# CMA Provisional Findings on Redetermination of Ofwat’s 2019 Final Price Determinations

## Third party submission to the CMA on Botex cost assessment

**October 2020**

Professor David Saal

Centre for Productivity and Performance
School of Business and Economics
Loughborough University
Loughborough, LE11 3TU
UK

## Introduction and Motivation

It is well known that during PR2019 I have worked closely with Anglian Water, but I emphasize that I now write as an academic and practitioner of cost modelling who is genuinely concerned with regard to the regulatory precedent that the CMA will set if its Final Determinations remain unchanged from its Provisional Findings. By accepting almost all of Ofwat's cost assessment modelling, and as a result, the flawed cost modelling framework Ofwat has relied on to justify its models, the CMA's provisional findings indicate to Ofwat and other regulators that basic cost assessment practices and standards need not be maintained. When we consider that Ofwat's Wholesale Botex modelling assessed a total of £17.7 billion of Wholesale Wastewater costs, and £17.4 billion of Wholesale Water Costs, a higher standard should be set with regard to the quality and robustness of cost assessment modelling, than the CMA has set. Moreover, I believe that evidence that I have either directly provided to the CMA or indirectly provided via Anglian Water has not been duly considered in your Provisional Determinations.

I firstly briefly summarize some of the evidence that I have provided the CMA, which I believe has not been properly considered in your Provisional Findings, and its implications. While I will highlight previously submitted evidence that demonstrates that both Ofwat's Water and Wastewater modelling is flawed, I will not propose alternative modelling for water, and particularly trust that the CMA will consider and address concerns with regard to Ofwat's integrated wholesale water models.

As it appears that the case with regard to the inappropriateness of Ofwat's modelling still needs to be made, I then provide a detailed assessment of Ofwat's Wholesale Wastewater models, demonstrate their lack of robustness, and also demonstrate that relatively simple changes to these models can be used to provide economically, and econometrically robust cost estimates. In sum, I believe the modelling provided here unequivocally demonstrates the flaws in Ofwat's wholesale wastewater modelling, but also provides potential solutions that the CMA could employ. E.g. I believe that the alternative models provided here provide a set of models that are broadly consistent with Ofwat's modelling choices and variable selections, that can provide a robust bottom up assessment of Botex costs.

However, as with Water, Ofwat should have triangulated its models with an Integrated Wholesale Wastewater model, and my reading of the CMA Provisional Findings suggest that is has only considered the model that I and my colleague provided in our assessment of Ofwat's IAP modelling,[1] which I agree with the CMA was not robust after Ofwat changed its cost definitions and added a year of data for its Final Determinations. I must emphasize that the original purpose of that model was not to put forward a definitive model but to refute Ofwat's assertions at IAP that it could not develop an integrated model and thereby encourage it to do so. Anglian Water sponsored my colleague Maria Nieswand and I to develop robust alternative Collection, Bioresource Plus and Integrated Wholesale Water models, and submitted a brief report, and more than a dozen

[1] Saal and Nieswand (2019) A Review of Ofwat's January 2019 Wholesale Water and Wastewater Botex Cost Assessment Modelling for PR19. March 2019 -– A report commissioned and published by Anglian Water https://www.anglianwater.co.uk/siteassets/household/about-us/5a-final-report-assessment-of-ofwat-cost-modelling-for-anglian-water.pdf

supporting Stata codes and worksheets underlying that report to the CMA.[2] However, the CMA has not appeared to considered this evidence in its Provisional Findings. Most significantly, these models include integrated wastewater and bioresource plus models that rely on Ofwat's threshold density control variables and do not rely on the partially extrapolated data for large plant shares that the CMA rejected in its Provisional Findings. Thus, the CMA already has access to a credible integrated wholesale wastewater model with which it can triangulate a bottom up assessment of costs.

## Further Evidence that has not Received Due Consideration by the CMA

The following evidence submitted to the CMA has not received appropriate consideration, noting that I am only focusing on some of the most important omissions, which I believe will materially alter your determinations.

- The CMA has received but does not appear to have considered evidence that unequivocally demonstrates that both of Ofwat's integrated wholesale water models are systematically biased that was summarized in Saal & Nieswand (2020) with details provided on pages 12-18 of Saal(2019b).[3, 4] This is because both models not only impose an inappropriate and statistically rejectable parameter restriction, but also because Ofwat inappropriately **imposes** via this statistically rejectable parameter restriction that the **coefficient on the length of mains variable must be negative.** Thus, Ofwat's Integrated WW models are both statistically inappropriate and inappropriate as a model of costs because Ofwat **has actually imposed a negative relationship between costs and network length without testing if this is statistically appropriate in the model.** By accepting Ofwat's models the CMA is therefore accepting cost assessment of £17.4 billion of wholesale water costs that can be demonstrated to be systematically biased.

- The CMA appears not to have considered valid arguments that Ofwat's SWC2 model is not robust for regulatory cost assessment as this model includes a coefficient that would be considered insignificant in any normal practice.[5] By doing so, the CMA sets a poor regulatory

---

[2] Saal & Nieswand (2020b)"*Incrementally Improving Ofwat's Collection and Bioresource Plus Modelling, and Demonstrating the Feasibility of Integrated Wholesale Wastewater Regulatory Cost Assessment Modelling*" submitted as REP14 in Anglian Water PR19 Reply to Ofwat's Responses to Anglian's Statement of Case https://assets.publishing.service.gov.uk/media/5eda1d0ed3bf7f45fcf2c62c/REP01_REP10_Combined_Anglian_Reply_to_Ofwat_new.pdf

[3] Saal and Nieswand (2020): CMA Redetermination of Ofwat's 2019 Final Price Determinations: Third party submission to the CMA on Botex cost assessment. May 2020. https://assets.publishing.service.gov.uk/media/5ebebdd6d3bf7f5d37fa0da4/Saal_and_Nieswand__002__Redacted.pdf

[4] Saal (2019b) A Consideration and Correction of Systematic Bias in Ofwat's Integrated Wholesale Water Models – submitted to the CMA as a supporting document for Saal & Nieswand (2020)

[5] Nieswand & Saal (2020) Scrutinising Ofwat's PR19 Final Determination Models on Sewerage Collection: Economic Invalidity, Triangulation, and Non-transparency of Modelling Principles: Third party submission to the CMA on Botex cost assessment

precedent with regard to statistical inference and the level of appropriate significance that is required in a cost assessment model. Moreover, as per the analysis carried out in this document, the CMA would also be accepting that Ofwat does not appear to have corrected this problem by simply including the square of its logged density control in addition to the already included logged density control.

- As discussed further below in reference to my empirical consideration of Ofwat's wholesale wastewater modelling, it would appear that the CMA has misunderstood evidence emphasised by myself in Saal & Nieswand (2020) and by Anglian Water with regard to the inappropriateness of Ofwat's 8 year random effect models. Moreover, this misunderstanding would have been avoided if the CMA had considered the empirical evidence provided to it about this issue in Saal (2019b). This evidence demonstrated substantial bias in Ofwat's Integrated Wholesale Water Models, because Ofwat estimated efficiency for a five-year panel, while using a single random effect estimated with an 8 year panel model. Saal (2019b) also clearly demonstrated resolution of this issue involved using a five year panel consistent with the period that Ofwat was actually measuring efficiency for. We therefore urge the CMA to reconsider this issue, and to test the cost assessment implications of using a more appropriate five-year panel for cost assessment of both wholesale water and wastewater.

- For completeness, the evidence not duly considered by the CMA includes the set of collection, bioresource plus, and integrated wholesale water models in Saal & Nieswand (2020b), and already mentioned in the introduction. Most significantly, this potentially includes an integrated wholesale wastewater model that the CMA should consider to triangulate Ofwat's bottom up cost modelling with.

## Demonstrating and Correcting Misspecification in Ofwat's Wholesale Wastewater Modelling

### Sewage Collection Models

#### The Case Against Ofwat's Models and the CMA's Provisional Determination

Ofwat employed two sewage collection models which remained unchanged in their explanatory variables between the December 2019 Initial Assessment of Plans and its December 2020 Final Determinations, despite it having considerably changed the definition of modelled costs at both the DD and the FD[6]. Moreover, Ofwat in fact ignored clear evidence with regard to issues in the SWC1 model at the IAP put forward to it by Anglian Water in Saal & Nieswand (2019)[7] and used the same explanatory variables in both the DD and FD. This implies that the cost assessment of nonappealing companies was avoidably biased in Ofwat's Final Determination, because it did not take due consideration of evidence put forward to it as part of the PR2019 process.

This lack of a change in Ofwat's Sewage Collection modelling in the face of clear evidence is particularly emblematic of Ofwat's problematic approach to cost assessment in PR2019. However, while the CMA has appropriately rejected the use of SWC1 in its provisional findings , it has not rejected SWC2 despite evidence and arguments submitted to the CMA (Nieswand and Saal, 2020 pp. 11-13)[8] that this model is also invalid by standard statistical significance inference criterion.

Thus, the CMA's efficiency assessment determination of £5.862 billion of 2015-19 collection costs, and projection of these models forward in the price determination is not based on even a single model that can not in any way be considered robust for regulatory cost assessment by normal standards.

Moreover, despite the clear statistical inappropriateness of both of Ofwat's sewage collection models, the CMA appears not to have:

1. considered developing its own collection models (as it did in the PR2014 Bristol Water price determination case)
2. taken due consideration of alternative models that have been put forward by itself and other companies as part of the PR2019 regulatory process including at the Ofwat's cost assessment consultation exercise[9].

---

[6] Considerations of whether it is appropriate for a regulator to change cost definitions midstream and whether the resulting regulatory framework where such changes are required/allowed/appropriate/consistent are beyond the scope of this review.

[7] Saal and Nieswand (2019) A Review of Ofwat's January 2019 Wholesale Water and Wastewater Botex Cost Assessment Modelling for PR19. March 2019 -– A report commissioned and published by Anglian Water https://www.anglianwater.co.uk/siteassets/household/about-us/5a-final-report-assessment-of-ofwat-cost-modelling-for-anglian-water.pdf

[8] Nieswand & Saal (2020) Scrutinising Ofwat's PR19 Final Determination Models on Sewerage Collection: Economic Invalidity, Triangulation, and Non-transparency of Modelling Principles: Third party submission to the CMA on Botex cost assessment https://assets.publishing.service.gov.uk/media/5ebebd7286650c278d449745/Nieswand_and_Saal_Redacted.pdf

[9] https://www.ofwat.gov.uk/consultation/cost-assessment-pr19-consultation-econometric-modelling/

3. sought and/or published clarification from Ofwat about why its "robust" economic modelling approach" could not produce any economically or statistically robust sewage collection models
4. Queried and/or published details with regard to whether any of the over 1500 models that CEPA estimated for Ofwat, or as part of the further wastewater modelling done for Ofwat by Vivid economics[10], resulted in alternative economically and statistically robust collection models, regardless of whether such models fit within Ofwat's modelling framework.
5. Given any consideration of the model evidence and provided Stata coding demonstrating fundamental flaws in Ofwat's collection modelling (REP51 & REP61 ) nor the simple corrections of Ofwat's collection models contained within, as well as the more sophisticated sewage collection models that Anglian Water requested myself and Dr Maria put forward as in a report that was put forward as REP14 in Anglian Water's replies to Ofwat's response to Statements of Case.[11]

**Recommendations and Further Evidence**

Given the statistical invalidity of the sewage collection cost models underlying Ofwat's and hence the CMA's provisional determinations, I would therefore urge the CMA to

1. Provide due consideration to the sophisticated alternative approach to Collection Modelling developed by myself and Dr Nieswand and that Anglian Water chose to put forward on page 8-9 of REP14, In Anglian's replies to Ofwat's response to Statements Cases.

2. Perhaps more significantly, I would strongly urge the CMA to reconsider its blanket rejection of SWC1 and acceptance of SWC2, in favor of the evidence and incremental adjustments of these models demonstrated below. These arguments build from the evidence with regard to model mis-specification provided in Nieswand & Saal (2020) and the above mentioned REP51 & REP61, with the latter also providing further evidence with regard improving Ofwat's models. As argued below this approach requires a recognition of the issues with Ofwat's models, and an honest acknowledgement that once statistically inappropriate variables are removed, both SWC1 and SWC2 are at their core two output models. Simple addition of appropriate density controls, including either Ofwat's logged weighed average density and its square, or the alternative density controls based on the threshold density variables that Ofwat also developed as part of PR19, then provides statistically and economically robust corrections of Ofwat's SWC1 and SWC2 models, which then broadly

[10] Anglian Water Services Limited, Bristol Water Plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations: Provisional Findings, Competition and Markets Authority, 29 Sept 2020, page 101.
https://assets.publishing.service.gov.uk/media/5f7c467ee90e070dde709cee/Water_provisional_determinations_report_all_-_September_2020_---_web_-online-2.pdf

[11] Saal & Nieswand (2020b)"*Incrementally Improving Ofwat's Collection and Bioresource Plus Modelling, and Demonstrating the Feasibility of Integrated Wholesale Wastewater Regulatory Cost Assessment Modelling*" submitted as REP14 in Anglian Water PR19 Reply to Ofwat's Responses to Anglian's Statement of Case
https://assets.publishing.service.gov.uk/media/5eda1d0ed3bf7f45fcf2c62c/REP01_REP10_Combined_Anglian_Reply_to_Ofwat_new.pdf

remain consistent with its modelling approach. **Most fundamentally, adoption of these models will allow the CMA to build from Ofwat's preferred modelling approach and have a statistically robust triangulated assessment of sewage collection costs, and thereby avoiding the alternative effect endorsement of Ofwat's assessment of £5.9 billion of sewage collection costs, in the absence of statistically valid models**

## Providing Robust Extensions of SWC1 and SWC2 for Sewage Collection Regulatory Cost Assessment

**SWC1** – As already concluded by the CMA, the true underlying specification of SWC1 (re1) effectively employs only three scale variables (sewer length, properties and pumping capacity) and sewer length has an inappropriate negative sign and is statistically insignificant. While the CMA has chosen to simply exclude this model from its analysis, removal of the network length variable reveals the true basis of Ofwat's SWC1 model which includes a properties scale variable and a pumping control measured as total pumping capacity (re30). The simple addition of Ofwat's own preferred density controls (lnwedensitywastewater and lnsqrwedensitywastewater) provides a model (re33) that is not only fully consistent with the statistically significant variables included in SWC1, but also is consistent with Ofwat's standard approach of using a scale variable (properties) a pumping control (pumping capacity) and density controls.

Thus, simple mathematical understanding of the underlying estimated relationship in SWC1 coupled, with complete application of Ofwat's own modelling framework, rather than Ofwat's reliance on the mathematically invalid approach to controlling for density as ln(properties/sewer length), results in a fully valid alternative to SWC1.

**I therefore suggest that rather than simply abandoning use of SWC1, the CMA should consider the use of the Corrected SWC1 specification provided in specification re33 in the following table. Doing so would be consistent with the factors that Ofwat claims are important to control for in modelling, would improve the CMA's own cost assessment, but would also send a signal to future regulators that the quality of the underlying model specification, is more important than a rigid and, in this case, clearly econometrically inappropriate modelling framework**

**Moreover, I would also emphasise that Ofwat's steadfast insistence on the validity of its SWC1 model and its insistence that it adheres to its underlying modelling approach of "only including a single scale variable and controls", despite this issue having been raised at the IAP by Saal & Niewsand (2019), has had a significant negative impact on PR2019 as all companies price reviews have been impacted. It is therefore of great worth that the CMA has already signalled to future regulators with regard to taking due care with cost assessment specifications.**

**SWC2** – While the CMA accepted the arguments made in Nieswand & Saal (2020) and elsewhere that Ofwat's specification of SWC1 is invalid, its Provisional Determination has ignored the clear unequivocal case also made by Nieswand & Saal (2020) that Ofwat's SWC2 model (re2) is also not valid because it includes a statistically insignificant coefficient, as by any normal statistical standards a 0.146 probability on the logged density variable in this model should cause the researcher to reject the inclusion of this density control and to seek an alternative specification. It is therefore my opinion that the CMA has ignored valid evidence submitted to it, and also sent a clear signal to future regulators that they do not need to meet even meet basis standards of statistical inference when specifying their models. E.g. at face value, as argued by Nieswand & Saal (2020) neither SWC1 nor SWC2 where valid specifications, and the CMA should at a minimum have sought alternative Sewage collection models for its price redeterminations.

However, closer inspection of SWC2 after the CMA's provisional decisions reveals that the invalidity of this model appears to result from nothing more than  Ofwat's failure to follow its own standard practice, as demonstrated in its Wholesale Water modelling to include and/or test both the log and squared log of its weighted density control variable.  Moreover, it also appears to have resulted from Ofwat's failure to check if changes in its modelled cost definitions, as well as the extension of the sample period at FD, impacted its models.

Thus, at IAP, and despite a highly significant chi-squared test statistic of 50.69 for the joint significance of both the logged density term and its square demonstrated here , Ofwat did not include a squared density term in its IAP model.  This may or may not have been appropriate based on opinions with regard to individual coefficient significance tests at IAP, but  as noted by Saal & Nieswand (2019) it did result in Ofwat employing an SWC2 model  at IAP that implied that costs always **increased** with increased density.

**Ofwat's SWC2 model at IAP after adding lnsqrwedensitywastewater**

| lnrealbotexswc | Coef. | Robust Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lnsewerlength | .6883505 | .1039828 | 6.62 | 0.000 | .4845479 | .8921531 |
| lnpumpingcapperlength | .3279452 | .1559806 | 2.10 | 0.036 | .0222289 | .6336615 |
| lnwedensitywastewater | -2.064903 | 1.583292 | -1.30 | 0.192 | -5.168099 | 1.038293 |
| lnsqrwedensitywastewater | .1569232 | .1038333 | 1.51 | 0.131 | -.0465864 | .3604328 |
| _cons | 3.775657 | 5.932829 | 0.64 | 0.525 | -7.852475 | 15.40379 |
| sigma_u | .20369568 | | | | | |
| sigma_e | .09522398 | | | | | |
| rho | .82065486 | (fraction of variance due to u_i) | | | | |

**Ofwat's SWC2 model at FD after adding lnsqrwedensitywastewater**

| lnrealbotexswc | Coef. | Robust Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lnsewerlength | .8578102 | .1084003 | 7.91 | 0.000 | .6453495 | 1.070271 |
| lnpumpingcapperlength | .5839226 | .1845717 | 3.16 | 0.002 | .2221687 | .9456765 |
| lnwedensitywastewater | -2.564431 | 1.377875 | -1.86 | 0.063 | -5.265017 | .1361545 |
| lnsqrwedensitywastewater | .1853555 | .090482 | 2.05 | 0.041 | .0080141 | .362697 |
| _cons | 4.085201 | 5.092309 | 0.80 | 0.422 | -5.895541 | 14.06594 |
| sigma_u | .15613959 | | | | | |
| sigma_e | .08834018 | | | | | |
| rho | .75751635 | (fraction of variance due to u_i) | | | | |

However, it would seem reasonable that a regulator would do a basic test on the validity of its modelling after making changes not only to the time period estimated, but also the definition of costs to be modelled, and that if it argues for the use of density controls and squared terms in some models it should check the significance of these in its new models.  However, as demonstrated above Ofwat does not appear to have done even this basic re-estimation of its Final Determination

SWC2 model.  e.g both logged and squared weighted density would have been found to be statistically significant if Ofwat had properly specified its model.

I note that as density is commonly understood to have a nonlinear impact on costs, the simple revision of SWC2 illustrated here should be adopted for at least two reasons.   Firstly, as Ofwat's SWC2 model (re2) indicates that increasing density always has an increasing impact on costs, it is mis-specified as the simple inclusion of the squared term reveals that costs are decreasing in density, but that costs eventually will increase with higher density.  E.g. the revised specification is consistent with common understanding of the impact of density on cost.   Secondly, I believe it is again important to send a signal to future regulators that they must be more careful in their modelling and must make basic checks on model consistency when they changed the definition of modelled costs and period of estimation.

While this correction to can be done directly to Ofwat's SWC2 model, the below table takes  the approach of first revealing that SWC2 is really a fully equivalent model where sewerlength and pumping  are scale variables that, nonetheless,  capture the impact of size and pumping as standard in Ofwat's models (re29), which, as suggested above, should be corrected by simply adding a squared density term (re35).

Let us consider the suggested corrections to SWC1(re33) and SWC2(re35).  Both meet Ofwat's standards, as they include a scale variable, a pumping control, and a density control.  They include different scale controls, and therefore provide an appropriate triangulation, as despite the CMA asserting with regard to water models that because scale variables are highly correlated it is not necessary to consider alternative specifications, the accompanying cost assessment spreadsheet reveals considerable differences between models using alternative scale variables.  Furthermore, as specifications re28 & re30 and red29 & re31 respectively demonstrate for SWC1 & SWC2, these models are in fact fully consistent with the true underlying specifications that Ofwat used itself!

### Providing Appropriate Density Triangulation for Sewage Collection Modelling Using Ofwat's Density Threshold Controls

Ofwat's chosen models and arguments effectively illustrate that it required triangulation over density controls for sewage collection, although its misspecification of SWC1 meant that it only really included density controls in SWC2.  We therefore note, that while the corrected Ofwat models triangulate over different scale variables, they do not triangulate over density.  However, as demonstrated in the underlying work on sewage modelling submitted to the CMA as part of Anglian Water's response to Ofwat's response to its statement of case to the CMA Saal & Nieswand (2020b), Ofwat itself developed but abandoned effective density controls, which can be effectively implemented to provide the same nonlinear impact on collection costs described above.

Thus, by replacing Ofwat's weighted density controls, with Ofwat's own threshold based density controls, as demonstrated to the CMA but not considered by it in Saal & Nieswand (2020b), and the supporting Stata codes and worksheets accompanying it,  it is straight forward to triangulate the corrected versions of Ofwat's SWC1 and SWC2 models.  Thus, in both the threshold density alternative to SWC1 (re32) and SWC2 (re34) both the variables popdensity4000 and popdensity6000 are individually and statistically significant at at the least the standard accepted by Ofwat as revealed in its SWC2 model.   Moreover, the negative sign on popdensity4000 reveals that costs decrease as share of population living in areas with density greater increases.  However, this negative effect is offset by the positive sign on popdensity6000 as costs are increasing at density levels above 6000.

**In Sum, given the illustrated failings in Ofwat's models and the consistency of the proposed corrections to its modelling with Ofwat's underlying revealed modelling approach, the CMA should in its final determination, send a clear signal to future regulators and consider alternative and robust models of sewage collection such as those illustrated here.**

| **Collection Modelling - 8 Year Panel (2012-2019)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| | **SWC1 Model** | | | | | **SWC2 Model** | | | | |
| | Ofwat Models | | | Corrected Ofwat Models with its preferred density controls | Alt Ofwat Models with its Density Threshold Variables | | | | Corrected Ofwat Models with its preferred density controls | Alt Ofwat Models with its Density Threshold Variables |
| Model Robust for CA? | Ofwat SWC1 | Ofwat SWC1 restated | Ofwat SWC1 True | Corrected Ofwat SWC1 | Alt Ofwat SWC1 | Ofwat SWC2 | Ofwat SWC2 restated | Ofwat SWC2 True | Corrected Ofwat SWC2 | Alt Ofwat SWC2 |
| Model Robust for CA? | no removed by CMA | no removed by CMA | no nested in 32 and 33 | yes | yes | no density is insignificant | no density is insignificant | no reset test and nested in 34 and 35 | yes | Yes, within sig levels accepted by Ofwat in FD SWC2 |
| | re1 | re28 | re30 | re33 | re32 | re2 | re29 | re31 | re35 | re34 |
| | b/p | b/p | b/p | b/p | b/p | b/p | b/p | b/p | b/p | b/p |
| lnsewerlength | 0.839*** | -0.476 | | | | 0.896*** | 0.290* | 0.371** | 0.274* | 0.400*** |
| | {0.000} | {0.144} | | | | {0.000} | {0.095} | {0.018} | {0.063} | {0.004} |
| lnpumpingcapperlength | 0.317* | | | | | 0.606*** | | | | |
| | {0.080} | | | | | {0.006} | | | | |
| ln(properties/sewerlength) | 0.998*** | | | | | | | | | |
| | {0.005} | | | | | | | | | |
| lnpumpingcapacity | | 0.317* | 0.394** | 0.430** | 0.332** | | 0.606*** | 0.645*** | 0.584*** | 0.551*** |
| | | {0.080} | {0.023} | {0.012} | {0.013} | | {0.006} | {0.003} | {0.002} | {0.000} |
| lnproperties | | 0.998*** | 0.520*** | 0.414*** | 0.550*** | | | | | |
| | | {0.005} | {0.000} | {0.005} | {0.000} | | | | | |
| lnwedensitywastewater | | | | -2.179** | | 0.178 | 0.178 | | -2.564* | |
| | | | | {0.040} | | {0.146} | {0.146} | | {0.063} | |
| lnsqrwedensitywastewater | | | | 0.153** | | | | | 0.185** | |
| | | | | {0.030} | | | | | {0.041} | |
| popdensity4000 | | | | | -0.783*** | | | | | -0.782 |
| | | | | | {0.003} | | | | | {0.107} |
| popdensity6000 | | | | | 1.644*** | | | | | 2.054*** |
| | | | | | {0.000} | | | | | {0.001} |
| _cons | -8.124*** | -8.124*** | -7.189*** | 1.654 | -6.875*** | -6.415*** | -6.416*** | -6.451*** | 4.085 | -5.679*** |
| | {0.000} | {0.000} | {0.000} | {0.685} | {0.000} | {0.000} | {0.000} | {0.000} | {0.422} | {0.000} |
| | | | | | | | | | | |
| R_squared | 0.931 | 0.931 | 0.915 | 0.927 | 0.944 | 0.882 | 0.882 | 0.861 | 0.902 | 0.915 |
| RESET_P_value | 0.152 | 0.152 | 0.108 | 0.326 | 0.212 | 0.185 | 0.185 | 0.035 | 0.248 | 0.136 |
| N | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |

## Correcting Systematic Bias in Ofwat's Bioresource Modelling

Ofwat employed two specifications to triangulate its cost assessment of bioresources. Both models use the natural log of sludge produced as an appropriate scale variable, with BR1 using the percentage of load treated in size bands 1-3 and the log of Ofwat's preferred weighted average density measures, and BR2 using only the log of sewage treatment works per number of properties. However, neither of these models can be considered to be robust for regulatory cost assessment as can be easily demonstrated. Moreover, it is straightforward to produce corrected version of these models that are appropriate for regulatory cost assessment even within the rigid modelling framework that Ofwat has set itself.

In BR1 Ofwat relies on its favoured weighted average density measure, but it is noticeable that it does not include the squared term in the model, while its own precedent in wholesale water modelling suggests this may be appropriate. Simple comparison of BR1 (re5) and its extension to include the squared average density term and both of Ofwat's preferred sewage treatment plant size controls (pctbands13 and pctbands6) in re9 is doubly revealing.

Firstly, the inclusion of both density parameters is highly jointly significant, and the squared term is also individually significant at the 0.106 significance level, which is well within Ofwat's revealed standards, as exemplified by the 0.146 significance level of the weighted average density coefficient in its SWC2 model, and the 0.120 significance in its WRP2 model for the squared weighted density term. Thus, it would appear that the exclusion of the squared density term in the BR2 model by Ofwat is a good example of Ofwat's arbitrary approach to statistical inference, which as discussed above, was already raised by Nieswand and Saal (2020) in relation to the Ofwat's SWC2 model.

Secondly, the appropriate inclusion (by Ofwat's standards) of the logged weighted density term , and testing in a general to specific model of which of Ofwat's sewage plant size controls is statistically appropriate reveals that Ofwat's chosen control pctbands13 in BR1 is actually highly statistically insignificant while pctbands6 is highly statistically significant.

The resulting corrected BR1 Model (re10) remains fully consistent with Ofwat's chosen variables, and its modelling approach, as it includes a scale variable, density controls, and a sewage treatment plant size variable, and is therefore conceptually equivalent to Ofwat's BR1. However, in stark contrast, the model is statistically valid, as it is the appropriate specific model that should be tested down from the re9, while consideration of re9, demonstrates unequivocally that Ofwat's BR1 model (re1) is the inappropriate restriction of this model.

Moreover, when considered post-estimation, the model not only allows for a more robust impact of density with inclusion of a squared term , but is also consistent with what I believe is industry understanding is with regard to co-located treatment of sludge at a sewage treatment plant. E.g. this becomes feasible at a plant size of approximately 25,000 population equivalent, which is approximately the scale threshold for band 6 works.

In BR2 (re6) Ofwat understandably attempted to triangulate BR1, by considering the number of works per property served as the only added control variable other than the sludge scale variable in the model.

This model specification is therefore similar to that employed by Ofwat in its Integrated Wholesale Water Models (WW1 & WW2). E.g it includes a log of ratio, where the two variables in the ratio do not otherwise appear in the model. However, this is potentially problematic as brought to the CMA's attention in the attachments that were summarised and included in the Saal & Nieswand (2020) submission to the CMA.[12] Thus, Saal (2019b), provided the CMA evidence of systematic bias in Ofwat's Integrated wholesale water modelling , which it did not act upon its provisional determinations, as this approach implies a maintained parameter restriction, which must be tested and not rejected for the model to be appropriate. As, Saal (2019b) unequivocally demonstrated that Ofwat's integrated wholesale water models are systematically biased because of a maintained restriction that can be rejected, it should not have only acted on this evidence but also been careful to scrutinise Ofwat's other models for such potential bias.

Given the presence of such systematic bias in two of Ofwat's other Final Determination models, it is necessary to test if similar bias exists in Ofwat's BR2 model. Thus, the below table includes a test of the maintained hypothesis that the cost elasticity of properties is exactly the negative of the cost elasticity of works, which is the maintained restriction in Ofwat's model. As the reported restriction test probability of 0.52 for the BR2 (re6) model indicates that we can reject this hypothesis, we can conclude that Ofwat has not imposed an inappropriate restriction on this model. E.g at face value it was statistically appropriate for Ofwat to restrict re11 to BR2(re6).

Nevertheless, BR2 still does not provide a statistically valid alternative bioresources model. Thus, as demonstrated by re12, ln(works/properties) becomes highly statistically significant when the variable pctbands6 is added to it, and standard general to specific modelling results in specification re13. Moreover, we note that this model is highly consistent with Ofwat's modelling approach, because as with BR2 it includes a single further control variable beyond the scale control, and as with the models employed by Ofwat for Bioresources Plus and Sewage Treatment, it provides an alternative triangulation to its BR1 model, with BR1 including pctbands13 and re13 including pctbands6. E.g. simple general to specific testing reveals that the general model re12 should not be restricted to BR2 as Ofwat does, but should be restricted to re13. Stated more simply, BR2 is not an appropriate triangulation of BR1, because its single control variable ln(works/properties) has less explanatory power than pctbands6, which we emphasise is also a valid measure of plant sizes, NOT included by Ofwat in BR1.

Despite these arguments for the use or re13 as a correction of BR2, it is in fact a statistically invalid restriction of re10, as demonstrated by the high joint statistical significance of the inclusion of the two density terms to this model. Thus, there is no valid correction of BR2 and BR1-Cor(re10) is the appropriate Bioresources Model that should have been obtained by Ofwat's approach to modelling, had it simply considered both of its plant size control variables and both density terms .

---

[12] Saal and Nieswand (2020): CMA Redetermination of Ofwat's 2019 Final Price Determinations: Third party submission to the CMA on Botex cost assessment. May 2020.
https://assets.publishing.service.gov.uk/media/5ebebdd6d3bf7f5d37fa0da4/Saal_and_Nieswand__002__Redacted.pdf

In contrast, Ofwat appears to have only considered the pctbands13 variable as appropriate in its modelling, and therefore has not derived a model that is statistically and conceptually valid.[13]

### Providing Appropriate Density Triangulation for Bioresource Modelling Using Ofwat's Density Threshold Controls

As discussed and demonstrated in Saal & Nieswand (2020b) and the supporting Stata codes and spreadsheets for Bioresource Plus Modelling, Ofwat's plant size share variables are closely related to the density of service. E.g plants are small in areas of lower density. With regard to Ofwat's Bioresource modelling the following correlations demonstrate the correspondence between serving with small plants and the share of population living at a density less than 600. Moreover, such a density control has the advantage of being truly exogenous as Ofwat emphasises, as plant sizes could be influenced by managerial decisions.

```
.         cor  popsparsity600 pctbands6 pctbands13
(obs=80)

             |  popspa.. pctba~s6 pctba~13
-------------+---------------------------
popspar~y600 |   1.0000
   pctbands6 |  -0.8904   1.0000
  pctbands13 |   0.8263  -0.9258   1.0000
```

This high correlation also suggest why care is needed when modelling with density and size controls as they are closely related to each other. However, given this close correlation, it is unsurprising that the alternative specification including popsparsity600 (re36) provides a statistically robust alternative to the single corrected version of Ofwat's bioresource models

**I therefore strongly urge the CMA to consider the application of the demonstrated BR-Cor and BR-Alt models in its Final Determinations, which has been unequivocally demonstrated to be statistically superior to both of Ofwat's mis-specified Bioresources models. In the absence of such a correction, the CMA's own Bioresources cost assessment and hence its Final Determinations will suffer from demonstrated model misspecification.**

[13] Although not reported here, models 14 and 15 in the accompanying Stata code how Ofwat is likely to have derived BR1 via an incomplete general to specific testing process that did not include pctbands6 in the testing process, despite this model being one of its preferred plant size variables.

## Bioresources Modelling - 8 Year Panel (2012-2019)

| | BR1 Model | | | BR2 Model | | | | BR ALTERNATIVE |
|---|---|---|---|---|---|---|---|---|
| | BR1 | | BR1-Cor | BR2 | | | BR2-Cor | BR-ALT |
| Suitable For Cost Assessment? | No Nested in re9, which tests to BR1-Cor | no insig coefs | Yes, within individual sig levels accepted by Ofwat in FD SWC2 & due to joint significance test | No Nested in 12, which tests to 13 | no prop insig and parameter restriction accepted | no insig coefs | no nested in BR1-Cor | Yes, within sig levels accepted by Ofwat in FD SWC2 |
| | re5 | re9 | re10 | re6 | re11 | re12 | re13 | re36 |
| | b/p | b/p | b/p | b/p | b/p | b/p | b/p | b/p |
| lnsludgeprod | 1.274*** | 1.139*** | 1.190*** | 1.265*** | 1.660** | 1.225*** | 1.140*** | 1.149*** |
| | {0.000} | {0.000} | {0.000} | {0.000} | {0.038} | {0.000} | {0.000} | {0.000} |
| pctbands13 | 0.057** | -0.033 | | | | | | |
| | {0.017} | {0.483} | | | | | | |
| pctbands6 | | -0.022*** | -0.016*** | | | -0.015 | -0.021*** | |
| | | {0.007} | {0.000} | | | {0.137} | {0.000} | |
| lnwedensitywastewater | -0.295** | -2.964* | -2.337* | | | | | |
| | {0.028} | {0.073} | {0.068} | | | | | |
| lnsqrwedensitywastewater | | 0.188 | 0.144 | | | | | |
| | | {0.106} | {0.109} | | | | | |
| lnswtwperpro | | | | 0.397* | | 0.171 | | |
| | | | | {0.067} | | {0.542} | | |
| lnworks | | | | | 0.387* | | | |
| | | | | | {0.072} | | | |
| lnproperties | | | | | -0.84 | | | |
| | | | | | {0.313} | | | |
| popsparsity600 | | | | | | | | 1.04 |
| | | | | | | | | {0.108} |
| _cons | -0.389 | 11.781* | 8.669* | 0.994* | 5.626 | 0.498 | -0.004 | -2.193* |
| | {0.648} | {0.098} | {0.076} | {0.100} | {0.447} | {0.498} | {0.981} | {0.092} |
| | | | | | | | | |
| **Joint Sig and Parameter Restiction Tests** | | | | | | | | |
| test of joint sig of density controls chi2( 2) | | 9.55 | 11.05 | | | | | |
| sig | | 0.01 | 0.00 | | | | | |
| test of ln(works/properties) restriction chi2( 1) | | | | 0.43 | | | | |
| sig | | | | 0.512 | | | | |
| | | | | | | | | |
| R_squared | 0.819 | 0.835 | 0.834 | 0.789 | 0.796 | 0.814 | 0.816 | 0.778 |
| RESET_P_value | 0.668 | 0.036 | 0.164 | 0.166 | 0.353 | 0.000 | 0.273 | 0.341 |
| N | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| parameters | 4 | 6 | 5 | 3 | 4 | 4 | 3 | 3 |

## Considering How to Correct Systematic Bias in Ofwat's Sewage Treatment and Bioresource Plus Modelling

Ofwat's Sewage Treatment and Bioresource Plus Models are identical despite the exclusion of sludge related costs from the former modelled cost, and the fact that we should expect the exclusion or inclusion of sludge treatment costs to influence the determinants of costs.

These models appropriately include sewage treatment load as a scale proxy, and a generally accepted measure of treatment complexity, and are therefore triangulated solely on the inclusion of the share of treatment load for plants in size band 3 or smaller or those in band6. The below table demonstrates the implied assumptions in these models. E.g. when Ofwat uses the pctbands13 control it assumes that the only meaningful plant scale difference is between smaller bands 1-3 plants that account for an average of 3.82 percent of load, and larger bands 4-6 plants that account on average for 96.18 percent of load, with no meaningful differences between these categories allowed or considered. Similarly, with the pctbands6 control Ofwat assumes that there is no meaningful distinction between the 43.87 average treatment share for plants bigger than 250,000 population equivalent, and the 34.45 percent of treatment that occurs in plants in the 25,000 to 250,000 range. Given, that there is a generally accepted understanding that scale economies exist in sewage treatment, the range of the scale groups used by Ofwat is noteworthy, particularly considering that there is considerable variation in the shares of the sub-shares within both band 6 and bands 1 to 3, as further illustrated in the below table.

**Percentage of Load Treated by Size Band Category (2017)**

| | Bands 1 & 2 | Band 3 | Bands 1 to 3 | Bands 4 to 6 | | Bands 1 to 5 | Band 6 | Band 6 >250k | Band 6 25k to 250k |
|---|---|---|---|---|---|---|---|---|---|
| ANH | 1.34 | 4.13 | 5.47 | 94.53 | | 34.65 | 65.35 | 13.35 | 52.00 |
| NES | 0.96 | 1.65 | 2.60 | 97.40 | | 15.16 | 84.84 | 46.01 | 38.83 |
| NWT | 0.60 | 0.83 | 1.42 | 98.58 | | 10.43 | 89.57 | 40.49 | 49.08 |
| SRN | 0.46 | 2.17 | 2.62 | 97.38 | | 17.46 | 82.54 | 24.24 | 58.30 |
| SVT | 0.68 | 1.80 | 2.48 | 97.52 | | 17.50 | 82.50 | 45.56 | 36.94 |
| SWB | 3.60 | 6.31 | 9.91 | 90.09 | | 41.86 | 58.14 | 0.00 | 58.14 |
| TMS | 0.16 | 0.52 | 0.68 | 99.32 | | 5.69 | 94.31 | 71.61 | 22.71 |
| WSH | 2.36 | 3.87 | 6.23 | 93.77 | | 26.26 | 73.74 | 30.27 | 43.48 |
| WSX | 0.74 | 3.71 | 4.45 | 95.55 | | 28.09 | 71.91 | 28.72 | 43.19 |
| YKY | 0.85 | 1.50 | 2.36 | 97.64 | | 19.71 | 80.29 | 44.26 | 36.03 |
| | | | | | | | | | |
| Average | 1.17 | 2.65 | 3.82 | 96.18 | | 21.68 | 78.32 | 34.45 | 43.87 |

Further consideration of the below table, which considers the number and share of sewage treatment plants by size band, reinforces a general impression that Ofwat's size bandings may be insufficient to capture the differences in sewage treatment and bioresource plus costs driven by variation in plant sizes. Thus, while band 1 and 2 plants only account for an average of 1.17 percent of all load, they account for 57.79 percent of all treatment plants in England and Wales, while band 3 plants only account for 17.72 percent of all plants. Thus, in general consideration of these tables, an understanding that scale economy relationships will not be perfectly linked to any available data, and a desire to provide robust cost assessment models should cause the modeller to carefully consider a variety of alternative empirical specifications so as to best model, with available data, the underlying cost relationship. E.g. it should seem reasonable that it is a valid concern and need to test whether breaking Ofwat's size band groups or changing them might yield superior results better reflecting industry cost conditions.

| **Number of Works by Size Band Category (2017)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Bands 1 & 2** | **Band 3** | **Bands 1 to 3** | **Bands 4 to 6** | | **Bands 1 to 5** | **Band 6** | |
| ANH | 575 | 249 | 824 | 314 | | 1089 | 49 | |
| NES | 301 | 44 | 345 | 67 | | 391 | 21 | |
| NWT | 360 | 64 | 424 | 143 | | 503 | 64 | |
| SRN | 136 | 92 | 228 | 137 | | 323 | 42 | |
| SVT | 568 | 184 | 752 | 261 | | 948 | 65 | |
| SWB | 460 | 98 | 558 | 90 | | 633 | 15 | |
| TMS | 116 | 80 | 196 | 155 | | 298 | 53 | |
| WSH | 573 | 135 | 708 | 127 | | 814 | 21 | |
| WSX | 198 | 98 | 296 | 110 | | 381 | 25 | |
| YKY | 385 | 82 | 467 | 152 | | 583 | 36 | |
| | | | | | | | | |
| Total | 3672 | 1126 | 4798 | 1556 | | 5963 | 391 | |
| | | | | | | | | |
| **Percentage of Works by Size Band Category (2017)** | | | | | | | | |
| | **Bands 1 & 2** | **Band 3** | **Bands 1 to 3** | **Bands 4 to 6** | | **Bands 1 to 5** | **Band 6** | |
| ANH | 50.53 | 21.88 | 72.41 | 27.59 | | 95.69 | 4.31 | |
| NES | 73.06 | 10.68 | 83.74 | 16.26 | | 94.90 | 5.10 | |
| NWT | 63.49 | 11.29 | 74.78 | 25.22 | | 88.71 | 11.29 | |
| SRN | 37.26 | 25.21 | 62.47 | 37.53 | | 88.49 | 11.51 | |
| SVT | 56.07 | 18.16 | 74.23 | 25.77 | | 93.58 | 6.42 | |
| SWB | 70.99 | 15.12 | 86.11 | 13.89 | | 97.69 | 2.31 | |
| TMS | 33.05 | 22.79 | 55.84 | 44.16 | | 84.90 | 15.10 | |
| WSH | 68.62 | 16.17 | 84.79 | 15.21 | | 97.49 | 2.51 | |
| WSX | 48.77 | 24.14 | 72.91 | 27.09 | | 93.84 | 6.16 | |
| YKY | 62.20 | 13.25 | 75.44 | 24.56 | | 94.18 | 5.82 | |
| | | | | | | | | |
| Total | 57.79 | 17.72 | 75.51 | 24.49 | | 93.85 | 6.15 | |

Given this reasonable consideration, n partnership with Anglian Water, both Oxera, and Saal & Nieswand (2020b) developed models using data available for 4 of the 8 years modelled by Ofwat, which allowed the breakout of the pctbands6 data illustrated above for 2017, which is one of the years for which data is available for plants within band 6. While the CMA, does not seem to have considered any of the evidence provided in Saal & Nieswand (2020b) it did reject Oxera's models, largely on the grounds that it was necessary to extrapolate the data for several of the years, By extension I would assume it would also similarly reject the Saal & Niewsand (2020b) bioresource plus models that were also submitted to it, but which it did not comment on in its provisional determinations.

However, this decision would not be appropriate for several reasons.

Firstly, the absence of data collection is a failure on Ofwat's part and not that of companies, and disallowing the use of the available 4 years of data to demonstrate statistically significant differences in scale economies for large plants greater than 250,000 in population equivalent scale should not so readily done.

Secondly, it is not unequivocally inappropriate to use extrapolated data, or alternatively a single year's data in a panel specification when data is missing, and this is feasible with a random effects model. As the number of plants and their configuration is very stable, and as a practitioner of econometrics, I do not believe that there is a credible argument against the use of this data, and in my professional opinion they demonstrate that Ofwat's models are not robust for regulatory cost assessment

Thirdly, The CMA's disallowance of such models should provide much more careful statistical and empirically evidenced arguments, which I believe do not exist. As plant size configurations are stable, the CMA must provide stronger econometrically valid arguments to reject specifications based on breaking out band 6 data with extrapolated data

Fourthly , and given the data stability argument made above, even if the CMA continues to disallow the direct use of models including extrapolated data, the models provided by Saal & Nieswand (2020b), and the corrections of Ofwat's modelling presented below, at a minimum demonstrate convincing statistical evidence that Ofwat's models are not robust. Thus, even if the CMA continues to use only Ofwat's models it should be willing to accept cost adjustment claims from companies that suffer from plant level diseconomies of scale not controlled for in Ofwat's models.

Finally, the CMA has not considered evidence provided to it in Saal & Nieswand (2020b) which not only provided Bioresource Plus and Integrated Wholesale Wastewater models based on the use of plant size shares for plants greater than 250,000 population equivalent. Thus, Saal & Nieswand (2020) also provided further models that used Ofwat's population density threshold data to provide alternative models with which to triangulate its plant size share models. Thus, the CMA should actually consider the evidence submitted to it in Saal & Nieswand (2020b) and the corrections of Ofwat's models presented below. As such consideration will reveal, these alternative density threshold models are not only robust themselves, but also confirm the findings and implications of the models based on extrapolated large plant size data, which have been incorrectly rejected by the CMA.

## Correcting Systematic Bias in Ofwat's Sewage Treatment and Bioresource Plus Modelling

We first consider if Ofwat's specification of Sewage Treatment and Bioresource Plus Models are superficially robust by simply testing if the choice of the single size band share employed by Ofwat is appropriate.

Ofwat's SWT1 (re3) and BRP1 (re7 models employ the pctbands13 control. In the below tables specification re22 and re 16 respectively test if this is statistically valid by including an additional variable pctbands12 ( the share of load in bands 1 &2), which has the effect of testing whether there is a significant difference between the share of load in bands 1 &2 and the share in band 3. For Bioresources Plus, pctbands12 is insignificant, suggesting that Ofwat's use of pctbands13 is superficially appropriate. In contrast, for Sewage Treatment re22 and the appropriate restriction of this model to re23 reveals that BRP1 is mis specified. E.g if Ofwat wishes to use a small works treatment share variable, pctbands12 is appropriate for Sewage Treatment. Please note that this evidence is logically consistent, as scale economies are greater for sludge treatment than for sewage treatment. E.g. a model for sewage treatment alone should be expected to find small scale diseconomies for smaller plants, than a model that includes both sewage treatment and sludge treatment costs.

We now repeat this analysis for Ofwat's SWT2 (re4) and BRP2 (re7) models which employ the pctbands6 control. In the below tables specification re24 and re18 respectively test if this is statistically valid by including an additional variable pctbandsover250k ( the share of load in plants larger than 250,00 population equivalent), which has the effect of testing whether there is a significant difference between band 6 plants that are less than or greater than 250,000 in size. For both Sewage Treatment and Bioresources Plus, the pctbands6 variable becomes insignificant indicating that no significant difference remains relative to plants in size bands 1 to 5, while the very large plants variable is significant. Thus, Ofwat's SWT2 and BRP2 models are not statistically valid, as re25 and re19 respectively result from appropriate testing of Ofwat's models. E.g. they provide clear evidence that Ofwat has set the large plant threshold share too low with pctbands6.

However, I consider the above discussed acceptances and revisions of Ofwat's models to be superficial because they do not consider whether both small and large plant size controls should be employed. In contrast, for SWT re26 demonstrates that the inclusion of both pctbands12 and pctband6over250k is statistically appropriate, while appropriate restriction of re17 to re20 yields a similar finding for Bioresources Plus. Thus, while in my opinion re26 and re20 should be preferred by the CMA relative to Ofwat's respective SWT and BRP models, at a minimum they clearly provide statistically valid evidence that Ofwat's models do not adequately control for plant scale effects on sewage treatment and Bioresource Plus costs. Such evidence should therefore not be disregarded by the CMA, as it is valid evidence that Ofwat's treatment cost models are biased, and company assessments will therefore not be accurate.

### Alternative Models based on Ofwat's density threshold share data, which support the need for alternative size controls in Ofwat's Modelling

As already discussed above, the CMA should consider the alternative density threshold based models for Bioresource Plus Modelling and Integrated Wholesale Wastewater models that were provided to it in Saal & Nieswand (2020b) and its accompanying Stata codes and worksheets. However, within this document, the tables below provide re27 and re21 which include Ofwat's sewage load scale variable and treatment complexity variable but replace plant scale share variables with density threshold based data. Focusing on the BRP model re21, this alternative model includes a positive coefficient for popsparsitty600 and a negative coefficient for popdensity4000. E.g. it finds that companies with a larger share of served population in low density areas have higher treatment costs, while those with larger shares of population in high density areas have lower costs. As density of population served is a primary determinant of plant size, these models provide an independent confirmation of the need for alternative controls to those provided in Ofwat's models, which also support the conclusion obtained by using Ofwat's extrapolated data. E.g. they provide valid alternatives to Ofwat's models that do not rely on extrapolated data.

| Sewage Treatment Modelling - 8 Year Panel (2012-2019) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **SWT1 Model** | | | **SWT2 Model** | | | **SWT -Corrected** | **SWT AL** |
| | SWT1 | | SWT-Cor | SWT2 | | SWT2-Cor | SWT-Cor | SWT-ALT |
| Suitable For Cost Assessment? | No Nested in re22, which tests SWT1-COR | no insig coefs | Yes in limited test of SWT1, No as nested in SWT-Cor | No Nested in re24, which tests SWT2-COR | no insig coefs | Yes in limited test of SWT2, No as nested in SWT-Cor, but data not accepted by CMA | Yes, within sig levels accepted by Ofwat in FD SWC2 | yes |
| | re3 | re22 | re23 | re4 | re24 | re25 | re26 | re27 |
| | b/p | b/p | b/p | b/p | b/p | b/p | b/p | b/p |
| lnload | 0.779*** | 0.782*** | 0.781*** | 0.773*** | 0.800*** | 0.776*** | 0.836*** | 0.729*** |
| | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} |
| pctnh3below3mg | 0.004*** | 0.004*** | 0.004*** | 0.004*** | 0.004*** | 0.004*** | 0.004*** | 0.004*** |
| | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} |
| pctbands13 | 0.045*** | 0 | | | | | | |
| | {0.010} | {0.996} | | | | | | |
| pctbands6 | | | | -0.013** | -0.002 | | | |
| | | | | {0.025} | {0.811} | | | |
| pctbands12 | | 0.137 | 0.132*** | | | | 0.089*** | |
| | | {0.104} | {0.004} | | | | {0.001} | |
| pctbands6over250K | | | | | -0.007 | -0.007** | -0.005 | |
| | | | | | {0.108} | {0.047} | {0.140} | |
| popsparsity600 | | | | | | | | 0.549** |
| | | | | | | | | {0.049} |
| _cons | -5.228*** | -5.256*** | -5.235*** | -3.988*** | -4.973*** | -4.799*** | -5.731*** | -4.699*** |
| | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} |
| | | | | | | | | |
| R_squared | 0.878 | 0.869 | 0.87 | 0.865 | 0.914 | 0.914 | 0.909 | 0.876 |
| RESET_P_value | 0.461 | 0.593 | 0.584 | 0.442 | 0.628 | 0.581 | 0.48 | 0.274 |
| N | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |

| Bioresources Plus Modelling - 8 Year Panel (2012-2019) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **BRP1 Model** | | **BRP2 Model** | | | **BRP Corrected** | | **BRP ALTERNATIVE** |
| | BRP1 | | BRP2 | | BRP2-Cor | | BRP-Cor | BRP-ALT |
| Suitable For Cost Assessment? | No Nested in re17, which tests to BRP-Cor | no insig coefs | No Nested in re18, which tests to BRP-Cor | no insig coefs | Yes in limited test of BRP2, No as nested in BRP-Cor, but data not accepted by CMA | no insig coefs | statisticaly valid but data not accepted by CMA | yes |
| | re7 | re16 | re8 | re18 | re19 | re17 | re20 | re21 |
| | b/p | b/p | b/p | b/p | b/p | b/p | b/p | b/p |
| lnload | 0.765*** | 0.758*** | 0.762*** | 0.815*** | 0.818*** | 0.836*** | 0.841*** | 0.795*** |
| | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} |
| pctnh3below3mg | 0.005*** | 0.005*** | 0.005*** | 0.005*** | 0.005*** | 0.005*** | 0.005*** | 0.006*** |
| | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} |
| pctbands13 | 0.038* | 0.038 | | | | -0.026 | | |
| | {0.060} | {0.339} | | | | {0.253} | | |
| pctbands6 | | | -0.011** | 0.001 | | | | |
| | | | {0.022} | {0.855} | | | | |
| pctbands12 | | -0.005 | | | | 0.081* | 0.028*** | |
| | | {0.948} | | | | {0.055} | {0.006} | |
| pctbands6over250K | | | | -0.009*** | -0.009*** | -0.009*** | -0.009*** | |
| | | | | {0.000} | {0.000} | {0.000} | {0.000} | |
| popsparsity600 | | | | | | | | 0.642*** |
| | | | | | | | | {0.007} |
| popdensity4000 | | | | | | | | -0.308* |
| | | | | | | | | {0.066} |
| _cons | -4.753*** | -4.667*** | -3.709*** | -4.989*** | -4.983*** | -5.195*** | -5.325*** | -5.283*** |
| | {0.001} | {0.002} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} | {0.000} |
| | | | | | | | | |
| R_squared | 0.918 | 0.918 | 0.92 | 0.954 | 0.954 | 0.956 | 0.955 | 0.927 |
| RESET_P_value | 0.198 | 0.26 | 0.311 | 0.544 | 0.577 | 0.474 | 0.422 | 0.266 |
| N | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |

## High Level Cost Assessment Implications of Correcting Ofwat’s Models and Employing the Alternative Threshold based Specifications.

The below table summarizes the above evidence with regard to the robustness of Ofwat’s Wholesale Wastewater models, and demonstrates that based on the arguments made above, not a single model used by Ofwat in its Final Determinations or in the CMA’s Provisional Determinations can be considered robust for regulatory cost assessment.

| **Ofwat's WWW Models - 8 Year Panel (2012-2019)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Suitable For Cost Asse | no removed by CMA | no density is insignificant | No Nested in re22, which tests SWT1-COR | No Nested in re24, which tests SWT2-COR | No Nested in re9, which tests to BR1-Cor | No Nested in 12, which tests to 13 | No Nested in re17, which tests to BRP-Cor | No Nested in re18, which tests to BRP-Cor |
| | Collection | | SWT | SWT | BR | BR | BRP | BRP |
| | re1 | re2 | re3 | re4 | re5 | re6 | re7 | re8 |
| | b/p | b/p | b/p | b/p | b/p | b/p | b/p | b/p |
| lnsewerlength | 0.839*** | 0.896*** | | | | | | |
| | {0.000} | {0.000} | | | | | | |
| lnload | | | 0.779*** | 0.773*** | | | 0.765*** | 0.762*** |
| | | | {0.000} | {0.000} | | | {0.000} | {0.000} |
| lnsludgeprod | | | | | 1.274*** | 1.265*** | | |
| | | | | | {0.000} | {0.000} | | |
| pctbands13 | | | 0.045*** | | 0.057** | | 0.038* | |
| | | | {0.010} | | {0.017} | | {0.060} | |
| pctbands6 | | | | -0.013** | | | | -0.011** |
| | | | | {0.025} | | | | {0.022} |
| pctnh3below3mg | | | 0.004*** | 0.004*** | | | 0.005*** | 0.005*** |
| | | | {0.000} | {0.000} | | | {0.000} | {0.000} |
| lnpumpingcapperleng | 0.317* | 0.606*** | | | | | | |
| | {0.080} | {0.006} | | | | | | |
| lndensity | 0.998*** | | | | | | | |
| | {0.005} | | | | | | | |
| lnwedensitywastewater | | 0.178 | | | -0.295** | | | |
| | | {0.146} | | | {0.028} | | | |
| lnswtwpperpro | | | | | | 0.397* | | |
| | | | | | | {0.067} | | |
| _cons | -8.124*** | -6.415*** | -5.228*** | -3.988*** | -0.389 | 0.994* | -4.753*** | -3.709*** |
| | {0.000} | {0.000} | {0.000} | {0.000} | {0.648} | {0.100} | {0.001} | {0.000} |
| | | | | | | | | |
| R_squared | 0.931 | 0.882 | 0.878 | 0.865 | 0.819 | 0.789 | 0.918 | 0.92 |
| RESET_P_value | 0.152 | 0.185 | 0.461 | 0.442 | 0.668 | 0.166 | 0.198 | 0.311 |
| N | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |

In contrast, consideration of the following table reveals that the models resulting from robust consideration of Ofwat's modelling, while broadly staying consistent with its previous underlying model and variable type choices, are robust for regulatory cost assessment

| Corrected Ofwat WWW Models - 8 Year Panel (2012-2019) | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| Suitable For Cost Assessment? | yes | yes | Yes, within sig levels accepted by Ofwat in FD SWC2 | Yes, within individual sig levels accepted by Ofwat in FD SWC2 & due to joint significance test | statisticaly valid, even if data not accepted by CMA |
| | Collection | | SWT | BR | BRP |
| | re33 | re35 | re26 | re10 | re20 |
| | b/p | b/p | b/p | b/p | b/p |
| lnproperties | 0.414*** | | | | |
| | {0.005} | | | | |
| lnpumpingcapacity | 0.430** | 0.584*** | | | |
| | {0.012} | {0.002} | | | |
| lnsewerlength | | 0.274* | | | |
| | | {0.063} | | | |
| lnload | | | 0.836*** | | 0.841*** |
| | | | {0.000} | | {0.000} |
| lnsludgeprod | | | | 1.190*** | |
| | | | | {0.000} | |
| pctbands12 | | | 0.089*** | | 0.028*** |
| | | | {0.001} | | {0.006} |
| pctbands6 | | | | -0.016*** | |
| | | | | {0.000} | |
| pctbands6over250K | | | -0.005 | | -0.009*** |
| | | | {0.140} | | {0.000} |
| pctnh3below3mg | | | 0.004*** | | 0.005*** |
| | | | {0.000} | | {0.000} |
| lnwedensitywastewater | -2.179** | -2.564* | | -2.337* | |
| | {0.040} | {0.063} | | {0.068} | |
| lnsqrwedensitywastewater | 0.153** | 0.185** | | 0.144 | |
| | {0.030} | {0.041} | | {0.109} | |
| _cons | 1.654 | 4.085 | -5.731*** | 8.669* | -5.325*** |
| | {0.685} | {0.422} | {0.000} | {0.076} | {0.000} |
| | | | | | |
| R_squared | 0.927 | 0.902 | 0.909 | 0.834 | 0.955 |
| RESET_P_value | 0.326 | 0.248 | 0.48 | 0.164 | 0.422 |
| N | 80 | 80 | 80 | 80 | 80 |

Moreover, using alternative models based on Ofwat's threshold density controls such as those developed in Saal & Nieswand (2020b) and not considered in the CMA's review of evidence provided to it, provides another set of models that are not only robust for regulatory cost assessment, but as discussed above, remain broad consistency with Ofwat's underlying modelling choices and variable selection.

**Alternative Density Threshold WWW Modelling - 8 Year Panel (2012-201**

| | | | | | |
|---|---|---|---|---|---|
| Suitable For Cost Assessment? | yes | Yes, within sig levels accepted by Ofwat in FD SWC2 | yes | Yes, within sig levels accepted by Ofwat in FD SWC2 | yes |
| | Collection | | SWT | BR | BRP |
| | re32 | re34 | re27 | re36 | re21 |
| | b/p | b/p | b/p | b/p | b/p |
| lnproperties | 0.550*** | | | | |
| | {0.000} | | | | |
| lnpumpingcapacity | 0.332** | 0.551*** | | | |
| | {0.013} | {0.000} | | | |
| lnsewerlength | | 0.400*** | | | |
| | | {0.004} | | | |
| lnload | | | 0.729*** | | 0.795*** |
| | | | {0.000} | | {0.000} |
| lnsludgeprod | | | | 1.149*** | |
| | | | | {0.000} | |
| pctnh3below3mg | | | 0.004*** | | 0.006*** |
| | | | {0.000} | | {0.000} |
| popsparsity600 | | | 0.549** | 1.04 | 0.642*** |
| | | | {0.049} | {0.108} | {0.007} |
| popdensity4000 | -0.783*** | -0.782 | | | -0.308* |
| | {0.003} | {0.107} | | | {0.066} |
| popdensity6000 | 1.644*** | 2.054*** | | | |
| | {0.000} | {0.001} | | | |
| _cons | -6.875*** | -5.679*** | -4.699*** | -2.193* | -5.283*** |
| | {0.000} | {0.000} | {0.000} | {0.092} | {0.000} |
| | | | | | |
| R_squared | 0.944 | 0.915 | 0.876 | 0.778 | 0.927 |
| RESET_P_value | 0.212 | 0.136 | 0.274 | 0.341 | 0.266 |
| N | 80 | 80 | 80 | 80 | 80 |

Furthermore, while specific details of the implications of each model on estimated costs is beyond the scope of this report, the below table (which is supported by an accompanying workbook) demonstrates that the correction of biases in the assessment of total wholesale wastewater costs due to reliance on Ofwat's models has a considerable impact on the cost assessment of the three sewage companies seeking price redeterminations.

**Cost Implications of Alternative Modelling Approaches - 8 Year Panel (2012-2019)**

**WWW Cost Implications- CMA Provisional Decision**

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | CMA Upper Quartile | | 0.990 |
| | Actual | Predicted | Upper Quartile Adjusted Predicted | Backward Looking Excess Cost | "Efficiency Score" | Inefficiency (Eff Score/ Upper Quartile) |
| ANH | 2062.1 | 2075 | 2054.6 | 7.5 | 0.994 | 1.004 |
| NES | 860.0 | 870 | 861.1 | -1.0 | 0.989 | 0.999 |
| YKY | 1683.5 | 1600 | 1584.2 | 99.3 | 1.052 | 1.063 |

***Models Employed in Triangulated Wholesale Wastewater Costs***

***Sewage Collection re2 Sewage Treatment re3 & re4, Bioresources re5 & re6, Bioresources Plus re7 & re8***

**WWW Cost Implications - Corrected Ofwat Modelling**

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | CMA Upper Quartile | | 0.967 |
| | Actual | Predicted | Upper Quartile Adjusted Predicted | Backward Looking Excess Cost | "Efficiency Score" | Inefficiency (Eff Score/ Upper Quartile) |
| ANH | 2062.1 | 2152 | 2080.5 | -18.4 | 0.958 | 0.991 |
| NES | 860.0 | 830 | 802.4 | 57.7 | 1.036 | 1.072 |
| YKY | 1683.5 | 1569 | 1516.4 | 167.1 | 1.073 | 1.110 |

***Models Employed in Triangulated Wholesale Wastewater Costs***

***Sewage Collection re33 & re35 Sewage Treatment re26, Bioresources re10, Bioresources Plus re20***

**WWW Cost Implications - Alternative Density Threshold Modelling**

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | CMA Upper Quartile | | 0.945 |
| | Actual | Predicted | Upper Quartile Adjusted Predicted | Backward Looking Excess Cost | "Efficiency Score" | Inefficiency (Eff Score/ Upper Quartile) |
| ANH | 2062.1 | 2189 | 2067.3 | -5.2 | 0.942 | 0.997 |
| NES | 860.0 | 904 | 853.6 | 6.5 | 0.952 | 1.008 |
| YKY | 1683.5 | 1607 | 1518.2 | 165.2 | 1.047 | 1.109 |

***Models Employed in Triangulated Wholesale Wastewater Costs***

***Sewage Collection re32 & re34 Sewage Treatment re27, Bioresources re36, Bioresources Plus re21***

## Demonstrating Ofwat's Inappropriate Wholesale Wastewater Modelling due to the Inappropriate Application of an 8 year random effect model to estimate efficiency for a five year period and illustration that alternatives to Ofwat's models are broadly robust to such estimation

While the CMA's provisional determination acknowledged and even attempted to test the implications of the appropriate period for estimating a random effects efficiency model, that was raised by Anglian Water, it does not appear to have understood the issue that was being raised. E.g. the issue raised related to the inappropriateness of estimating an econometric model with an 8 year random effects model when a five year efficiency measures is required. In contrast, the CMA's discussion with regard to this issue suggests strongly that it only considered how measuring efficiency for a different length of time, while still using Ofwat's estimated 8 year random effects model.

It seems unlikely that this misunderstanding would have occurred if it had reviewed pages 4-11 of Saal (2019b) which was submitted to it as part of the supporting materials for Saal & Nieswand (2020).[14] Thus, Saal (2019b) discussed why Ofwat's estimation of a longer random effects panel model to estimate efficiency for only a five year period is methodologically inappropriate because the single estimated random effect employed for each company is estimated for the entire 8 year period, and is therefore not consistent with the period that efficiency is being estimated for. Moreover, Saal (2019b) also demonstrated the impact of using the wrong time period for estimating a five year random effects based efficiency model on Ofwat's the integrated wholesale wastewater model and cost assessment conclusions

It also should be emphasized that while this issue is related to a potentially obvious source of bias that would result if cost conditions and model parameters have changed between the earlier period and the later period, (which as Ofwat does not use time controls is actually demonstrated to be true in Saal (2019b)) the primary point of the contention being raised is in fact methodological. As each company only has a single random effect that random effect will be influenced by all 8 years of the panel, and will result in the composed panel error terms of an 8 year panel. However, this 8 year random effect will nonetheless be different from and hence biased from the random effect and composed error terms resulting from a five year panel, Thus, if the regulator's goal is to estimate efficiency in a five year period it should use a random effect estimated with the period for which efficiency is being measured.

I would finally note that Ofwat may emphasize that it needs a longer panel to estimate complex models with a limited number of observations. However, given the excessively parsimonious models that Ofwat employs, this argument is simply not tenuous. E.g. if the models only include a maximum of say 5-6 parameters, it is perfectly feasible to estimate a robust panel model with only

[14] Saal and Nieswand (2020): CMA Redetermination of Ofwat's 2019 Final Price Determinations: Third party submission to the CMA on Botex cost assessment. May 2020. https://assets.publishing.service.gov.uk/media/5ebebdd6d3bf7f5d37fa0da4/Saal_and_Nieswand__002__Redacted.pdf

the 50 observations, provided that the model being estimated is well specified. Furthermore, while we would expect models to be broadly stable, it is likely that some parameter change and adjustment to control variables would be necessary if we believe that cost conditions can change between regulatory periods and across time. Thus, while we would not expect a model to entirely collapse when estimated with a 5 year panel instead of an 8 year panel, some limited change in the resulting specification to make it consistent with cost conditions in the actual period of efficiency assessment can be expected.

Given this discussion, and the CMA's clear misunderstanding of the issues being raised, I now consider the implications for the wastewater models developed above, when they are re-estimated with a methodologically appropriate 5 year panel consistent with Ofwat's 2015-19 cost efficiency period rather than the methodologically inappropriate 2012-19 period that Ofwat employed.

To accomplish this, and in the interest of time constraints in drafting this report I only briefly discuss the process and conclusions form this process:

- Using a 2015-19 panel database, I reran all 36 models that formed part of the consideration of the robustness of Ofwat's models, the above correction of those models, and specification of the alternative threshold density base models, and assessed the models for stability and appropriateness for used in a cost assessment model (Details are provided in the supporting materials submitted with this report)

- I report Ofwat's models immediately below, but now find that not a single model used by Ofwat is actually robust to estimation over the time period for which it actually assesses efficiency. As a result, it is not in fact possible to estimate wastewater cost efficiency appropriately for the 2015-19 period with Ofwat's models.

- I similarly report below corrected versions of Ofwat's models that I originally developed in the 2012-19 period after re-estimating them with 2015-19 data. In contrast to Ofwat's models, and while some moderate change in the model specifications occur, robust cost assessment models are available, and as reported below yield wholesale wastewater cost estimates that differ significantly from both those obtained with Ofwat's biased 8 year estimates, and those obtained with corrected versions of Ofwat's models estimated with an 8 year panel.

- With regard to the alternative threshold-based models, a similar result is obtained. As reported below, the single sewage treatment model developed in this category with the 8 year panel was not robust in the five year panel consistent with the actual period of efficiency assessment. Given the absence of a sewage treatment model the resulting overall cost efficiency assessment reported below is limited to aggregation of the collection models and the Bioresource Plus models. Nevertheless, unlike Ofwat's models cost assessment is still feasible with this modelling approach when it is applied with estimated random effect models that are consistent with the period that Ofwat was measuring efficiency for.

## Conclusions – Wholesale Wastewater Modeling

Given the evidence provided in this report, I strongly urge the CMA to reconsider its acceptance of Ofwat's suite of wholesale wastewater models which the above considerations have demonstrated not to be robust for regulatory cost assessment.  Moreover, I would urge the CMA  to consider the alternative models demonstrated to be robust in this report, while also triangulating any resulting bottom up cost assessment with the integrated wholesale wastewater, collection, and bioresource plus models that using threshold based density variables that were provided to it in Saal & Nieswand 2020b, and which my reading of the CMA's provisional determination suggests have not been considered.

| Ofwat's WWW Models - 5 Year Panel (2015-2019) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | SWC1 | WC2 | SWT1 | SWT2 | BR1 | BR2 | BRP1 | BRP2 |
| Suitable For Cost Assessment | no, removed by CMA | no insig density coefs, & also including length and pumping capacity in restated re28 specfication | no insig coefs | no insig coefs | no insig coefs | No paramater restriction rejected | no insig coefs | no insig coefs |
| | re1 | re2 | re3 | re4 | re5 | re6 | re7 | re8 |
| | b/p | b/p | b/p | b/p | b/p | b/p | b/p | b/p |
| lnsewerlength | 0.873*** | 0.932*** | | | | | | |
| | {0.000} | {0.000} | | | | | | |
| lnpumpingcapperlength | 0.311 | 0.576*** | | | | | | |
| | {0.139} | {0.006} | | | | | | |
| lndensity | 0.944** | | | | | | | |
| | {0.023} | | | | | | | |
| lnwedensitywastewater | | 0.154 | | | -0.298 | | | |
| | | {0.146} | | | {0.174} | | | |
| lnload | | | 0.805*** | 0.780*** | | | 0.836*** | 0.795*** |
| | | | {0.000} | {0.000} | | | {0.000} | {0.000} |
| pctbands13 | | | 0.025 | | 0.105*** | | 0.035 | |
| | | | {0.304} | | {0.002} | | {0.179} | |
| pctnh3below3mg | | | 0.001 | 0.002 | | | 0.002 | 0.004 |
| | | | {0.611} | {0.488} | | | {0.211} | {0.108} |
| pctbands6 | | | | -0.008 | | | | -0.009 |
| | | | | {0.313} | | | | {0.166} |
| lnsludgeprod | | | | | 1.481*** | 1.472*** | | |
| | | | | | {0.000} | {0.000} | | |
| lnswtwperpro | | | | | | 0.545 | | |
| | | | | | | {0.109} | | |
| _cons | -8.291*** | -6.619*** | -5.406** | -4.402** | -1.526 | 1.235 | -5.568** | -4.209*** |
| | {0.000} | {0.000} | {0.000} | {0.000} | {0.179} | {0.294} | {0.001} | {0.000} |
| | | | | | | | | |
| **Joint Sig and Parameter Restriction Tests** | | | | | | | | |
| test of ln(works/properties) restriction chi2( 1) | | | | | | 3.36 | | |
| sig | | | | | | 0.0669 | | |
| | | | | | | | | |
| R_squared | 0.934 | 0.889 | 0.866 | 0.856 | 0.818 | 0.756 | 0.909 | 0.907 |
| RESET_P_value | 0.588 | 0.409 | 0.679 | 0.704 | 0.249 | 0.323 | 0.424 | 0.534 |
| N | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |

| Corrected Ofwat WWW Models - 5 Year Panel (2015-2019) | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| Suitable For Cost Assessmen | yes | yes | Yes on staistical testing, but even if data not accepted by CMA | yes | Yes on staistical testing, but even if data not accepted by CMA |
| | Collection | | SWT | BR | BRP |
| | re33 | re35 | re25 | re10 | re19 |
| | b/p | b/p | b/p | b/p | b/p |
| lnproperties | 0.500*** | | | | |
| | {0.003} | | | | |
| lnpumpingcapacity | 0.366** | 0.536*** | | | |
| | {0.043} | {0.003} | | | |
| lnsewerlength | | 0.354*** | | | |
| | | {0.010} | | | |
| lnload | | | 0.811*** | | 0.792*** |
| | | | {0.000} | | {0.000} |
| lnsludgeprod | | | | 1.287*** | |
| | | | | {0.000} | |
| pctnh3below3mg | | | 0.006** | | 0.007*** |
| | | | {0.022} | | {0.000} |
| pctbands6 | | | | -0.021** | |
| | | | | {0.018} | |
| pctbands6over250K | | | -0.012*** | | -0.011*** |
| | | | {0.001} | | {0.000} |
| lnwedensitywastewater | -2.079** | -2.182** | | -3.826*** | |
| | {0.024} | {0.050} | | {0.005} | |
| lnsqrwedensitywastewater | 0.144** | 0.158** | | 0.244** | |
| | {0.021} | {0.030} | | {0.011} | |
| _cons | 0.862 | 2.448 | -5.107*** | 14.115*** | -4.634*** |
| | {0.813} | {0.537} | {0.000} | {0.006} | {0.000} |
| | | | | | |
| | | | | | |
| | | | | | |
| R_squared | 0.94 | 0.915 | 0.91 | 0.843 | 0.944 |
| RESET_P_value | 0.839 | 0.693 | 0.937 | 0.119 | 0.624 |
| N | 50 | 50 | 50 | 50 | 50 |

## Alternative Density Threshold WWW Modelling - 5 Year Panel (2015-2019)

| | | | | | |
|---|---|---|---|---|---|
| | yes | yes | | Yes, within sig levels accepted by Ofwat in FD SWC2 | yes |
| | Collection | | SWT | BR | BRP |
| | re32 | re34 | | re36 | re21 |
| | b/p | b/p | | b/p | b/p |
| lnproperties | 0.642*** | | | | |
| | {0.000} | | | | |
| lnpumpingcapacity | 0.232** | 0.446*** | | | |
| | {0.022} | {0.000} | | | |
| lnsewerlength | | 0.502*** | | | |
| | | {0.000} | | | |
| lnload | | | | | 0.672*** |
| | | | | | {0.000} |
| lnsludgeprod | | | | 1.300*** | |
| | | | | {0.000} | |
| pctnh3below3mg | | | | | 0.011** |
| | | | | | {0.021} |
| popsparsity600 | | | | 1.411 | 0.859* |
| | | | | {0.105} | {0.057} |
| popdensity4000 | -0.969*** | -0.970** | | | -0.552** |
| | {0.000} | {0.018} | | | {0.023} |
| popdensity6000 | 1.974*** | 2.428*** | | | |
| | {0.000} | {0.000} | | | |
| _cons | -7.073*** | -5.578*** | | -3.081* | -3.931*** |
| | {0.000} | {0.000} | | {0.070} | {0.000} |
| | | | | | |
| | | | | | |
| | | | | | |
| R_squared | 0.966 | 0.944 | | 0.752 | 0.917 |
| RESET_P_value | 0.857 | 0.437 | | 0.299 | 0.467 |
| N | 50 | 50 | | 50 | 50 |

## Cost Implications of Alternative Modelling Approaches - 5 Year Panel (2015-2019)

**WWW Cost Implications- CMA Provisional Decision**

It is infeasible to carry out cost assessment in a 2015-19 panel data set consistent with
the period in which Ofwat assesses efficiency for
as none of its models are robust to estimation in the correct panel data set for such efficiency assessment

***Models Employed in Triangulated Wholesale Wastewater Costs***

***Sewage Collection re2 Sewage Treatment re3 & re4, Bioresources re5 & re6, Bioresources Plus re7 & re8***

**WWW Cost Implications - Corrected Ofwat Modelling**

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | CMA Upper Quartile | | 0.942 |
| | Actual | Predicted | Upper Quartile Adjusted Predicted | Backward Looking Excess Cost | "Efficiency Score" | Inefficiency (Eff Score/ Upper Quartile) |
| ANH | 2062.1 | 2263 | 2130.8 | -68.7 | 0.911 | 0.968 |
| NES | 860.0 | 804 | 757.0 | 103.0 | 1.070 | 1.136 |
| YKY | 1683.5 | 1592 | 1498.6 | 184.9 | 1.058 | 1.123 |

***Models Employed in Triangulated Wholesale Wastewater Costs***

***Sewage Collection re33 & re35 Sewage Treatment re25, Bioresources re10, Bioresources Plus re19***

**WWW Cost Implications - Alternative Density Threshold Modelling**

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | CMA Upper Quartile | | 0.961 |
| | Actual | Predicted | Upper Quartile Adjusted Predicted | Backward Looking Excess Cost | "Efficiency Score" | Inefficiency (Eff Score/ Upper Quartile) |
| ANH | 2062.1 | 2188 | 2102.2 | -40.2 | 0.942 | 0.981 |
| NES | 860.0 | 896 | 860.5 | -0.5 | 0.960 | 0.999 |
| YKY | 1683.5 | 1731 | 1663.1 | 20.4 | 0.972 | 1.012 |

***Models Employed in Triangulated Wholesale Wastewater Costs***

***Sewage Collection re32 & re34 Sewage Treatment N/A, Bioresources re36, Bioresources Plus re21***