Cost Assessment
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**Strategy & Regulation**

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Dear Sir or Madam,

**Cost assessment for PR19: a consultation on econometric cost modelling**

Thank you for providing this opportunity for continuing dialogue on the econometric modelling, as part of the open and constructive engagement process that Ofwat has adopted on this topic for PR19. As requested, we have completed the consultation response sheet for each model (attached). In addition, we set out in Appendix A to this letter some more detailed observations on the effects of density in the treated water distribution models.

It will be important that appropriate efficient totex cost allowances are set for all price controls at PR19. If the allowances are too high, customers will bear additional costs (albeit that this will be ameliorated by the totex sharing mechanism). If they are set too low, this could put at risk the ability of companies to continue to invest to deliver the services that their customers require. As the econometric modelling plays a key role in informing the appropriate cost allowances, we welcome the opportunity to respond to this consultation.

While the econometric cost models are an important part of the process to determine efficient costs in AMP7, we expect Ofwat to use these in conjunction with other regulatory tools in forming its overall judgement. Where econometric models are used, these should be fit for purpose, underpinned by robust statistical tests, sensible coefficients and the most representative cost drivers.

We provide some further commentary on the following topics, below:

- overall approach to cost assessment;
- model design – treatment of density;
- regional wages;
- levels of aggregation;
- enhancement models;
- measure of density;

- retail models;
- growth; and
- grants & contributions.

**Overall approach to cost assessment**

Econometric cost models have some limitations in estimating the efficient whole life cost of providing services which customers want. For example, they do not fully recognise differences in service levels across the industry, or differences in asset health. Equally, backward looking models cannot easily take account of societal and political shifts, such as in attitudes towards resilience, or deal with emerging issues, such as the impact of climate change (especially if those impacts are non-linear). It is also unclear as to the extent to which the historical data set, upon which the models draw, truly reflects the optimum and efficient cost of opex and capex in a long-term context or whether it reflects short or medium-term decisions to limit expenditure.

There are a number of important, but implicit, assumptions that underpin econometric analysis of efficient costs. Specifically, the analysis assumes that the underlying data is the cost necessary to keep the industry in steady state (rather than allowing quality to decline), and further that such a steady state is the same for each company (i.e. that it takes each company the same time to renew their networks, and that they renew the same proportion of their networks each year). If either of these assumptions is incorrect, the results would be unreliable, and could misstate the efficient cost of maintaining companies in a steady state.

The majority of reported performance metrics within the water sector are lagging, rather than leading indicators. This presents a risk that even if the reported metrics appear to indicate that the industry is in steady state, elements which are not measured may in fact be in decline. For example, the recent freeze/thaw event generated a greater than expected detrimental effect on performance, which may reflect an underlying need to increase the resilience of networks.

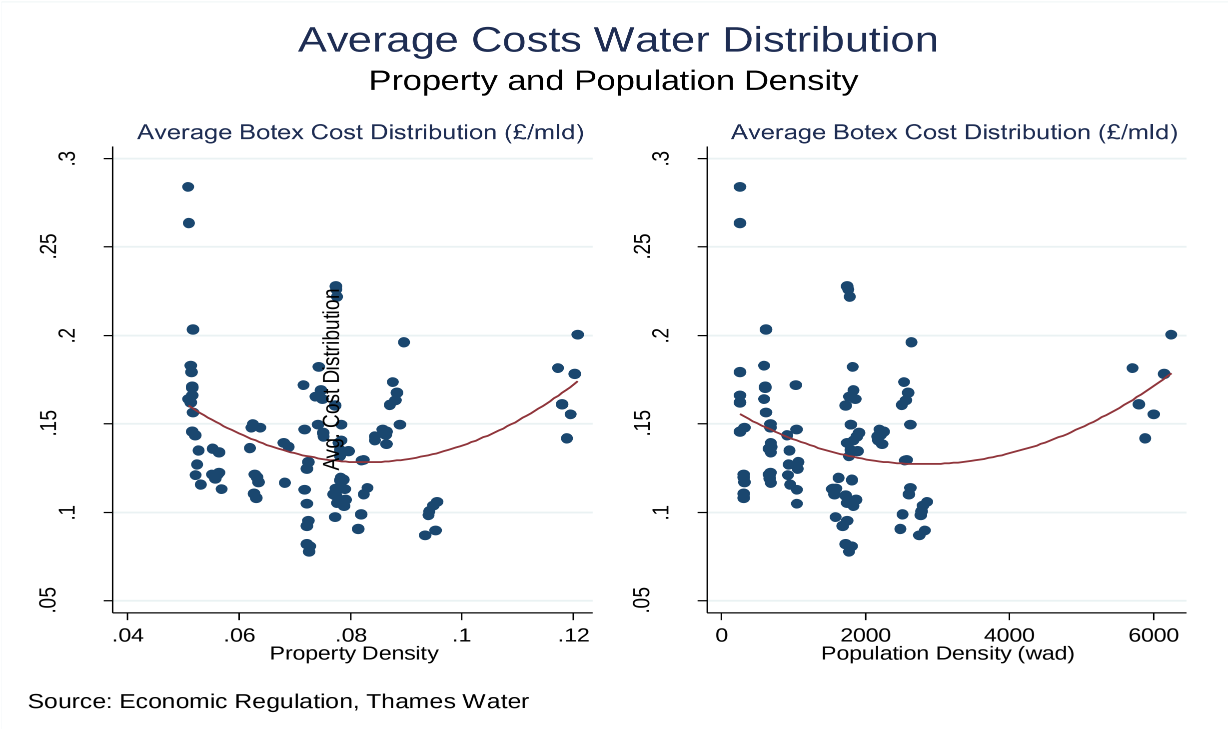
Given the long-term nature of the industry,[1] the efficient costs for any given undertaker will, at least in part, be a function of the underlying quality of the asset base inherited at privatisation, and the need to renew and update those assets over time. For Ofwat to rely on modelled outputs, therefore, it will be important to investigate if historical industry spend is sufficient to maintain a steady state. To the extent that it is not, an additional allowance would need to be made for this.

The focus of our response below, and of the detailed response template, is on how the models can be developed to be as good as they can be, prior to the necessary application of regulatory judgement (including the review of cost adjustment and policy adjustment claims and enhancement cases) to cater for the limitations of the models as highlighted above.

[1] For example, ~40% of our water network and ~30% of our sewerage network is over 100 years old

**Model design – treatment of density**

Density is a key cost driver within the water distribution network. There is strong evidence that there are economies of density at very low levels, and diseconomies of density at very high levels. This is true, whether density is measured by reference to properties or to population, as shown in the graphs below. A good econometric model, therefore, will be one that accounts for this.




A flexible function model form, such as a translog or semi-translog provides a recognised method to cater for this type of factor. Applied to the water distribution segment, such models provide more robust results, with notably stronger statistical test outcomes[2] than alternative cost models which adopt a simpler functional form, such as Cobb-Douglas. We recognise that the CMA questioned the use of translog models at PR14[3] – however, this was in context of the entire wholesale water service value chain where the activities are diverse in nature, and not for the more disaggregated elements of the value chain (which Ofwat is currently intending to adopt for PR19), where the activities modelled are of a more similar nature. Based upon the evidence above, a semi-translog model would provide better outcomes reducing the risk of excluding relevant drivers such as regional wages (see below), and would provide a more robust model for assessment of efficient costs for water distribution.

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[2] Including RESET tests, F-test, VIF and $R^2$

[3] See CMA, Bristol Water plc: A reference under section 12(3)(a) of the Water Industry Act 1991, Appendices 1.1 – 4.3

We set out in Appendix B a revised set of suggested water distribution models, combining the Thames Water models from the consultation with additional drivers from the Ofwat models. These new models give statistically superior results to either the Thames Water models or the Ofwat models, including higher $R^2$ predictive power with regional wage factors yielding sensible magnitude, sign and statistical significance.

An additional advantage of the semi-translog models is that they allow for the impact of network scale on costs to vary with density, and vice-versa. In other words, they allow for non-linear effects of scale and density on costs, and for the costs to be affected by the interaction of scale and density. These models show that the impacts on costs of an additional length of mains and of higher density depend on both size and density of the network. It will be important, therefore, that the models allow for this.

### Regional wages

Regional wages are a key cost driver, recognised as such by academics[4] and regulators alike. We are concerned that forcing the selection of simplified model specifications, by excluding translog and semi-translog models from consideration, would lead to omitted variable bias – particularly with respect to regional wages. Omitting an important cost driver, such as regional wages, would adversely affects the estimated coefficients, efficiency scores and forecast outputs, leading the outputs of a model to misrepresent the efficient costs.

One of the advantages of using a more flexible functional form, such as a full or semi-translog specification, is that it would enable inclusion of regional wages as a cost driver with statistically significant results and appropriate signage. Our proposed new models, as set out in Appendix BB, include regional wages as a key cost driver.

### Levels of aggregation

As the value chain is aggregated into higher and higher levels, it becomes more difficult to design a single model to encompass all of the key cost drivers associated with the very broad ranges of activity included. This is implicit in some of the criticisms set out by the CMA in the past. For example, treatment, distribution and resource activities are very different, each with distinct cost drivers – combining these into one model to predict an efficient cost is very challenging. This challenge is exacerbated where the reference data set relates to a limited time period, during which many cost drivers vary little, if at all (as is the case here). Our conclusion, therefore, is that the primary modelling should take place at a disaggregated level, with higher level models at the network plus level and total service level operating as cross-checks.

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[4] Shleifer, A. (1985). A theory of Yardstick Competition. The RAND Journal of Economics. Vol 16, No. 3, pp. 319-327; Jaskow, P. and Schmalensee, R. (1986). Incentive Regulation for Electric Utilities. Yale Journal on Regulation.

## Enhancement models

We support an approach which includes econometric modelling of botex, where the underlying data may provide a reasonable indication of the true cost of maintaining the long-term capability of assets, subject to the caveats set out earlier. The ability of econometric models to capture efficient enhancement costs may be more limited, particularly in view of the significant variation between companies' enhancement expenditure, and its volatility over time. Fitting linear cost models to a dataset with such different magnitudes of expenditure is unlikely to result in a model that captures the impact of the cost drivers accurately. Even with smoothing, annual costs for single companies can vary by a factor of 3 or 4 within a few years. There is a material risk, therefore, that the outputs from such an approach could not be relied upon as a reasonable estimate of the efficient costs of enhancement. Ofwat will, therefore, need to review the evidence contained in company business plans carefully to assess the efficiency of enhancement expenditure.

The enhancement cost dataset from which any models would draw is limited. There are ten companies with four years of data, and three companies with just two to three years of data. Indeed, none of the enhancement models have more than 70 observations. This is unlikely to be sufficient for a reliable Random Effects model. As a consequence, we think that for enhancement activities an alternative method, such as a bottom up review of business plans, will need to be considered where econometric models are unable to provide robust outcomes.

The August return datasets for the econometric models do not specifically capture historical enhancement opex. Conversely, the PR19 totex tables do allow enhancement opex to be forecast. It would be helpful if Ofwat could confirm that forecast enhancement opex will be removed from any modelling of botex for PR19.

## Measure of density

Density is a key cost driver, for which there are two potential measurement bases: properties per length of mains and population per $km^2$. These can be materially different. In general, population density is a poor proxy for property density (and vice versa) as, for example, business areas have few residents, but high property density. It will be important to select the measure of density that best reflects the costs incurred by companies.

The extent of cost reflectivity can be derived from considering the engineering aspects of the density measures. Specifically, each communication pipe is a connection to the main. This results in a 'weak' point in the network that is more likely to leak (requiring repair and maintenance work) and/or fail (and require replacement). In dense areas with a lot of communications pipes, therefore, the cost per metre of repair/maintenance and replacement is significantly higher than in areas where the distance between properties (i.e. connections), and thus communication pipes, is greater, i.e. lower distance generally equates to higher cost per metre and vice versa. This effect is evident in the Water UK Leakage Performance Indicator data from 2003/04 to 2013/14, which shows that the industry found almost as many leaks on mains fittings as the mains themselves and more than twice as many leaks on communication pipes as on mains. A property based metric would, therefore, better capture the cost impact of density for companies.

We note that Ofwat's suggested approach uses a population-based measure. For the reasons explained above, this is less cost reflective than a property based measure, particularly for companies that supply large cities. It will be important to reflect the correct costs in the modelling, or to make an adjustment to the modelled output to compensate for this.

### Retail household models

A reliable econometric model will include all the relevant cost drivers and variables. This leads us to be concerned about the potential reliability of the models for retail household proposed by Ofwat, as they contain relatively few cost drivers. Specifically, drivers known to be important, such as deprivation, bill size, and metering density are missing from some models, and transience is not included in any of Ofwat's proposed models. Omitting these will adversely impact fit, efficiency and accuracy. To be reliable, therefore, we believe that the following variables need to be included in the models:

**Table 1: Important cost drivers to include in the retail household models**

| Model | Important drivers |
|---|---|
| Bad debt costs | Bill size, deprivation, transience[5] |
| Costs other than bad debt | % of metered customers |
| Total costs | Deprivation, bill size |

*Source: Thames Water*

To the extent that there are different possible measures of these cost drivers, it will be important to select the most appropriate ones. In the case of deprivation in the bad debt costs models, for example, this would entail selecting a measure that reflects the socioeconomic circumstances that give rise to non-payment of water bills. One such option would be income deprivation on an "after housing costs" basis.

[5] We note that Economic Insight's report posted on the marketplace for ideas makes a strong case for including transience in models of bad debt (and potentially total) costs.

## Growth assumptions

An appropriate assumption relating to growth (or company size) is an important element of determining efficient costs. Previous methodologies to estimate growth have used historical trends as a guide, either at industry or company level. Historical growth may not be a good guide to the future activity or volumes where population is expected to increase materially faster during AMP7 than AMP5 or AMP6. As an example, our projected P50 AMP7 growth in our Water Resources Management Plan is around 1% p.a. in AMP7, which is significantly different to historic growth rates for the industry of ~0.1% p.a. The potential impact of this on predicted modelled AMP7 costs for Thames Water is significant (of the order of £0.5bn for water distribution alone). We would expect Ofwat's methodology to draw from the same evidence base as companies, in line with guidance for completion of WRMPs to address this.

## Grants & contributions

We note that Ofwat has focused on gross costs (before deduction of grants and contributions) for cost modelling purposes. It would be helpful to understand the process by which Ofwat will determine the necessary deductions for grants and contributions in order to arrive at net totex allowances, particularly given the revised rules on charging for developer services activities.

We hope these responses are helpful in finalising the most robust cost models to help inform Ofwat's wider judgement on what efficient costs it should allow for AMP7. If you would like to discuss any of the issues raised in this letter in more detail, please do not hesitate to get in touch. In addition, we are working on a more detailed technical paper on the design of water distribution models, which expands on the key points and evidence noted above. We expect to make this available to Ofwat and publish it on the marketplace for ideas shortly.

Yours faithfully

**Nick Fincham**
**Director of Strategy & Regulation**

**Appendix A: Treated Water Distribution – detailed observations**

This appendix provides supplementary commentary on the effects of density and regional wages in the Ofwat's treated water distribution models, when the scale variable is number of properties. This supplements our comments in the consultation response spreadsheet.

### Correlation analysis

Model OTWD1 treats the scale/output variable as the number of properties. Density is not included in this model. We have analysed this model, and this analysis included looking at the correlations between various parameters, as shown in Table 1.1 below.

**Table 1.1: Correlation matrix of the drivers with density and regional wages**

| | ln_pro~s | ma~w_prp | ln_pup~s | ln_prp~y | ln_wad.. | ln_reg~s |
|---|---|---|---|---|---|---|
| ln_propert~s | 1.0000 | | | | | |
| mains_reli~p | -0.3072 | 1.0000 | | | | |
| ln_pupm_st~s | 0.1521 | -0.0039 | 1.0000 | | | |
| ln_prp_dsity | 0.1467 | 0.0716 | -0.6776 | 1.0000 | | |
| ln_wad_water | 0.2059 | 0.0746 | -0.6918 | 0.9673 | 1.0000 | |
| ln_reg_wages | 0.0355 | 0.0917 | -0.5509 | 0.6575 | 0.6642 | 1.0000 |

***Source***: *Economic Regulation, Thames Water*

### Observations on density

It can be seen from the table that there is a high negative correlation of density (property or population) and booster pumping station per length of mains (-0.6776 and -0.6918, respectively). This negative correlation suggests that the denser an area is, the fewer booster pumping stations per mains are needed. This arises because companies tend to build large pumping stations with high capacity in denser areas (as this is more cost-efficient), whereas in sparse or low density areas companies need more, smaller, pumping stations, as this is again a more cost-effective strategy. This evidence suggests that, by omitting density from the model the results might suffer from omitted variable bias, affecting the estimated coefficient, efficiency scores and frontier. The same conceptual issue may be a problem for any of the TWD models that exclude density.

### Observations on regional wages

Similarly, it can be seen from Table 1.1 that there is high positive correlation between regional wages and density (property or population). This suggests that it will be important to include regional wages in the models, to mitigate the risk of omitted variable bias.

### Alternative models specifications

To confirm the observations above, we have derived a number of alternative model specifications that include both density and region wages, based on enhancing the OWTD1 model. Specifically, we took model OTWD1 and extended it by including the effect of density, using either property density or population (wad) density metrics. Table 1.2 shows the results and confirms how the coefficient of booster pumping stations per length of mains is biased downwards. The result is that model OTWD1 has a coefficient of 0.305 when excluding density, and models OTWD1_Dprp (that include property density) and OTWD1_Dp (that include population density) show an estimated coefficient of around 0.50, confirming the effect of omitting density.

Furthermore, these models also suffer the exclusion/omission of regional wages when density is included. Models OTWD1_DprpW and OTWD1_DpW include regional wages in the models with an upward or overestimation effect. The RESET test suggest issues with the functional form of these two models. By adding the square effect of density, the effect of regional wages becomes sensible in magnitude and sign, as the last two models in Table 1.2 shows (also, the density coefficients become statistically significant). There might be other interaction terms for density that could be still missing but need to be explored further. For example, the interaction of the number of properties and density.

**Table 1.2: Model OWTD1 extended in stages buy adding density, regional wages and higher order terms**

| | OTWDD1<br>b/se | OTWDD1_Dprp<br>b/se | OTWDD1_Dp<br>b/se | OTWDD1_DprpW<br>b/se | OTWDD1_DpW<br>b/se | OTWDD1_Dpr~2<br>b/se | OTWDD1_DpW2<br>b/se |
|---|---|---|---|---|---|---|---|
| ln_properties | 1.087*** | 1.058*** | 1.057*** | 1.057*** | 1.062*** | 1.042*** | 1.067*** |
| | (0.05) | (0.03) | (0.03) | (0.02) | (0.03) | (0.02) | (0.03) |
| mains_relined_rene~p | 0.463*** | 0.405*** | 0.407*** | 0.385*** | 0.394*** | 0.410*** | 0.389*** |
| | (0.09) | (0.11) | (0.12) | (0.10) | (0.11) | (0.07) | (0.07) |
| ln_pupm_stns_mains | 0.305** | 0.526*** | 0.500*** | 0.597*** | 0.556*** | 0.512*** | 0.509*** |
| | (0.13) | (0.14) | (0.12) | (0.14) | (0.13) | (0.12) | (0.12) |
| ln_prp_dsity | | 0.411 | | 0.176 | | | |
| | | (0.30) | | (0.20) | | | |
| Ln_wad_water | | | 0.101 | | 0.019 | | |
| | | | (0.09) | | (0.06) | | |
| ln_reg_wages | | | | 1.925** | 2.090** | 0.956 | 0.911 |
| | | | | (0.84) | (0.90) | (0.68) | (0.81) |
| ln_densityN | | | | | | 0.302* | |
| | | | | | | (0.17) | |
| ln_densityN_SQ | | | | | | 2.925*** | |
| | | | | | | (0.72) | |
| ln_wad_waterN | | | | | | | 0.165** |
| | | | | | | | (0.08) |
| ln_wad_waterNSQ | | | | | | | 0.239*** |
| | | | | | | | (0.07) |
| constant | -2.226** | 0.032 | -1.827*** | -5.489** | -6.743*** | -3.660* | -3.681 |
| | (0.79) | (1.27) | (0.52) | (2.14) | (2.13) | (1.75) | (2.23) |
| R2 | 0.9669 | 0.9702 | 0.9690 | 0.9751 | 0.9747 | 0.9809 | 0.9802 |
| R2_Adj | 0.9660 | 0.9690 | 0.9677 | 0.9738 | 0.9734 | 0.9797 | 0.9789 |
| VIF_Max | 1.132 | 2.197 | 2.561 | 2.693 | 3.157 | 2.809 | 5.113 |
| RESET_p_val. | 0.626 | 0.091 | 0.222 | 0.023 | 0.031 | 0.169 | 0.025 |
| Obs. | 107.000 | 107.000 | 106.000 | 106.000 | 106.000 | 106.000 | 106.000 |

* p<0.10, ** p<0.05, *** p<0.01

**Source**: Economic Regulation, Thames Water

## Appendix B: Merging Thames' and Ofwat's insights from models OTWD1-OTWD8[6]

A new version of the models for water treated distribution based on Thames and Ofwat insights can be expressed as follows:

$$
\begin{aligned}
&Ln(Gross\ Botex\ Water\ Distribution_{it}) \\
&\quad = \alpha + \beta_1 \ln(Length\mathrm{Mains}_{it}) + \beta_2 \ln(PropertyDensity_{it}) + \beta_3 \ln(RegionalWages_{it}) \\
&\quad + \beta_4 (MainsRelined\&Renewed\ per\ main\ _{it}) + \frac{1}{2}\beta_5 \ln(LengthMains_{it}^2) \\
&\quad + \frac{1}{2}\beta_6 \ln(PropertyDensity_{it}^2) + \beta_7 \ln[(LengthMains_{it})(PropertyDensity_{it})] \\
&\quad + \beta_8 \ln(Booster\ Pumping\ Stations\ per\ mains_{it}) + \beta_9 TimeTrend + \varepsilon_{it}
\end{aligned}
$$

The result of this model is represented in model **TMS_Ofw4** in Table 2.1, as follows:

### Table 2.1: Hybrid Thames Water – Ofwat models

| | TMS_Ofw3<br>b/se | TMS_Ofw4<br>b/se | TMS_Ofw5<br>b/se | TMS_Ofw6<br>b/se | TMS_Ofw7<br>b/se | TMS_Ofw8<br>b/se | TMS_Ofw9<br>b/se |
|---|---|---|---|---|---|---|---|
| | Semi-Translog | | | | | | |
| ln_mains | 0.998*** | 1.014*** | 1.00*** | 1.020*** | 1.017*** | 1.057*** | 1.061*** |
| | (0.03) | (0.03) | (0.05) | (0.03) | (0.03) | (0.04) | (0.04) |
| ln_Prp_Density | 1.347*** | 1.232*** | | 1.217*** | 1.175*** | 1.064*** | 1.069*** |
| | (0.15) | (0.16) | | (0.15) | (0.20) | (0.17) | (0.14) |
| ln_Pop_Density (wad) | | | 0.467*** | | | | |
| | | | (0.08) | | | | |
| ln_mains_SQ | -0.101* | -0.082* | -0.120 | -0.070 | -0.065 | -0.073 | -0.010 |
| | (0.05) | (0.05) | (0.07) | (0.05) | (0.05) | (0.05) | (0.05) |
| ln_Density_SQ | 3.071*** | 2.687*** | | 3.022*** | 3.161*** | 3.092*** | 2.825*** |
| | (0.57) | (0.59) | | (0.60) | (0.63) | (0.83) | (0.62) |
| ln_Pop_Density (wad)_SQ | | | 0.346*** | | | | |
| | | | (0.08) | | | | |
| Ln(main)Ln(density) | 0.297* | 0.294** | | 0.288** | 0.290** | 0.418*** | 0.346*** |
| | (0.15) | (0.14) | | (0.12) | (0.13) | (0.13) | (0.08) |
| Ln(main)Ln(Pop_density_wad) | | | 0.06* | | | | |
| | | | (0.03) | | | | |
| mains_relined_renew_prp | 0.217*** | 0.220*** | 0.192*** | 0.225*** | 0.204*** | 0.258*** | 0.233*** |
| | (0.03) | (0.03) | (0.04) | (0.03) | (0.04) | (0.04) | (0.03) |
| ln_pupm_stns_mains | 0.315** | 0.345** | 0.310*** | 0.351*** | 0.337*** | | 0.383*** |
| | (0.12) | (0.12) | (0.10) | (0.12) | (0.12) | | (0.09) |
| ln_wage | | 0.823* | 0.663 | 0.731* | 0.865 | 0.521 | 0.975** |
| | | (0.42) | (0.81) | (0.39) | (0.56) | (0.52) | (0.44) |
| ln_avg_pmph_distribution | | | | 0.058 | 0.061 | 0.065 | 0.052* |
| | | | | (0.03) | (0.04) | (0.05) | (0.03) |
| ln_resv_towers_mains | | | | | | 0.124 | |
| | | | | | | (0.13) | |
| mains_450mm_610mm_prp | | | | | | | 0.146* |
| | | | | | | | (0.08) |
| time | 0.019** | 0.024** | 0.021 | 0.025*** | 0.022** | 0.033** | 0.028*** |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| constant | 3.928*** | 3.850*** | 3.980*** | 3.819*** | 3.887*** | 3.641*** | 3.587*** |
| | (0.19) | (0.19) | (0.27) | (0.18) | (0.19) | (0.24) | (0.20) |
| R2 | 0.9828 | 0.9835 | 0.9808 | 0.9843 | | 0.9819 | 0.9852 |
| R2_Adj | 0.9814 | 0.9820 | 0.9790 | 0.9826 | | 0.9800 | 0.9835 |
| R_overall | | | | | 0.984 | | |
| VIF_Max | 3.899 | 4.246 | 5.294 | 4.298 | | 5.297 | 5.841 |
| RESET_p_val. | 0.029 | 0.072 | 0.068 | 0.130 | | 0.092 | 0.487 |
| Obs. | 107.000 | 106.000 | 106.000 | 106.000 | 106.000 | 106.000 | 106.000 |

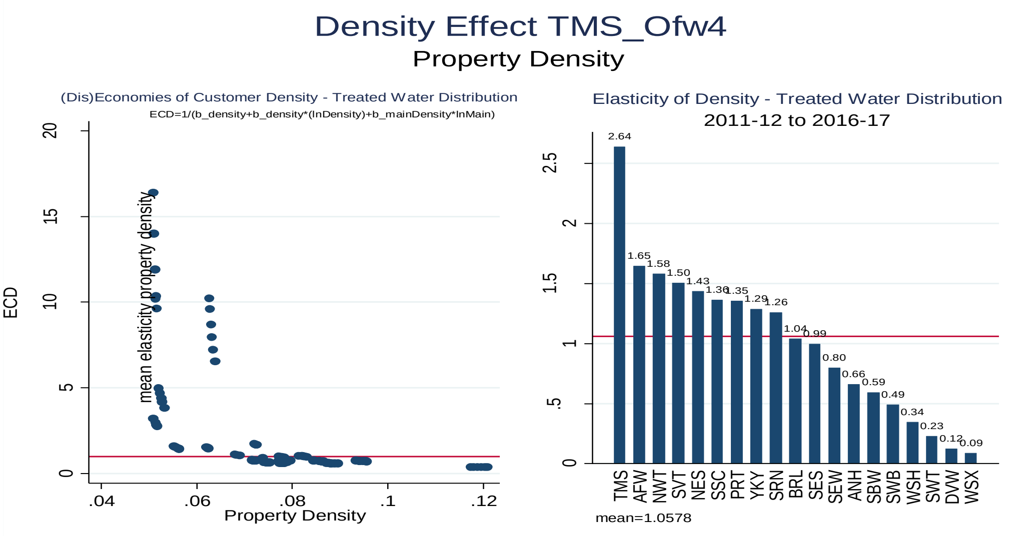
* p<0.10, ** p<0.05, *** p<0.01

**Source**: Economic Regulation, Thames Water

6 We have adjusted the botex version of costs and regional wages at 2016/17 prices using CPIH to convert them to real prices using the file called '*Company specific labour cost indices.xlsx*, sheet: Interface, variable 2 SOC split". The numbers in brackets are the standard errors, no the p-value.

Model TMS_Ofw3 is included to illustrate the impact of including regional wages. The other models in Table 2.1 are an extension of model TMS_Ofw4, adding other drivers and methods such as Random effects (see model TMS_Ofw7). Based on the results of model TMS_Ofw4, we can derive the effects of (dis)economies of density as shown in Figure 2.1.

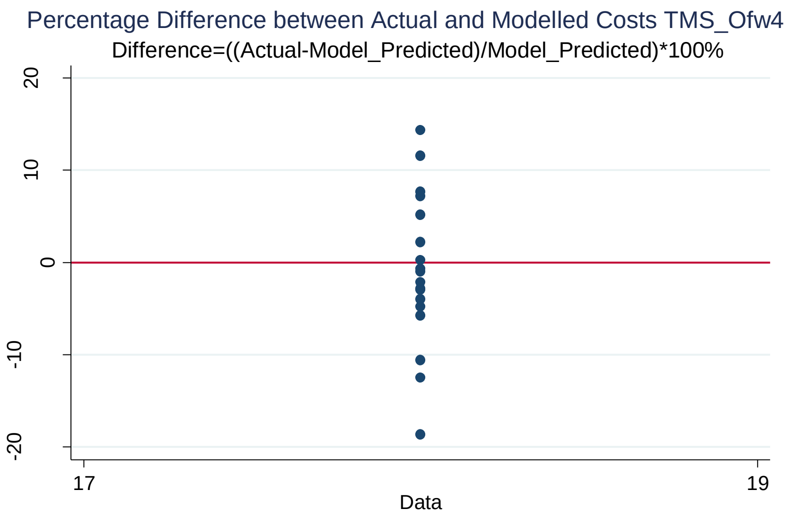
**Figure 2.1**




Source: Economic Regulation, Thames Water

Finally, the predicted power of the models represented in the percentage variance of predicted costs from actual costs is improved substantially. For example model TMS_Ofw_4 ranges between -18.64% to 14.32%, see Figure 2.2, which is significantly improved compared to the original Ofwat and Thames models.

**Figure 2.2**




Source: Economic Regulation, Thames Water