that each dam in their impounding reservoir fleet meets safety standards. Since the Toddbrook dam safety incident of 2019 these dam safety regulations have been enforced with increasing rigour. This drives high maintenance requirements per dam and leads to increased costs for companies with large dam fleets. Crucially, this won't be reflected by the treatment complexity variables because although reservoir sources are associated with higher treatment complexity, the key cost driver is the number of dams a company has to maintain. This information wouldn't be captured by a treatment complexity variable.	Number of impounding reservoirs per unit of distribution input. We have normalised this variable to prevent correlation with the scale variable.
Economies of scale	Larger treatment works are able to benefit from lower unit costs of treatment.	Weighted average population density, derived at a Middle-layer Super Output Area (MSOA) level with an associated squared term. This reflects areas where companies serve a densely populated region and can rationalise their treatment assets.

2.3 Treated water distribution

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	More customers require a company to operate a larger network and incur higher costs as a result.	Length of mains, which aligns to Ofwat's PR19 model.
Population density	Providing services in a highly dense area can drive higher costs because it is harder to schedule and carry out work on the network. Conversely, highly rural regions present operational challenges through a highly dispersed population meaning more assets must be operated per customer, leading to higher unit costs overall.	Weighted average population density, derived at a Middle-layer Super Output Area (MSOA) level with an associated squared term. In theory, the squared term allows the model to reflect the increased costs at both ends of the density spectrum through a U-shaped parabola. We consider this is appropriate in principle, however we note that this should apply at the MSOA level, not at the company level. In particular, one would expect that a company with an equal number of very sparse and very densely populated MSOAs would have higher costs than a company with only "average" density MSOAs. Rather than squaring the average density of the MSOAs in a company's region, it may be more appropriate to square the average of the root-squared MSOA level data. We intend to consider this issue further in the future.

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Topography	Water must be pumped to customers against the influence of gravity and friction. More pumping requirements mean that more pumping assets need to be operated and maintained.	Number of booster pumps normalised by mains length, which aligns to Ofwat's PR19 model. While average pumping head is frequently represented as a more suitable driver, it seems clear to us that the number of booster pumping stations is superior. The recent Turner and Townsend report revealed material issues around the consistency of how pumping head is estimated and reported across the industry. Although pumping head may appear, superficially, to be more exogenous than booster pumping stations, the variation between companies and over time in the calculation methods used to estimate pumping head make this driver too endogenous to be relied upon. We therefore strongly oppose the use of pumping head in cost assessment until these data consistency issues are resolved. We set out our concerns in section 2.6. In the context of a variable that is inconsistent across the industry, it's reasonable to assume that companies will have developed an asset base they need to overcome the influence of pumping head. Therefore, using booster pumps should appropriately reflect pumping requirements across the industry. This aligns with our principles of cost assessment[3], whereby variables that are under the influence of companies, but only in the long-term, can be used in the absence of an appropriate consistent, exogenous variable. Additionally, an asset-based measure may be more capable of reflecting maintenance requirements.

2.4 Water network plus

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	More customers require a company to operate a larger asset base and incur higher costs as a result.	Length of mains, which aligns to Ofwat's PR19 model.

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[3] UUW (2021) *The principles of regulatory cost assessment.* Available here.

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Population density	A densely populated region provides the opportunity for companies to benefit from economies of scale in treatment. Conversely, it can also driver higher costs through the challenges that operating on a denser network imposes. Finally, a less densely populated region provides less scope to benefit from economies of scale in treatment and could lead to higher costs on the network, due to the challenges of operating in rural environments.	Weighted average population density, derived at a Middle-layer Super Output Area (MSOA) level with an associated squared term. The squared term allows the model to reflect the increased costs at both ends of the density spectrum, although the potential problem with this assumption noted in section 2.3 may also be relevant here. The coefficient should reflect the net effect of the opposing effects of different levels of population density on cost.
Topography	As per section 2.3. We also note that the Water Network Plus split is better able to control for differences in pump configuration across the value chain boundary across the industry.	As per section 2.3.
Treatment complexity	As per section 2.2.	As per section 2.2.

2.5 Wholesale water

All relevant cost drivers have been captured in the preceding discussion.

2.6 The Turner & Townsend report demonstrates that pumping head is not robust enough to use in cost assessment at PR24

Pumping head reflects the work that companies' pumps are required to do, for example by capturing the height water must be pumped and frictional losses from the edges of the pipe. In theory, it is an appealing cost driver for power costs. However, at PR19 Ofwat did not use the measure due to serious concerns about its robustness and consistency. Pumping head is not directly measured – it is a theoretical calculation that is subject to many assumptions, and is very susceptible to differences in individual company methodology (in this respect, we consider that this driver is, effectively, endogenous). However, companies continue to promote its use, despite the evident major shortcomings and inconsistencies in its estimation. UUW's cost assessment principles paper[4] suggests that any variable that is subject to immediate management influence should not be considered for inclusion within cost assessment. We consider this is the case with pumping head, due to the sensitivity of the measure to the estimation method.

Despite this, the industry (in conjunction with Ofwat and Turner & Townsend) has recently undertaken a major exercise to better understand differences in methodology across each company. The aim was to establish best practice and a suitable path forward so that pumping head can be confidently used at future price reviews. However, the report highlighted significant discrepancies across the industry, such that we do not support the use

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[4] UUW (2021) *The principles of regulatory cost assessment.* Available here.

of pumping head within cost assessment until these are sufficiently addressed and independently verified (now and in the future). For example:

- Table 3 shows that there is significant variation in the proportion of APH that is based upon measured data and a wide variety in the proportion of sites that use measured data.
- Table 5 in T&T's report revealed a wide variety of approaches to measuring and estimating pumping head. We do not consider that this will produce data that is consistent across companies. Additionally, we note that different companies may have different definitions of 'measured'.
- APH related to water exports should not be included in APH, but seven companies do. This issue should be rectified going forward, but historic data will still be inconsistent.
- T&T made some recommendations but we are not aware of any significant progress being made against these.
- We would also note that companies tend not to use APH operationally so have historically not been incentivised to focus on improving measurements.

The issues highlighted above (and additional issues set out within the report not covered here) mean that two companies with otherwise identical asset bases and topographical features, but which have different approaches to estimating/reflecting pumping head, will have entirely different pumping head values. This outcome is entirely contrary to the benchmarking process and would pose serious doubts as to the appropriateness of any cost assessment modelling resulting from the use of a pumping head as a cost driver.

Additionally, the sensitivity of pumping head to differences in methodology and the wide range of methodological approaches across the industry documented by T&T raises the possibility that this measure is potentially under the influence of companies (and is, effectively, endogenous). We do not consider that this is aligned with Ofwat's principle to focus upon exogenous cost drivers.

In our view, these considerations raise significant concerns about the consistency of this data over the historical period of the dataset. Even if the industry improves pumping head reporting in a consistent way in the future, it won't be possible to backcast this more consistent approach. This means that the historical dataset used as part of cost assessment will continue to reflect inconsistent data and methodological differences well into the future.

Instead, we support the continued use of booster pumping stations per length of main. This represents an easily verifiable and consistent data source, which is also capable of reflecting a wider variety of costs than APH; APH focuses upon power cost, whereas booster pumping stations is an asset based measure, meaning it reflects maintenance requirements as well. As a result, we do not consider booster pumping stations to be a poor reflection of pumping head. We consider the opposite is the case – it is not within company control in the short term, and is more readily verifiable and consistent, and is therefore the most appropriate exogenous cost driver available.

3. Wastewater models

3.1 Sewage collection

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	More customers require a company to operate a larger network and incur higher costs as a result.	Total length of public and formerly private sewers, which aligns to Ofwat's PR19 model.
Population density	Providing services to a densely populated region can act to increase costs on the wastewater network. For example, it is more difficult to schedule and carry out work in busy areas. Unlike water, we do not consider there to be a U-shaped relationship between density and cost. Sewer networks are more of a passive asset than water networks, which means there is limited scope for additional related costs. Additionally, some very rural areas tend to use septic tanks meaning there will be limited associated network costs in these areas (contrary to the supply of water services to rural areas) or there may be a very small works nearby, which would minimise costs in the local network.	Weighted average population density, derived at a Middle-layer Super Output Area (MSOA) level, which aligns with Ofwat's PR19 model (noting that we are using a more granular measure of WAD than Ofwat did at PR19).
Topography	Although sewers are gravity-fed wherever possible, in some areas it's necessary to pump sewage against gravity. This can present significant operational problems in certain areas, particularly bowl-shaped areas. Manchester is one such area, which can be represented as a densely populated bowl. The natural drainage route to the Mersey is a major chokepoint and can become overwhelmed at times of heavy rain, particularly when there is significant run-off from the surrounding Pennines. We note that this reveals an interrelationship between topography and urban run-off.	Pumping capacity per length, which aligns with Ofwat's PR19 model. However, our recent work on the drivers of sewer flooding highlighted some concerns over how well this driver reflects issues like that encountered in Manchester.

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Urban run-off	Urban run-off is rainfall onto urban areas, which tends to drain into the sewer network. In regions where there is consistent heavy rainfall, this can lead to hydraulic and pluvial issues. Climate change is predicted to make this problem worse, with forecasts of more rain being compounded by urban creep, where green land that naturally drains water is replaced by impermeable surfaces in turn causing more rainfall to enter the sewer system. Urban run-off leads to more activity on the sewer network. For example, increased levels of sewer maintenance are needed to maximise the hydraulic capacity of the existing network while targeted capital investment is required to increase capacity in problem areas. Our work in this area has revealed a clear, compounding relationship between urban run-off and the prevalence of combined sewers; combined sewers reduce the capacity of the network during heavy rainfall and this reduced capacity can lead to significant hydraulic issues. This means that the impact of urban run-off is worse in areas with a high prevalence of combined sewers.	Urban rainfall per sewer length, where the urban element is reflected at the MSOA level. We use urban rainfall because this best reflects urban run-off. We also implement an interaction term where urban rainfall is multiplied by the % of combined sewers, which captures the compounding effect of high urban run-off and a high prevalence of combined sewers. We consider that a granular understanding of urban areas will best reflect urban run-off which is why we prefer the MSOA definition of urban. We are currently considering whether it is feasible to implement an even more granular definition of urban areas as part of an urban rainfall measure. We will provide more details of this in future.
Combined sewers	Combined sewers operate at hydraulic capacity for a larger proportion of the time which means that more maintenance activity is required to maximise the capacity available – the asset is ‘worked’ harder. For example, combined sewers tend to have higher average flow than a separate system, which means that a blockage or collapse on a combined sewer has more potential to cause operational issues than on an equivalent separate system. As noted above, there is a clear compounding, relationship between combined sewers and urban run-off, which makes the effect of urban run-off more severe in areas where there is a high prevalence of combined sewers.	Combined sewers as a percentage of legacy and formerly private sewers. We also implement an interaction term where urban rainfall is multiplied by the % of combined sewers, which captures the compounding effect of high urban run-off and a high prevalence of combined sewers.

3.2 Sewage treatment

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	More customers require a company to operate a larger asset base and incur higher costs as a result.	Load, which aligns with Ofwat's PR19 model.
Treatment complexity	WaSCs must treat sewage to a permitted level before discharging it back into the environment. Stringent permits result in higher operating costs, for example, through the purchase of additional chemicals, the operation/maintenance of UV assets and the higher costs associated with additional treatment stages. Internal estimates suggest that the installation of a UV treatment stage at a WwTW tends to increase costs at that works by around 15%. At PR19, Ofwat focused upon ammonia consents. We consider that if this variable is used again at PR24, it must be supplemented with a variable that reflects UV treatment requirements.	The weighted average number of days on which UV treatment is required, across permitted levels greater and less than 30mW/s/cm i.e. the total number of days on which a UV treatment stage with any permit was operated. We have also reflected days where a UV treatment stage with a permit greater than 30mW/s/cm was in operation i.e. excluding UV rigs with a permit less than 30mW/s/cm. This reflects the incremental increase in costs as UV treatment becomes more intense. The number of days is the key cost driver of interest as this relates best to the power maintenance requirement of a UV treatment stage. For example, the more days a UV treatment stage is in operation, the higher the need to replace UV bulbs.
Population density	Higher population density makes it economical to operate larger treatment works, which are better able to benefit from lower unit costs due to economies of scale. As Arup and Vivid Economics demonstrated[5], economies of scale exist at the asset level rather than the company level.	% load treated in bands 1-3 and % load treated above band 5, which aligns to Ofwat's PR19 models. These measures are able to reflect the fact that economies of scale exist at the asset level rather than a company level.

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[5] Arup and Vivid Economics (2017) *Understanding the exogenous drivers of wholesale wastewater costs in England and Wales*. Available here.

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Urban run-off	Urban run-off drains to a wastewater company's network and is then transported for treatment to the treatment works. This means that higher volumes of sewage need to be treated, which isn't reflected in load as load is derived using population information. More sewage leads to more pumping and leads companies to build assets with more capacity, in turn increasing maintenance requirements.	We have not included any treatment specifications that include rainfall, although we do observe higher volumes of wastewater drive higher costs within sewage treatment. We will consider this further in future.

3.3 Wastewater network plus

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	More customers require a company to operate a larger asset base and incur higher costs as a result.	Properties. We consider that this is best able to reflect scale both on the network and within wastewater treatment.
Treatment complexity	As per section 3.2	As per section 3.2
Population density	Providing services to a densely populated region can act to increase costs on the wastewater network. For example, it is more difficult to schedule and carry out work in busy areas. As per section 3.1, we do not consider there to be a U-shaped relationship between costs and density on the wastewater network. On the other hand, as per section 3.2, a densely populated region allows companies to benefit from economies of scale in their treatment assets.	% load treated in bands 1-3 and % load treated above band 5, which aligns to Ofwat's PR19 models. We consider that the variables used to capture population density for sewage treatment are capable of reflecting population density on the network. For example, a company serving a densely populated network will tend to have a higher % of load treated in WwTW assets above band 5.

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Urban run-off	Urban run-off leads to more activity on the sewer network. For example, increased levels of sewer maintenance is needed to maximise the hydraulic capacity of the existing network while targeted capital investment is required to increase capacity in problem areas. Urban run-off drains to a wastewater company's network and is then transported for treatment to the treatment works. This means that higher volumes of sewage need to be treated, which isn't reflected in load as load is derived using population information. More sewage leads to more pumping and leads companies to build assets with more capacity, in turn increasing maintenance requirements.	Urban rainfall per sewer length, where the urban element is reflected at the MSOA level. We use urban rainfall because this best reflects urban run-off into the network and also what arrives at the WwTW.

3.4 Bioresources

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	More customers require a company to operate a larger asset base and incur higher costs as a result.	Sludge produced, which aligns to Ofwat's PR19 approach.
Population density	Higher population density makes it economical to operate larger treatment works, which are better able to benefit from lower unit costs due to economies of scale. It also means that the distance between WwTW and Bioresources assets is likely to smaller, all else equal, reducing sludge transport costs. On the other hand, a denser region makes it harder to companies to spread sludge to land because there is likely to be less available land bank, leading companies to either drive further to dispose of sludge or adopt more expensive disposal processes. This will tend to increase sludge disposal costs.	Weighted average population density, derived at a Middle-layer Super Output Area (MSOA) level, which aligns with Ofwat's PR19 model (noting that we are proposing a more granular measure of WAD than Ofwat did at PR19). Number of WwTW per property, which aligns with Ofwat's PR19 model. These measures are able to reflect the fact that economies of scale exist at the asset level rather than a company level.

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
		% sludge produced at co-located assets, which replaces Ofwat's PR19 variable of % load treated in bands 1-3.
Rurality/asset configuration	Companies with more assets in rural locations can face higher transport costs when moving sludge from smaller WwTW to larger Bioresources assets. Additionally, we note Ofwat's intention to move towards a Bioresources-only model and associated efficiency challenge. We have previously represented our concerns about this approach to Ofwat if suitable care is not taken to reflect how companies configured their assets prior to the boundary between Bioresources and WwNP being drawn – this approach risks making companies with a larger proportion of their assets within WwNP appear efficient within Bioresources. We appreciate that Ofwat has stated companies should seek to be efficient across their entire value chain but WwNP is subject to cost sharing with customers whereas Bioresources is not – this creates an asymmetric impact across the industry that is not related to underlying efficiency.	We consider that this measure is better able to reflect asset configuration than the PR19 measure. Sites in bands 1-3 tend to produce poorer quality sludge, which is most likely to be tankered to the inlet of a larger WwTW for further processing in WwNP prior to crossing the price control boundary. This work including the transport cost is reported in WwNP. We consider % co-location is potentially a better measure of asset configuration because less co-location requires more work to be done within the Bioresources price control, such as increased dewatering at intermediate sites with onward transportation to AD centres which is all reported in the Bioresources price control. This activity means that % co-location will correlate more closely with the asset configuration across the Bioresources price control boundary. The coefficient will reflect the net effect of rurality and asset configuration.

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Treatment complexity	As P consents within wastewater treatment become increasingly stringent, the amount of inert material received by Bioresources will increase. This reduces the potential to generate energy from Bioresources and lead companies to adopt more complex Bioresources processes to address increased levels of inert material within sludge. For example, more stringent Phosphorous consents will lead to higher concentrations of phosphorous within the sludge received by Bioresources. We expect this driver to become increasingly relevant from AMP8 onwards. There may also be validity in exploring other treatment complexity variables, such as %AAD if these produce appropriate coefficients that align with engineering, operational and economic rationale.	% load treated at sites with a P consent less than 1mg/l. A consent of 1 is relatively stringent by (current) industry standards. This ensures that the model reflects the high concentrations of inert material produced by related P removal processes.

3.5 Bioresources plus

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Scale	As per sections 3.2 and 3.4	Load, which aligns with Ofwat's PR19 model approach
Population density	As per sections 3.2 and 3.4	As per section 3.2
Asset configuration	We note Ofwat's intention to move towards a Bioresources-only model and associated efficiency challenge. We have previously represented our concerns about this approach to Ofwat if suitable care is not taken to reflect how companies configured their assets prior to the boundary between Bioresources and WwNP being drawn – this approach risks making companies with a larger proportion of their assets within WwNP appear efficient within Bioresources. Adopting a Bioresources plus model split ensures that the model fully reflects any cost inter-relationship between wastewater treatment and Bioresources. We note that the same logic has led Ofwat to adopt a Water Resources Plus model split.	No cost driver is needed to reflect asset configuration due to the cost aggregation used in a Bioresources plus model.

Cost driver	Engineering, operational and economic rationale	How we have reflected the cost driver in the model
Treatment complexity	As per section 3.2	As per section 3.2

4. Residential retail

4.1 Bad debt

Cost driver	Operational and economic rationale	How we have reflected the cost driver in the model
Scale	More customers require a company to scale up operations and incur higher costs as a result.	We have structured our models as unit cost models, which aligns with Ofwat's approach at PR19.
Bill size	A larger wholesale bill size increases the retail business's exposure to each customer defaulting on bill payments.	Wholesale revenue per customer (residential)
Deprivation	Higher levels of deprivation within a region increases the likelihood that a company's customers default on bill payments. These defaults form the basis of bad debt costs. We note that past work by Reckon[6] identified that levels of bad debt are influenced more by levels of extreme deprivation than average deprivation. We are considering appropriate measures of extreme deprivation for cost modelling purposes and will share insight in future if these prove a more powerful explanatory of bad debt costs.	Income score, Equifax % default and Equifax credit risk score. The income score is a well understood measure. UUW uses the Equifax credit risk score internally to better understand which customers are at risk of falling into default to help us target help to those most in need of assistance. We will continue to consider appropriate measures of extreme deprivation to include in bad debt models.
Covid-19	We consider that there is a risk of a structural break within the historical panel due to the effect of Covid-19. Companies increased bad debt provisions and some customers faced increased hardship due to lower incomes.	We consider the 'smoothed' bad debt costs collected by Ofwat appear to be an appropriate way to mitigate the impact of higher bad debt provisions. The income score may not be as capable at explaining bad debt costs relating to covid. This is because this measure is only updated every few years, meaning it is less able to reflect year-on-year changes in bad debt costs. A measure that changes year-on-year, like those derived using Equifax data, may be better at appropriately reflecting the impacts of covid-19. We will further consider approaches which control for the change in the retail operating environment over time.

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[6] Reckon (2017) *Capturing deprivation and arrears risk in household retail cost assessment.* Available here.

4.2 Retail other costs

Cost driver	Operational and economic rationale	How we have reflected the cost driver in the model
Scale	More customers require a company to scale up operations and incur higher costs as a result.	We have structured our models as unit cost models, which aligns with Ofwat's approach at PR19.
Economies of scope	Water and wastewater companies provide two services to their customers, relative to water-only companies, which only provide one. Providing two services increases the potential for customer contact, which increases costs. Economies of scope mean that we would not expect costs to double when service provision doubles. The coefficient will reflect the economy of scope	% of customers receiving a water and wastewater service
Metering	It is the retailer's responsibility to read customer meters. Historically, this activity has led to higher costs. However, the advent of smart meters may facilitate significant cost savings for residential retail, meaning the relevance and significance of metering as a cost driver would be diminished. We also note that smart meters are helping companies to support customers to manage water usage and payments, avoiding bill shocks, and thereby bringing down operational costs. Additionally, it's possible for retailers to minimise meter reading costs by finding meter reading efficiencies e.g. using AMR meters to allow meter reading technology to be fitted to public service vehicles and take meter readings remotely. We consider metering may become a less relevant cost driver in future.	% meter penetration

4.3 Total retail costs

Cost driver	Operational and economic rationale	How we have reflected the cost driver in the model
Scale	As per sections 4.1 and 4.2	As per sections 4.1 and 4.2
Bill size	As per sections 4.1 and 4.2	As per sections 4.1 and 4.2
Deprivation	As per sections 4.1 and 4.2	As per sections 4.1 and 4.2
Covid-19	As per sections 4.1 and 4.2	As per sections 4.1 and 4.2

Cost driver	Operational and economic rationale	How we have reflected the cost driver in the model
Economies of scope	As per sections 4.1 and 4.2	As per sections 4.1 and 4.2
Metering	As per sections 4.1 and 4.2	As per sections 4.1 and 4.2

5. Corrections to wastewater data

The modelling process has required close examination of the datasets provided by Ofwat. This has revealed two issues with UUW's wastewater data. We have sought to correct these and have included corrected data within our submission. This section sets out more details about this.

5.1 Corrections to UV data

Following a review of our UV position versus others in the industry, we consider that the figures we previously reported for UV may differ from the definition Ofwat intended companies to provide. Ofwat asked for:

"Weighted average number of days that UV permit applies per year for STWs in size band [1]. This is to account for any seasonal application of UV permits. Please use the ratio of load of each STW where a UV permit applies and total load of STWs where a UV permit applies as the weight of each STW. These weights should be multiplied by the number of days the UV permit applies for each relevant STW and summed up to calculate a weighted average".

We initially interpreted this definition as asking for the weighted days **across all** size bands, rather than the weighted days **within each** size bands. Upon reflection, we realise it was Ofwat's intention to collect information about treatment days **within each size band**, as this better facilitates comparison between companies as part of cost assessment. The assumption underlying our initial approach can be seen by summing the 'total weighted days' data across all size bands that we initially provided to Ofwat, as set out in Table 1. This totals 365.

Table 1 UUW's UV data as set out in 'PR24_Cost_Assessment_Master_Dataset_Wholesale_Wastewater_Base_Costs_v3'

UUW values only	Weighted average number of days that UV permit applies per year for STWs in size band 1 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs in size band 2 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs in size band 3 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs in size band 4 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs in size band 5 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs above size band 6 - UV treatment works consents - Total	Total across all size bands
2011-12	0.038	0.172	2.056	16.325	14.094	332.314	365
2012-13	0.025	0.133	1.557	13.258	17.164	332.863	365
2013-14	0.022	0.122	1.679	12.714	20.874	329.589	365
2014-15	0.020	0.130	1.642	12.294	20.291	330.622	365
2015-16	0.020	0.000	1.793	12.280	20.435	330.470	365
2016-17	0.017	0.125	1.601	11.604	19.725	331.928	365
2017-18	0.063	0.112	1.551	11.519	18.912	332.844	365
2018-19	0.063	0.113	1.562	11.965	18.864	332.433	365
2019-20	0.065	0.111	1.602	11.769	19.039	332.414	365
2020-21	0.146	0.114	1.471	13.386	17.887	331.996	365
2021-22	0.147	0.113	1.486	12.979	17.889	332.385	365

This can be compared with our updated data, which we consider aligns with Ofwat's line definition and is set out in Table 2. As noted above, this reflects the weighted average number of days of UV treatment **within** each size band of UV works.

Table 2 UUW's UV data as set out in 'PR24_Cost_Assessment_Master_Dataset_Wholesale_Wastewater_Base_Costs_v3 UV and colocation correction' (supplied with UUW's submission)

UUW values only	Weighted average number of days that UV permit applies per year for STWs in size band 1 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs in size band 2 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs in size band 3 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs in size band 4 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs in size band 5 - UV treatment works consents - Total	Weighted average number of days that UV permit applies per year for STWs above size band 6 - UV treatment works consents - Total	Total across all size bands
2011-12	365	365	365	365	365	365	2,190
2012-13	365	365	365	365	365	365	2,190
2013-14	365	365	365	365	365	365	2,190
2014-15	365	365	365	365	365	365	2,190
2015-16	365	0	365	365	365	365	2,190
2016-17	365	365	365	365	365	365	2,190
2017-18	365	365	365	365	365	365	2,190
2018-19	365	365	365	365	365	365	2,190
2019-20	365	365	365	365	365	365	2,190
2020-21	365	365	365	365	365	365	2,190
2021-22	365	365	365	365	365	365	2,190

We request that Ofwat updates UUW's UV data within its records accordingly. We have provided an updated version of the relevant table from the UV information request within our submission, which sets out our corrected UV data. We have also provided a version of Ofwat's base cost assessment data file that includes corrected UV data.

5.2 Corrections to co-location data

We consider there may have been a transposition isue in the MP05615 column (000s, Percentage of sludge produced and treated at a site of STW and STC co-location). We requested an update to the Ofwat base dataset to reflect our updated, more appropriate methodology, as part of the wider data validation exercise following Ofwat's creation of the base data files for cost assessment.

The revised data (as submitted by UUW) is shown below. This required a revision to the figures from FY12 to FY18. The data from FY19 to FY22 did not require an amendment, so was intentionally left blank in the return. Note the percentage is displayed in a decimal format.

Table 3 - UUW's revised data submitted to the data validation exercise

2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
0.288	0.346	0.331	0.331	0.326	0.308	0.308				

What we believe may have happened is that all eleven values (FY12 to FY22) have been amended by Ofwat, rather than the stated seven. This has meant FY19 to FY22 data which was intentionally left blank now incorrectly pulls through to the dataset as four zeros.

The correct full dataset for all eleven years is shown below. We request that Ofwat updates the master dataset to reflect these additional years.

Table 4 - UUW's revised data – blank years added

2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
0.288	0.346	0.331	0.331	0.326	0.308	0.308	0.333	0.316	0.290	0.306

United Utilities Water Limited
Haweswater House
Lingley Mere Business Park
Lingley Green Avenue
Great Sankey
Warrington
WA5 3LP

unitedutilities.com

United Utilities

Water for the North West